The distribution, abundance and conservation of dugongs and other marine megafauna in Shark Bay Marine Park, Ningaloo Reef Marine Park and Exmouth Gulf

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EXECUTIVE SUMMARY

The importance of dugongs in Shark Bay, Ningaloo Reef and Exmouth Gulf

Shark Bay is believed to be home to more than 10% of the world's dugongs, (*Dugong dugon*), (Marsh *et al.*, 2002; Gales *et al.*, 2004), and the importance of Shark Bay as a significant habitat for dugongs was one of the reasons for its World Heritage listing. Shark Bay arguably offers the best opportunity to conserve dugongs in the world because it: a) is isolated from urban development; b) has a low level of Indigenous hunting and c) occurs within a Marine Park and World Heritage Area. The four systematic surveys of Shark Bay conducted to date suggest that the population is consistently above 10,000 dugongs. Ningaloo Reef and Exmouth Gulf also support significant dugong populations that are to be interconnected with Shark Bay. The last survey conducted in the Shark Bay / Ningaloo/ Exmouth region showed a dramatic decline in dugong abundance in association with a significant increase in Shark Bay, suggesting that dugongs had moved southward following the loss of seagrass during a cyclone event in the northern region. This finding was evidence of a link between the Shark Bay and Ningaloo-Exmouth dugong populations, which therefore, cannot be managed in isolation.

Aims of this project

The need for ongoing monitoring of dugong populations through aerial surveys is identified in the Shark Bay management plan. The Ningaloo management plan also identifies the need to undertake research "to better understand dugong populations, distribution and habitat requirements in the reserves and the adjacent areas of the Exmouth Gulf and determine the current status of dugong population in relation to historical levels". As the fourth comprehensive survey of dugong abundance and distribution in Shark Bay, Ningaloo and Exmouth Gulf, this project aimed:

- To provide a precise minimum estimate of the number of dugongs in the Shark Bay World Heritage Property, Shark Bay Marine Park, Ningaloo Marine Park and Exmouth Gulf;
- To obtain a reliable index of the relative density of dugongs, in various parts of Shark Bay, Ningaloo and Exmouth Gulf to compare with results of previous surveys as a basis for monitoring population changes and movements;
- To assess dugong habitat selection and utilisation;
- To determine dugong group sizes;
- To estimate a maximum level of human-caused mortalities (PBR) for both populations; and
- To record sightings and plot the distribution of other large animals (e.g. whales, sharks).

Methods

This survey followed the sampling design and survey protocol of all previous surveys, whereby straight-line parallel transects were flown in an east-west direction at a height of 450 ft. Dugongs and other marine megafauna sightings within 200 m strip transects on each side of the plane were called by four observers (two on each side) and recorded by the team leader. Sighting conditions were also recorded to allow the development of correction factors to account for dugongs that were unavailable (too low in the water column to be visible) or undetected (available but missed by both observers). These correction factors were calculated using the method previously applied to surveys in this region, as well as a recently developed and improved method.

Current dugong population status

Our surveys produced a population estimate of 9347 (± 1204 se) dugongs in Shark Bay according to the improved correction factors. This estimate differed from those obtained for

Shark Bay using the old correction factors, which indicated that the population had increased from 11021 (±1357 se) in 2002, to 14022 (± 1230 se) in 2007. However the estimate from this survey was likely inflated through observer differences in assessing the proportion of dugongs 'at the surface'; a component of the availability correction factor used to obtain the latter estimates. Without recalculating the estimate from the 2002 survey using the new method and statistically comparing this with the current survey estimate, it is difficult to assess whether this population increase was real.

The estimated population in Exmouth Gulf was 704 (± 354 se) dugongs according to the new method for calculating correction factors and 1411 (± 561 se) according to the previously used method. No population estimate is provided for Ningaloo Reef as only two dugongs were sighted in this survey area. Both estimates suggest the population in this region may have increased since the 1999 survey, which produced an estimate of less than 350 dugongs in the two areas combined. Again, a statistical comparison between the previous and current survey is needed to determine whether this increase is real. If it is real, the increase could not be explained by increased fecundity levels as the maximum reproduction rate for dugongs is considered to be 5% and no calves were sighted during this survey.

The suggested increase in dugong numbers in both the Ningaloo-Exmouth region and Shark Bay indicates that some dugongs have moved to these habitats areas from regions further north. Further research is needed the assess the status of dugong populations along the remainder of the northwest Australian coastline and determine movement patterns of dugongs between the various habitat areas.

Other marine megafauna

Other fauna recorded during this survey included bottlenose and Indo-Pacific humpback dolphins, turtles, sharks, seasnakes, manta rays, a minke whale and an unidentified whale. This was the first survey to record substantial numbers of Indo-Pacific humpback dolphins in western Shark Bay, thus extending the known range of this species. Similar to dugongs, this Shark Bay population of Indo-Pacific humpback dolphins experiences a relatively high level of protection, making this an important habitat area for this species. As very little is known about humpback dolphins in Australian waters, I suggest that Shark Bay provides an opportunity to research this species in a relatively accessible location.

Recommendations for the conservation of dugongs and other marine megafauna

<u>RECOMMENDATION 1</u>

That a Research and Monitoring Strategy be developed for dugongs in WA.

<u>RECOMMENDATION 2</u>

That the biologically and logistically feasible spatial scale upon which to manage dugongs be investigated through population genetic techniques.

<u>RECOMMENDATION 3</u>

That the program of aerial surveys in Shark Bay, Ningaloo Reef and Exmouth Gulf be continued, but extended to include dugong habitat northward of the Ningaloo-Exmouth region, to provide the basis for a spatial risk assessment of dugongs in WA.

<u>RECOMMENDATION 4</u>

That dugongs occurring along Ningaloo Reef and in Exmouth Gulf be satellite tagged to determine the habitat use in this area and movement between these habitats and those further north.

RECOMMENDATION 5

That the 2002 survey data be reanalysed using the improved Pollock *et al.* (2006) method for calculating correction factors to allow more accurate comparisons with the current survey.

RECOMMENDATION 6

That the dugong population estimates obtained from all surveys in the Shark Bay / Ningaloo / Exmouth region be compared statistically to determine if the apparent fluctuations in numbers are real.

RECOMMENDATION 7

That photo-identification studies and/or boat-based surveys be conducted of the Indo-Pacific humpback dolphin populations in Shark Bay and Exmouth Gulf to determine their abundance and distribution.

CONTENTS

INTRODUCTION

The status of dugongs in Shark Bay, Ningaloo Reef and Exmouth Gulf

Shark Bay is believed to be home to more than 10% of the world's dugongs, (*Dugong dugon*), (Marsh *et al.*, 2002; Gales *et al.*, 2004), and the importance of Shark Bay as a significant habitat for dugongs was one of the reasons for its World Heritage listing. The dugong population in Shark Bay is second only to that of the Torres Strait in size, and is arguably now the most important dugong population in the world because it: a) is isolated from urban development; b) has a low level of Indigenous hunting and c) occurs within a Marine Park and World Heritage Area. Thus Shark Bay offers the best opportunity to conserve dugongs in Australia. Throughout the dugong's Indo-Pacific range outside Australia, the dugong is represented by relict populations separated by large areas where its numbers have been greatly reduced or it is already extirpated (Marsh & Lefebvre, 1994; Marsh *et al.*, 2002). The four systematic surveys of Shark Bay conducted to date suggest that the population is consistently above a minimum (incorporating estimate error) of 8,000 dugongs (Marsh *et al.*, 1994; Preen *et al.*, 1997; Gales *et al.*, 2004; Holley *et al.*, 2006)

Ningaloo Reef and Exmouth Gulf also support significant dugong populations that are likely interconnected with Shark Bay (Gales *et al.*, 2004). The last survey conducted in this region, in 1999, suggested a dramatic decline in dugong abundance in the Ningaloo-Exmouth region, while numbers in Shark Bay simultaneously increased. This apparent shift in distribution was considered to be a result of the effects of a cyclone on the seagrass habitat in the Ningaloo-Exmouth region. Seagrass loss likely caused dugongs to migrate to the southern habitat in search of forage (Gales *et al.*, 2004). Further surveys conducted in Shark Bay in 2002 showed a possible decline in numbers considered indicative of dugongs having migrated back to their northern habitat, although the Ningaloo-Exmouth region was not surveyed at that time (Holley *et al.*, 2006). With the hypothesised link between the two habitat areas, neither dugong populations are now considered separately, but rather as two subpopulations. Dugongs also likely move between Ningaloo-Exmouth and habitats further north, although no research has been conducted to assess this.

Requirements for updated population distribution and abundance estimates

The Shark Bay and Exmouth Districts of the Department of Environment and Conservation (DEC) are responsible for the management of human impacts on the dugong populations in their respective areas under the *Wildlife Conservation Act 1950*. Management activities in Shark Bay are guided by the *Shark Bay Marine Reserves Management Plan* (CALM, 1996), and in the Ningaloo-Exmouth region by the *Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area* (CALM & MPRA, 2005). The need for ongoing monitoring of dugong populations through aerial surveys is identified in the Shark Bay management plan. The Ningaloo management plan also identifies the need to undertake research to better understand dugong population, distribution and habitat requirements in the reserves and the adjacent areas of the Exmouth Gulf and determine the current status of dugong population in relation to historical levels. This project is the fifth comprehensive survey of dugong abundance and distribution in Shark Bay, and fourth of Ningaloo and Exmouth Gulf. It will follow established methods for aerial surveys used in the dugong surveys conducted during the winter survey of 1989 (Marsh *et al.*, 1994), 1994 (Preen *et al.*, 1997), and 1999 (Gales *et al.*, 2004) and one summer survey (Shark Bay only) in 2002 (Holley *et al.*, 2006).

The functions of aerial surveys

A series of aerial surveys such as those conducted in the Shark Bay / Ningaloo / Exmouth region have a number of functions to aid in the management human impacts of marine mammals such as dugongs:

1. *Marine planning and spatial risk assessment through understanding distribution and abundance*

Aerial surveys such as that conducted here are the established methodology for estimating abundance and distribution of dugongs in order to establish spatial data on important habitat areas for this species. This information has been useful for marine planning and conservation. For example, on the Queensland coast, the identification of key habitats through aerial surveys lead to the establishment of a series of Dugong Protection Areas to reduce the impact of gill netting on this species (Marsh, 2000). More recently, aerial survey data has been used in a spatial risk assessment approach where the risk of anthropogenic impacts on dugongs and their seagrass habitat is assessed by comparing the distribution of these impacts with a spatially explicit model of dugong distribution (Grech & Marsh, in review). Spatial risk assessment allow the rapid assessment management actions to reduce human impacts such as the implementation of protected areas.

2. *Detecting population trends*

Monitoring dugong population numbers allows the detection of population trends. The surveys are designed to provide a snapshot absolute estimate of the dugong population in the area covered in each survey at the time of the survey (Pollock *et al.*, 2006).However, the large variability in population estimates resulting from large-scale movements (e.g., Marsh & Lawler, 2001a; Gales *et al.*, 2004; Marsh *et al.*, 2004), along with the slow rate of population increase for dugongs (Marsh, 1995a; Marsh, 1999), means that aerial surveys need to be conducted over many years to detect a gradual decline in population size. A declining population may, by that time, have reached a critically low level (Marsh, 1995b). Conversely, an estimated 16 annual aerial surveys would be needed to detect an increase of 5% per year even in a relatively large dugong population such as in Shark Bay or the Torres Strait (Marsh *et al.*, 2005).

3. *Estimating the potential biological removal*

Because of the time delay in detecting population trends, monitoring trends is not necessarily going to trigger management action in time to reverse a population decline. Wade (1998) suggests that when human impacts are known to be affecting a marine mammal population, a better estimate of impact would be to monitor mortality rates and determine the Potential Biological Removal (PBR). The PBR is the maximum level of human-caused mortality that can occur in a population from all causes (e.g. accidental entanglement in fishing nets or vessel strikes), while allowing the population to reach or maintain an optimal sustainable size, and is the product of a minimum population estimate (which relies on an accurate population estimate), half the maximum rate of increase, and a recovery factor that allows for population growth and compensates for uncertainties in population estimates or responses to human impacts (Wade, 1998). In the USA, monitoring anthropogenic mortalities rather than population trends is considered a more robust alternative for assessing the need for management action to protect marine mammal stocks, provided the required statistics are known or inferred with some confidence (Read & Wade, 2000). The USA *Marine Mammal Protection Act* defines the PBR of each marine mammal stock to be the maximum allowable annual removal limit. Using this criterion for assessing human impacts is considered to have significantly improved assessment of the status of marine mammal populations (Read & Wade, 2000).

Project objectives

Considering the dugong monitoring requirements in Shark Bay, the need to better understand dugong distribution and abundance in the Ningaloo-Exmouth region, and the link between these dugong habitat areas, the specific objectives of this project were:

- To provide a precise minimum estimate of the number of dugongs in the Shark Bay World Heritage Property, Shark Bay marine reserves, Ningaloo Marine Park and Exmouth Gulf;

- To obtain a reliable index of the relative density of dugongs, in various parts of Shark Bay, Ningaloo and Exmouth Gulf to compare with results of previous surveys as a basis for monitoring population changes and movements;
- To assess dugong habitat selection and utilisation;
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- To estimate a maximum level of human-caused mortalities (PBR) for both populations; and
- To record sightings and plot the distribution of other large animals (e.g. whales, sharks).

METHODS

Study Area

Shark Bay is situated midway along the coast of Western Australia (25°30'S, 113°30'E). The Bay is 13000 km^2 in area and divided into two embayments separated by the Peron Peninsula. Shark Bay is afforded a high level of protection as both a Marine Park and a World Heritage Area (WHA). One of the values for which the Bay was nominated as a WHA are the large expanses of seagrass meadows (4000 km^2) and diversity of seagrass species (12 species) within the area (Walker, 1989). The area experiences mean annual temperatures of 17-27°C and limited rainfall (mean 224 mm per year). The subsequent low freshwater input into the Bay has produced three salinity zones: oceanic, metasaline and hypersaline (enclosed sections such as south-eastern bay, CALM, 1996).

Ningaloo Reef is 200 km north of Shark Bay (22°30'S,113°48'E), and extends for 260 km along the western shore of the Cape Range Peninsula, which encloses Exmouth Gulf (22°0'S,114°24'E). The reef encloses a narrow lagoon extending 200 m to 6 km from the shoreline, with an average depth of 4 m. The reef and lagoon form the Ningaloo Reef Marine Park. Mean temperatures range between 19 and 29°C, and again, the area experiences a low mean rainfall of 296 mm per year. Low runoff into the reef lagoon results in relatively clear waters. In contrast, Exmouth Gulf contains fringing mangroves, mudflats, rock pavements and soft-bottom habitats, producing turbid waters (Preen *et al.*, 1997).

Aerial Surveys

Aerial surveys were conducted in Shark Bay between 30th May and 11th June 2007, and in Ningaloo Reef and Exmouth Gulf from 12th to 16th June 2007. This is slightly earlier in the year than previous surveys (late June / early July). Dugongs were the main focus of this survey. Consequently, the surveys were designed to maximise detection of this species. However, other species of marine megafauna were also counted, including whales, dolphins, turtles, sharks and sea snakes.

The surveys were conducted following the previous survey designs at both sites (Marsh *et al.*, 1994; Preen *et al.*, 1997; Gales *et al.*, 2004; Holley *et al.*, 2006), and covered the area shown in Table 1 and Figure 1. The transects were spaced at intervals of 2.5 nm (4.6 km). The transect strip width on each side of the aircraft was 200 m, providing a net transect strip width of 400 m. The transect strip was split into four equal zones and the outside of the transect strip and zones were delineated using marker poles attached to pseudo wing-struts (Marsh & Sinclair, 1989a). These markers were calibrated on the ground to account for the eye height of individual observers. The surveys were flown at a height of 450 ft (137 m) ASL, providing a survey intensity of 9-10%.

The survey methods follow those developed previously for dugong surveys (Marsh & Sinclair, 1989b; Marsh & Sinclair, 1989a; Pollock *et al.*, 2006) and used for previous surveys at both sites. A Partenavia 68B aircraft was used, with the survey team consisting of four dedicated observers and a survey leader. The two primary observers were seated in the middle seats and the two secondary observers in the rear seats.

The team leader entered all sightings called by the observers into a pocket computer using a specialised program developed for dugong aerial surveys. For each animal group sighted, the total number of animals visible was recorded, along with the number of animals at the surface, position in the transect (low – very high), and turbidity (see scale in Appendix 1). For dugongs and dolphins, the number of calves was also recorded. Dolphins and whales were identified to species where possible and observers were asked to assess how sure they were of the species (certain, probable or guess).

Table 1. Details of the area surveyed.

Block	Transects	Area (km²)	Total transect lengths (km)	Total sample area (km²)	Sample intensity
SB0	8	1161	275	110	0.10
SB1	12	1130	247	99	0.09
SB2	14	1485	347	139	0.10
SB3	12	2369	494	198	0.09
SB4	20	2702	594	238	0.09
SB5	4	820	177	71	0.09
SB6	12	2209	479	192	0.09
SB7	14	2819	608	243	0.09
NR1	43	816	171	68	0.09
EG1	18	2898	624	250	0.09

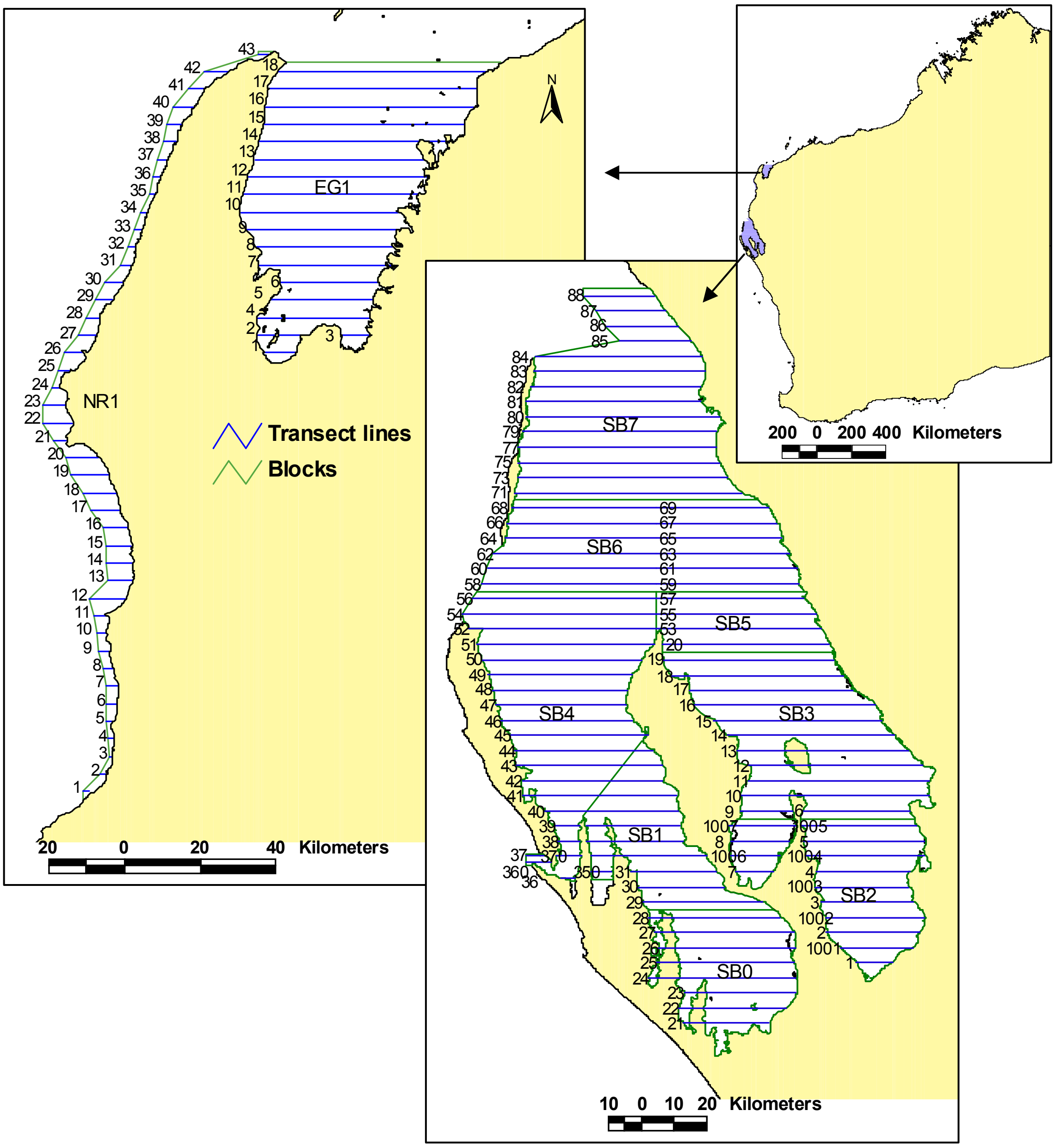

Figure 1. Map of the transects and blocks for the dugong aerial survey in Shark Bay (SB), Ningaloo Reef (NR) and Exmouth Gulf (EG1).

The survey leader entered data on environmental conditions at the beginning of each flight (cloud cover, cloud height, wind speed, wind direction and air visibility) and each transect (cloud cover). Every few minutes during each transect, and whenever conditions changed, the survey leader recorded Beaufort sea state, turbidity, and glare on each side (scored by the observers, scales in Appendix 1).

The observers and the survey leader communicated via aviation headsets connected to two intercoms, so that the secondary observers were isolated acoustically from the primary observers. Each intercom was connected to a separate track of a two-track digital voice recorder. This arrangement allowed the sightings of the two observers on each side of the aircraft to be independent and perception bias to be calculated as explained below.

Dugong data analysis

Analysis of sighting data to determine population estimates of dugongs in Shark Bay, Ningaloo Reef and Exmouth Gulf were conducted in two ways: (1) following methods used in all previous surveys (Marsh & Sinclair, 1989a), and (2) using modified methods developed by Pollock *et al.* (2006). Both methods allow estimates to be calculated using correction factors which account for availability bias (dugongs within the survey area but not 'available', i.e., not at the surface or visible) and perception bias (dugongs available but not detected by the observer).

Availability bias

In the Marsh and Sinclair (1989a) method, a correction factor for availability bias is calculated by standardising the proportion of animals classified by observers as 'at the surface' against the corresponding proportion in an earlier survey in shallow, clear water where all dugongs could be seen. This method assumes that the proportion of dugongs at the surface at any one time is independent of factors such as water depth, temperature and variation in dugong behaviour. Pollock *et al.* (2006) combined data obtained using two independent methodologies to develop availability probabilities for dugongs according Beaufort sea state and turbidity: (1) analysis of dive profiles from live animals fitted with timed depth recorders, and (2) observing the depth at which dugong models could be seen from the air (at the standard survey height) in various conditions. This information enabled the proportion of time dugongs spend within the upper section of the water column within which they are visible and thus the proportion of time they are 'available' to be counted to be estimated. Each dugong sighting was assigned an availability class (1-8) according to the turbidity and Beaufort sea state at the location of the sighting and used the availability probability estimates provided by Pollock *et al.* (2006) to correct for the number of dugongs missed at that location due to them being 'unavailable'.

Perception bias

A mark-recapture model was used to estimate the proportion of the 'available' dugongs that are actually counted under the survey conditions encountered (Marsh & Sinclair, 1989a; Pollock *et al.*, 2006). Each primary observer sighted (marked) a group of dugongs that may or may not have been seen (recaptured) by the corresponding secondary observer. Hence each secondary observer saw groups of dugongs in two categories: those that were "marked" and which they "recaptured" and those that were "unmarked". Each dugong sighting was categorised as being recorded by one or both observers. These categories were then fitted into a mark recapture framework to calculate the probability of a dugong group being seen (captured) by a tandem team. Pollock *et al.* (2006) describe how to fit generalised Lincoln-Petersen models to determine probability conditional on availability to vary by observer, experience (primary or secondary observers), and side (port or starboard) using the MARK program (White & Burnham, 1999). The perception probabilities used for each observer were those provided by the model that best fit the data according to Akaike's Information Criterion (AIC), which corrects for small sample bias. The probability that a dugong would be detected by at least one observer for each side of the aircraft was:

$$\hat{p}_d = 1 - (1 - \hat{p}_1)(1 - \hat{p}_2)$$

where $\hat{p}_1$ is the perception probability obtained for the primary and $\hat{p}_2$ the secondary observers (i = 1,2).

Population estimates

<u>Method 1 (Marsh & Sinclair, 1989a):</u>

The Ratio Method (Caughley & Grigg, 1981; Marsh & Sinclair, 1989a) was used to estimate the abundance of dugongs in each survey block and the associated standard errors. Each sighting was corrected for availability and perception biases and the mean group size per block before calculating the population estimate. Standard errors were estimated by accounting for these correction factors also.

<u>Method 2 (Pollock *et al.*, 2006):</u>

As outlined in Pollock *et al.* (2006), the Horvitz-Thompson population estimator was also applied for each survey block:

$$\hat{N} = \sum_{j=1}^{n} [1/\hat{p}_j]$$

where n is the number of dugongs counted within the survey and $\hat{p}_j$ is:

$$\hat{p}_j = p_b \hat{p}_{aj} \hat{p}_{dj}.$$

The above formula corrects each sighting for the proportion of the survey area sampled (p_t), the probability of that group of dugongs (j) being available given the conditions at the sighting location ($\hat{p}_{aj}$) and the probability of that group of dugongs being detected given that it was available ($\hat{p}_{dj}$).

Standard errors were obtained using a Monte Carlo simulation method as detailed in Pollock *et al.* (2006). All dugong groups containing more than 10 individuals were excluded from the above analysis and added to the final population estimate (Norton-Griffiths, 1978).

Dugong densities were calculated from the population estimates for each survey block by dividing the population estimate by the relevant block area.

Proportion of calves across years

A chi-squared test was performed to determine whether there was a difference in the proportions of calves sighted across the five years of aerial surveys for dugongs in Shark Bay and the Ningaloo-Exmouth regions. Data for previous surveys was obtained from published results (Preen *et al.*, 1997; Gales *et al.*, 2004; Holley *et al.*, 2006).

Comparison of ACF values across years

The availability correction factor (ACF) calculated using the Marsh and Sinclair (1989a) method was compared across years using a chi-squared test to determine whether there was a difference in the proportions of dugongs classified by observers as ‘at the surface’ in each year in Shark Bay and the Ningaloo-Exmouth region. Data for previous surveys was obtained according to the ACF provided in published results (Preen *et al.*, 1997; Gales *et al.*, 2004; Holley *et al.*, 2006). To determine which years pairs of years had significant differences, multiple chi squared tests were performed and the alpha level was adjusted downward using the Bonferroni correction to $\alpha = 0.04$.

Sustainable levels of human-caused mortality for dugongs

The sustainable level of human-related mortalities for dugongs in Shark Bay and the Ningaloo-Exmouth region was calculated using the Potential Biological Removal (PBR) method defined by Wade (1998), and subsequently used for dugongs by Marsh *et al.* (2004). This technique estimates the maximum number of animals that can be removed from the population other than by natural causes, while allowing the population to reach an optimum sustainable level (i.e., between carrying capacity and maximum net productivity). The following is the formula to calculate the PBR:

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

where: $\mathbf{N_{min}}$ = the 20th percentile of a log-normal distribution based on an absolute estimate of the number of animals N in the population.
$\mathbf{R_{max}}$ = the maximum rate of increase, for which Marsh *et al.* (2004) use a range of estimates of 0.01 – 0.05 to accommodate the uncertainty associated with the estimates of age of first reproduction, fecundity and natural mortality levels.
RF = a recovery factor of between 0.1 and 1, which if < 1, allows population growth and uncertainties in estimates of N_{min} or R_{max}, and for which Marsh *et al.* (2004) use 0.5, which is the default value for stocks of unknown status (Wade, 1998).

RESULTS

Survey conditions

Good conditions were experienced throughout most of the survey with the modal Beaufort sea state for all except three blocks in Shark Bay being ≤ 2 (Table 2, Appendix 3). The only section within which there were marginal conditions was in the northern half of Shark Bay Block 7. There was no cloud cover throughout most of the survey. Levels of glare were high for observers scanning the sea to the north of the aircraft throughout all survey areas, with often > 50% of their view being obstructed. Glare was much less of a problem for observers scanning south (Table 2, Appendix 3). Water visibility and depth (turbidity) was generally clear and shallow in most areas, except the northern half of Shark Bay Block 7 and the Exmouth Gulf (Table 2, Appendix 3). A high proportion of the survey was conducted in conditions where a high proportion of dugongs would be expected to be 'available' or visible to the observers according to the classes of availability probabilities provided by Pollock *et al.* (2006) (Table 3).

Table 2. Summary of the environmental conditions experienced within each block in Shark Bay (SB), Ningaloo Reef (NR) and Exmouth Gulf (EG).

	SB0	SB1	SB2	SB3	SB4	SB5	SB6	SB7	NR1	EG1
Wind Speed (kn)	4	3.67	4	3	0	3	3	4.50	6	4.33
Air Visibility (km)	>10	>10	>10	>10	>10	>10	>10	>10	>10	>10
Cloud Cover	0	0	0	0.73	0	3.75	0.50	0	0	0
Cloud Height (ft)	na	na	na	na /2000	na	2000	na /2000	na	na	na
Beaufort Sea State[1]	0.75	1.73	2.14	1.25	1.94	2.50	1.50	2.14	1.47	1.41
Glare South[1,2]	0.38	0.89	0.57	0	0.73	0	0.27	0.36	0	0
Glare North[1,2]	2.17	2.43	2.88	2.40	2.25	3.00	2.64	2.31	2.00	1.67
Turbidity[1,2]	1.29	1.78	1.64	2.00	1.86	2.33	2.58	3.07	1.85	3.50

[1] Mean of the mode for each transect
[2] Refer to Appendix 1 for scales

Table 3. The availability of dugongs according to environmental conditions as defined by Pollock *et al.* (2006) and the frequency and proportion of this survey that took place within each of the eight classes. A relatively high proportion of the better sighting conditions (availability classes 1 and 2) were experienced.

Class	Water turbidity[1]	Beaufort sea state	Probability	SB0	SB1	SB2	SB3	SB4	SB5	SB6	SB7	NR1	EG1
1	1 - Clear & shallow	≤ 2	1	0.43	0.25	0.37	0.48	0.17	0.26	0.14	0.09	0.29	0.12
2	2 - Turbid & shallow	≤ 2	0.65	0.35	0.34	0.18	0.25	0.27	0.16	0.36	0.19	0.37	0.14
3	3 - Clear & deep	≤ 2	0.46	0.22	0.06	0.01	0.21	0.14	0.14	0.32	0.23	0.16	0.11
4	4 - Turbid & deep	≤ 2	0.47	0.00	0.02	0.00	0.00	0.10	0.00	0.06	0.10	0.00	0.57
5	1 - Clear & shallow	≥ 3	1	0.00	0.04	0.11	0.00	0.03	0.02	0.00	0.00	0.02	0.00
6	2 - Turbid & shallow	≥ 3	0.47	0.00	0.17	0.32	0.01	0.14	0.16	0.04	0.11	0.10	0.02
7	3 - Clear & deep	≥ 3	0.30	0.00	0.01	0.01	0.05	0.11	0.26	0.08	0.17	0.06	0.02
8	4 - Turbid & deep	≥ 3	0.47	0.00	0.11	0.01	0.00	0.05	0.00	0.00	0.11	0.00	0.03

[1] See Appendix 1 for full turbidity scale.

Dugongs

Shark Bay

A total of 398 dugongs was sighted within the Shark Bay survey area in 262 groups (Table 4, Figure 2, Appendix 4). No groups of more than ten dugongs were sighted; the mean overall group size was 1.5 (± 0.04 se, range 1-5, Figure 3). A relatively high proportion of the dugongs sighted were calves (21.4%, N = 85), with most groups (73.4%) of two or more containing calves. One lone calf was sighted, although two adult dugongs were sighted on the same side of the aircraft in the vicinity.

The estimated size of the dugong population within the Shark Bay waters surveyed was 14022 (± 1230 se) according to the original analysis method (Marsh & Sinclair, 1989a, Table 5). The estimate according to the Pollock *et al.* (2006) method was much lower, giving 9347 (± 1204 se) dugongs. Both methods showed that the largest numbers of dugongs occurred in the north western part of the Bay (Blocks 4-7; Figure 2). Too few dugongs were sighted in Blocks 0-2 to calculate a population estimate. The density of dugongs was highest in Block 4 (method 1: 2.18 dugongs km^{-2}, method 2: 1.43 dugongs km^{-2}).

Ningaloo Reef and Exmouth Gulf

In the Ningaloo Reef block only two dugongs were sighted, both single animals (Table 4, Figure 2, Appendix 4). With so few sightings it was not possible to calculate a robust population estimate for this survey block. Observers saw 33 dugongs in Exmouth Gulf in 25 groups. The mean group size was 1.32 (± 0.13 se, range 1-3), and there were no calves seen (Figure 3). The estimated size of the Exmouth Gulf population according to the Marsh and Sinclair (1989a) method was 1411 (± 561 se) and 704 (± 354 se) according to the Pollock *et al.* (2006) method (Table 5). Most of the dugongs were sighted on the eastern side of the Gulf (Figure 2), providing densities of 0.49 and 0.24 dugongs km^{-2} respectively (Table 5).

Table 4. Raw counts and groups sizes of dugongs sighted in each survey block and across all survey areas.

Block	Total dugongs (port, starboard)	Total groups (port, starboard)	Calves	Mean group size (se)
SB0	0 (0, 0)	0 (0, 0)	0	
SB1	3 (2, 1)	2 (1, 1)	1	1.50 (0.50)
SB2	0 (0, 0)	0 (0, 0)	0	
SB3	9 (6, 3)	7 (5, 2)	1	1.29 (0.18)
SB4	168 (99, 69)	103 (57, 46)	39	1.63 (0.08)
SB5	43 (20, 23)	30 (16, 14)	11	1.43 (0.12)
SB6	113 (63, 50)	81 (44, 37)	23	1.40 (0.07)
SB7	62 (35, 27)	39 (22, 17)	10	1.59 (0.14)
Shark Bay	398 (225, 173)	262 (145, 117)	85	1.50 (0.04)
Ningaloo Reef	2 (0, 2)	2 (0, 2)	0	1.00 (0)
Exmouth Gulf	33 (12, 21)	25 (10, 15)	0	1.32 (0.13)

Table 5. Dugong population estimates using both methods for correcting for unseen dugongs, and densities (per km^2) of dugongs in each survey block and across all survey areas.

Block	Block area (km^2)	Method 1 (Marsh & Sinclair, 1989)		Method 2 (Pollock *et al.*, 2006)	
		Population estimate (SE)	Density	Population estimate (SE)	Density
SB0	1161	tfs		tfs[1]	
SB1	1130	tfs		tfs	
SB2	1485	tfs		tfs	
SB3	2369	316 (108)	0.13	192 (115)	0.08
SB4	2702	5900 (728)	2.18	3852 (714)	1.43
SB5	820	1530 (268)	1.87	1143 (343)	1.39
SB6	2209	4027 (274)	1.82	2759 (620)	1.25
SB7	2819	2249 (908)	0.80	1401 (650)	0.50
Shark Bay	14694	14022 (1230)	0.95	9347 (1204)	0.64
Ningaloo Reef	816	tfs		tfs	
Exmouth Gulf	2898	1411 (561)	0.49	704 (354)	0.24

[1] tfs = too few sighted

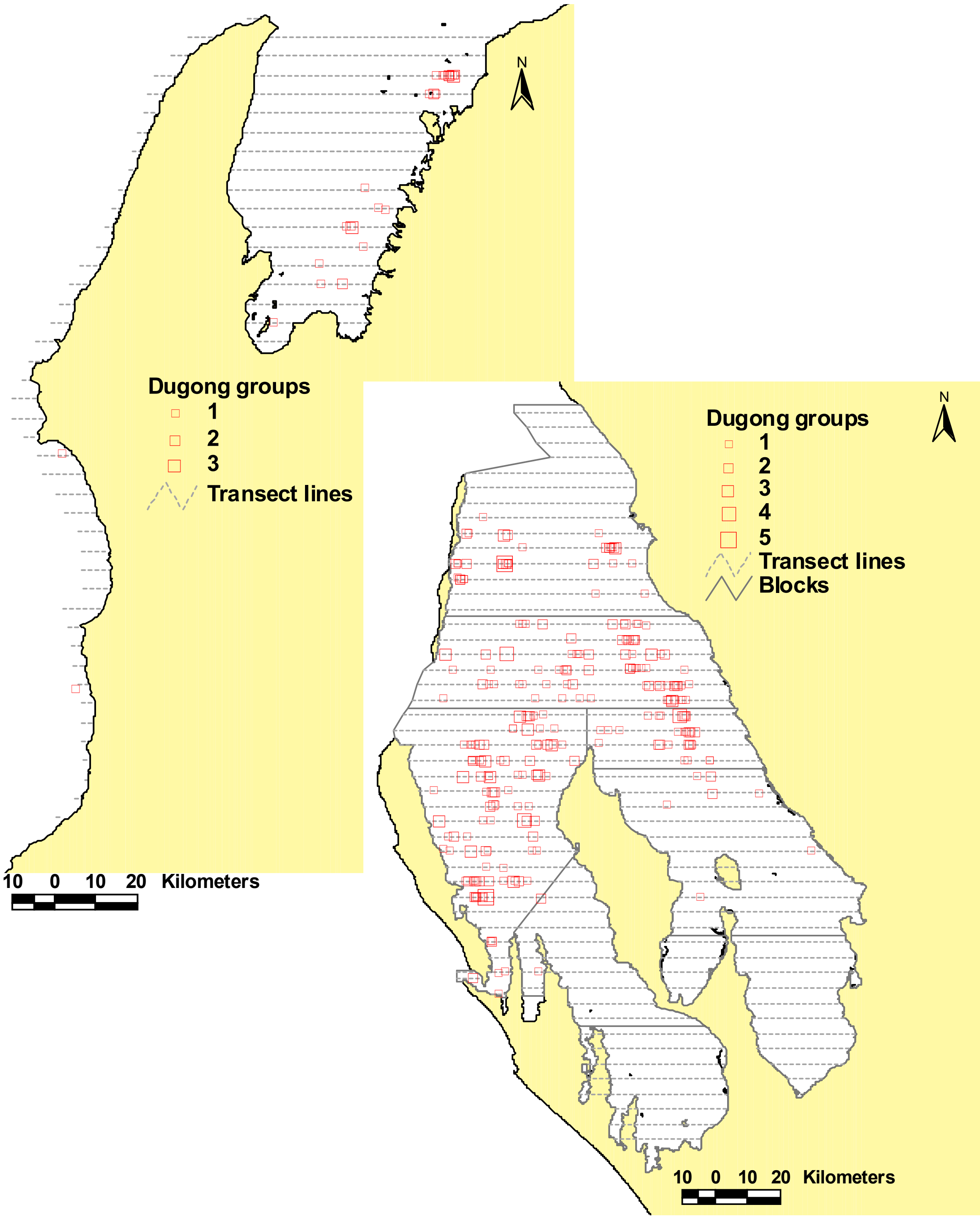

Figure 2. Sightings of dugongs Shark Bay, Ningaloo Reef and Exmouth Gulf in May/June 2007.

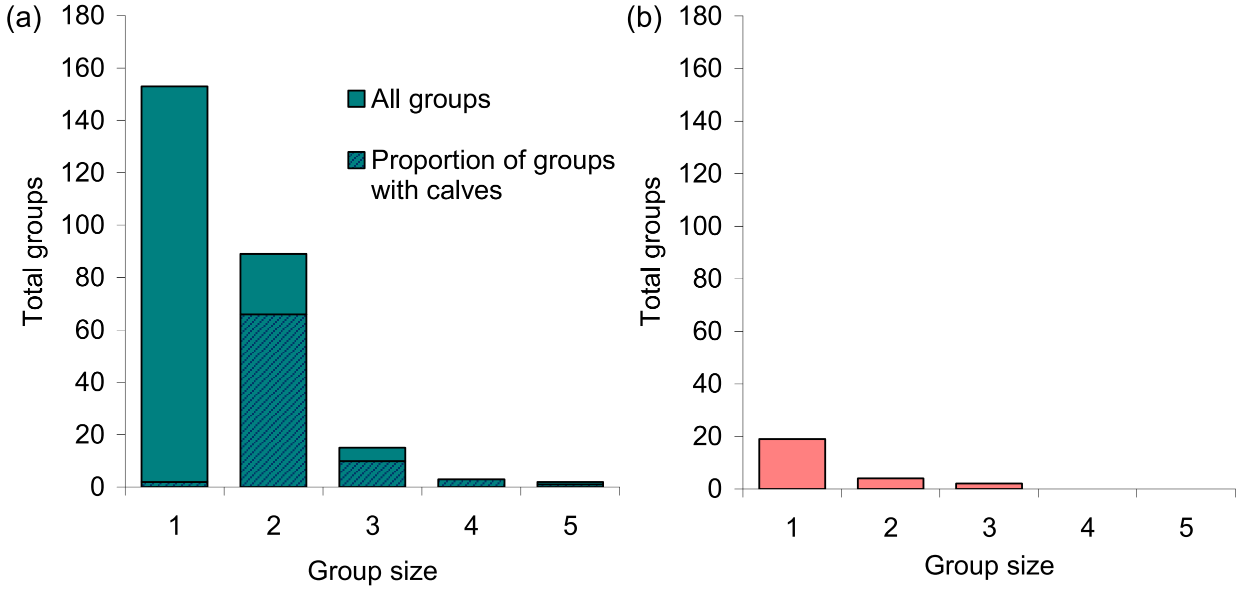

Figure 3. Dugong groups sighted and the proportion of those groups that contained calves in (a) Shark Bay and (b) Exmouth Gulf.

Proportion of calves across years

The proportion of calves sighted during each survey conducted in Shark Bay and the Ningaloo-Exmouth region has fluctuated between survey years. A chi-squared test showed that these differences across years were significant in Shark Bay ($\chi 2$ = 105.16, df = 4, P < 0.001). The proportion of calves sighted was higher than expected in 1989 (0.19), 1994 (0.166) and 2007 (0.214), while in 1999 and 2002 the proportion was much lower than expected (0.049 and 0.036 respectively, Table 6). Post hoc chi-squared analyses of the differences in proportions of calves between each of the consecutive years showed significant differences only between 1994 and 1999 ($\chi 2$ = 31.38, df = 1, P < 0.001) and between 2002 and 2007 ($\chi 2$ = 55.83, df = 1, P < 0.001).

The proportion of calves sighted across survey years also differed significantly in the Ningaloo-Exmouth region ($\chi 2$ = 17.23, df = 3, P < 0.001). Relatively high proportions of calves occurred in this region in the earlier surveys (1989 = 0.24, 1994 = 0.20), while no calves were sighted in 1999 or 2007 (Table 6). Post hoc analysis showed a significant difference between 1994 and 1999 ($\chi 2$ = 6.56, df = 1, P = 0.01).

Table 6. The number of calves and number of non-calves observed during each year of aerial surveys in Shark Bay and the Ningaloo-Exmouth region, with the expected values in parentheses.

Region	Age class	1989[a]	1994[a]	1999[b]	2002[c]	2007[d]
Shark Bay	Non-calves	286 (310.52)	242 (254.38)	508 (468.41)	372 (338.59)	313 (349.11)
	Calves	68 (43.48)	48 (35.62)	26 (65.59)	14 (47.41)	85 (48.89)
Ningaloo-Exmouth	Non-calves	43 (49.21)	32 (34.53)	29 (25.04)		35 (30.22)
	Calves	14 (7.79)	8 (5.47)	0 (3.96)		0 (4.78)

[a](Preen *et al.*, 1997), [b](Gales *et al.*, 2004), [c](Holley *et al.*, 2006), [d](this study)

Comparison of ACF values across years

The proportion of dugongs classified as 'at the surface' by observers differed significantly between years ($\chi 2$ = 21.37, df = 4, P < 0.001, Table 7) for surveys in Shark Bay, which therefore affected the Availability Correction Factor (ACF) used to calculate population estimates from each survey. Further comparisons between each year showed a significant difference between most years (Table 8), however, the current survey showed the greatest deviation of the observed frequencies of dugongs 'at the surface' from the expected value. There was no significant difference across years for the ACF calculated for the Ningaloo-Exmouth region ($\chi 2$ = 7.12, df = 3, P = 0.07, Table 7)

Table 7. The number of dugongs observed 'at' and 'below' the surface each year of aerial surveys in Shark Bay and the Ningaloo-Exmouth region, with the expected values in parentheses.

Region	Surface category	1989[a]	1994[a]	1999[b]	2002[c]	2007[d]
Shark Bay	at the surface	136 (128.59)	106 (125.56)	222 (231.21)	154 (167.13)	206 (171.02)
	below the surface	161 (168.41)	184 (164.44)	312 (302.79)	232 (218.87)	189 (223.98)
Ningaloo-Exmouth	at the surface	23 (28.83)	26 (20.23)	12 (14.67)		20 (17.7)
	below the surface	34 (28.17)	14 (19.77)	17 (14.33)		15 (17.3)

[a](Preen *et al.*, 1997), [b](Gales *et al.*, 2004), [c](Holley *et al.*, 2006), [d](this study)

Table 8. Results of multiple chi-squared tests to determine which pairs of years showed significant differences between the ACFs calculated from dugong surveys in Shark Bay (significant results in bold).

Comparison[1]	$\chi 2$	df	P[2]
2007 - 1989	13.39	1	**<0.0001**
2007 - 1994	18.07	1	**<0.0001**
2007 - 1999	13.32	1	**<0.0001**
2007 - 2002	14.42	1	**<0.0001**
2002 - 1989	2.59	1	0.107
2002 - 1994	7.27	1	**0.007**
2002 - 1999	2.53	1	0.112
1999 - 1989	1.49	1	0.222
1999 - 1994	6.17	1	**0.013**
1994 - 1989	6.24	1	**0.013**

[1] Calculated according to published results of previous surveys in 1989, 1994, 1999 and 2002 (Preen *et al.*, 1997; Gales *et al.*, 2004; Holley *et al.*, 2006)
[2] Tests were considered significant at the $\alpha = 0.04$ level according to the Bonferroni correction for alpha inflation which is caused by multiple tests.

Dolphins

Shark Bay

Dolphins were sighted throughout all blocks of the Shark Bay survey area except Block 2 (Table 6, Figure 4). A total of 370 dolphins was seen in 117 groups, and 76% of these were identified reliably to species (i.e. only those where the observers judged that their species identification was certain or probable). Most were bottlenose dolphins (*Tursiops sp.*, N = 256), and the only other species sighted was Indo-Pacific humpback dolphins (*Sousa chinensis*, N = 27). The mean group size for all dolphins throughout the survey area was 3.16 (± 0.44 se). The largest group was an estimated 40 bottlenose dolphins in Block 6, resulting in this Block having the largest total number and group size. However, Block 4 had the largest number of groups sighted. Indo-Pacific humpback dolphins were only sighted in the western bay (Figure 4). Very few calves were sighted, however, large groups of dolphins were not circled and counted during this dugong survey, and thus it was difficult for observers to determine the number of calves in large groups.

Ningaloo Reef and Exmouth Gulf

Six dolphins were sighted within the Ningaloo Reef survey area in a group of two and a group of four (Table 6, Figure 4). The latter group was identified as Indo-Pacific humpback dolphins while the former was not identified to species. No calves were sighted in this Block. Within Exmouth Gulf there were 15 dolphin groups totalling 41 animals, mostly occurring within the southern half of the Gulf (Figure 4). The mean group size was smaller than in Shark Bay (2.73

± 0.43 se) ranging from 1 to 6 animals. The observers identified 24 bottlenose and 7 Indo-Pacific humpback dolphins, and one calf which occurred within a group of three bottlenose dolphins.

Table 9. Raw counts and groups sizes of dolphins sighted in each survey block and across all survey areas.

Block	Total dolphins (port, starboard)	Total groups (port, starboard)	Calves	Mean group size (se)	Bottlenose dolphins[1]	Indo-Pacific Humpback dolphins[1]
SB0	38 (28, 10)	11 (6, 5)	0	3.45 (0.99)	25	9
SB1	28 (25, 3)	12 (9, 3)	0	2.33 (0.91)	18	2
SB2	0 (0,0)	0 (0,0)	0		0	0
SB3	57 (39, 18)	17 (7, 10)	1	3.35 (0.96)	51	0
SB4	94 (58, 36)	35 (14, 21)	1	2.69 (0.58)	52	16
SB5	10 (7, 3)	4 (2, 2)	0	2.50 (1.19)	7	0
SB6	108 (66, 42)	23 (8, 15)	1	4.70 (1.77)	82	0
SB7	35 (6, 29)	15 (6, 9)	3	2.33 (0.61)	21	0
Shark Bay	370 (229, 141)	117 (52, 65)	6	3.16 (0.44)	256	27
Ningaloo Reef	6 (0, 6)	2 (0, 2)	0	3.00 (1.00)	0	4
Exmouth Gulf	41 (30, 11)	15 (9, 6)	1	2.73 (0.43)	24	7

[1] Includes only those where observers' call on species identification was certain or probable (i.e. excluding those classed as a guess).

Turtles

Shark Bay

There were 546 turtles sighted throughout the survey area (except Block 2), with the highest number seen in Block 3 (Table 7, Figure 5). Turtles could not be identified to species from the height at the which survey was conducted. The turtles mostly occurred within the sheltered or shallow parts of the Bay. Most (90%) were single turtles producing a mean group size of 1.06 (± 0.02 se, range 1-4).

Ningaloo Reef and Exmouth Gulf

More turtles were seen on Ningaloo Reef (313 animals) than in Exmouth Gulf (286 animals, Table 7). The turtles were distributed relatively evenly throughout the Reef, but in the Gulf, were found more towards the eastern and southern sections (Figure 5). As in Shark Bay, most sightings were of single turtles both on the Reef and in the Gulf (77% and 81% respectively), resulting in mean groups sizes of 1.16 (± 0.04, max = 10) on the Reef and 1.04 (± 0.04, max = 6) in the Gulf.

Table 10. Raw counts and groups sizes of turtles sighted in each survey block and across all survey areas.

Block	Total turtles (port, starboard)	Total groups (port, starboard)	Mean group size (se)
SB0	93 (34, 59)	85 (30, 55)	1.09 (0.05)
SB1	34 (12, 21)	34 (12, 21)	1.00 (0.00)
SB2	0 (0,0)	0 (0,0)	
SB3	114 (48, 66)	105 (47, 58)	1.09 (0.03)
SB4	87 (29, 58)	85 (29, 56)	1.02 (0.02)
SB5	57 (22, 35)	51 (21, 30)	1.12 (0.05)
SB6	67 (37, 30)	64 (36, 28)	1.05 (0.03)
SB7	94 (42, 52)	92 (42, 50)	1.02 (0.02)
Shark Bay	546 (224, 321)	516 (217, 298)	1.06 (0.01)
Ningaloo Reef	313 (137, 176)	269 (115, 154)	1.16 (0.04)
Exmouth Gulf	286 (128, 158)	251 (117, 133)	1.14 (0.04)

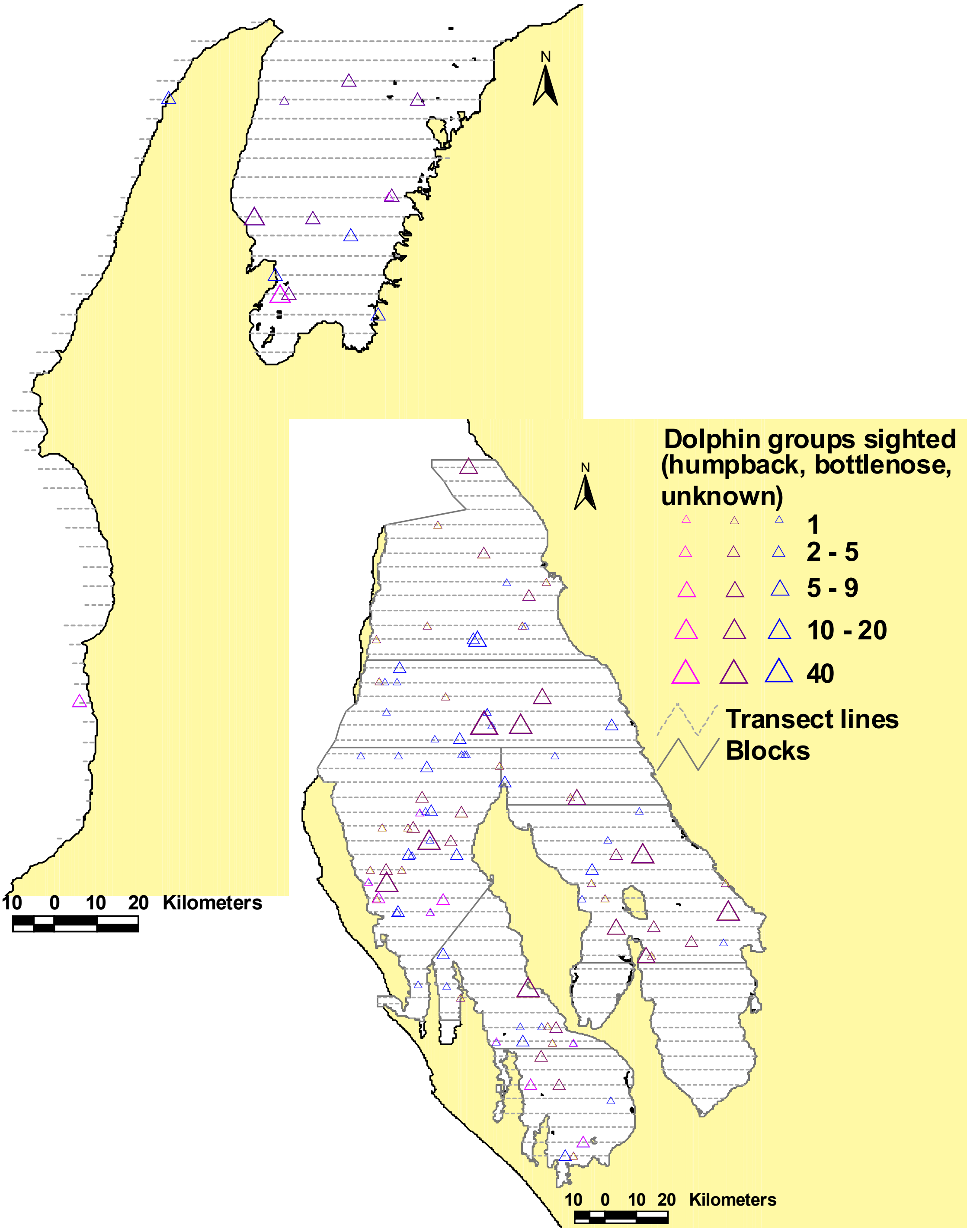

Figure 4. Sightings of dolphins at Shark Bay, Ningaloo Reef and Exmouth Gulf in May/June 2007, including those identified to species.

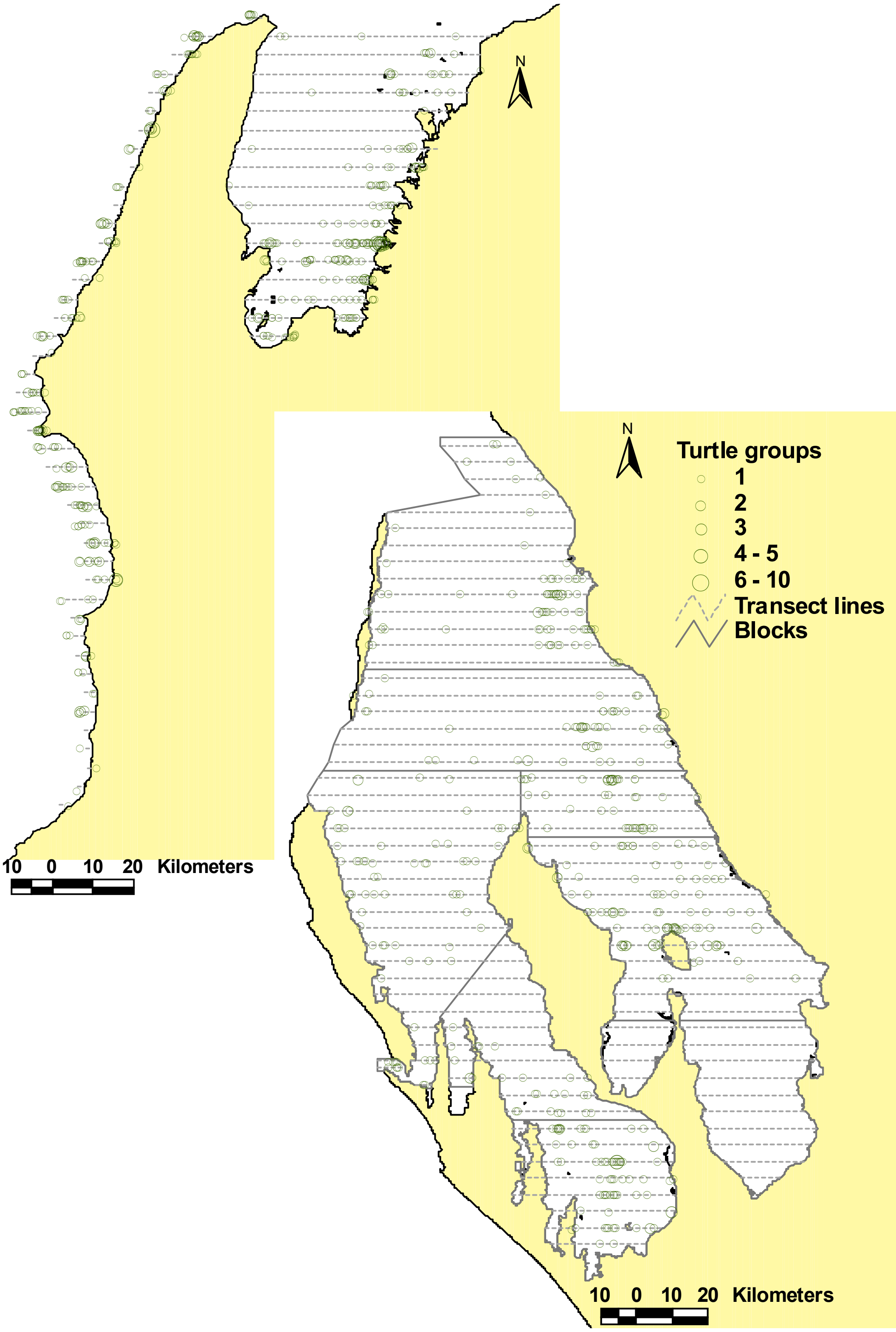

Figure 5. Sightings of turtles Shark Bay, Ningaloo Reef and Exmouth Gulf in May/June 2007.

Other animals sighted

Other animals encountered during the survey included seasnakes, sharks, manta rays and whales. Seasnakes are the hardest animals of the fauna surveyed to sight in marginal conditions and it is indicative of the good survey conditions that 74 were sighted in Shark Bay and 20 in Exmouth Gulf (Table 8). Seasnakes occurred mostly within the northern half of both Shark Bay (Blocks 6 and 7) and Exmouth Gulf. Only one seasnake was sighted on Ningaloo

Reef. Sharks occurred throughout all three survey areas with the highest number seen in Block 7 in Shark Bay and in the southern half of Ningaloo Reef. Manta ray sightings were only recorded in the Ningaloo Reef and Exmouth Gulf sites. The counts provided in Table 8 may be an over-estimate of the numbers due to difficulties in distinguishing between manta rays and other ray species. In the Gulf the manta rays were mostly in the shallow mangrove areas while on the Reef some were sighted in deeper water off the edge of the reef shelf. Two whales were sighted while flying on-transect in Shark Bay, with one identified as a minke (sighted in Block 7) and the other species undetermined. The latter was sighted outside of the strip transect in Block 6.

Table 11. Sightings of other animals recorded in the three survey areas.

	Seasnakes	Sharks	Mantas	Whales
Shark Bay	74	72		2[1]
Ningaloo Reef	1	27	14	
Exmouth Gulf	20	9	9	

[1] One whale was sighted outside the limits of the strip transect

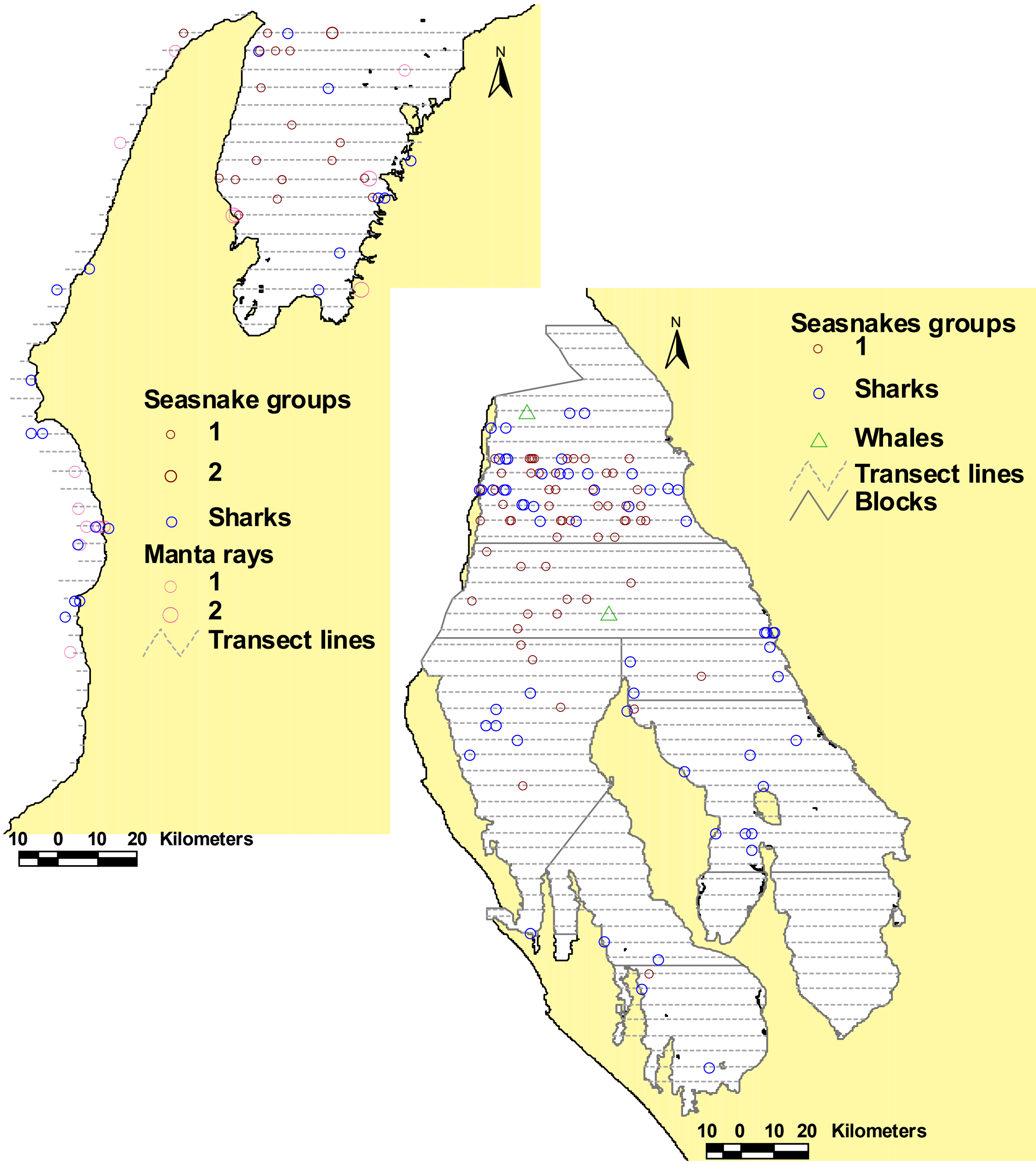

Figure 6. Sightings of seasnakes, sharks, whales and manta rays Shark Bay, Ningaloo Reef and Exmouth Gulf (manta rays recorded in the latter two locations only) in May/June 2007.

Sustainable levels of human-caused mortality of dugongs

The maximum sustainable number of human-caused mortalities was calculated by the PBR method using the estimates from this survey produced by the Pollock *et al.* (2006) method as this is the more accurate estimate. Because of the uncertainties about the life history and reproductive biology of dugongs, a range of PBR estimates are provided for dugongs in Shark Bay and Exmouth Gulf in Table 9, for different rates of maximum population growth rate (R_{max}) and using two different recovery factors: (1) 0.5, which is the default value for populations of unknown status, and (2) 1, which is only appropriate for populations where the stock structure and boundaries are well known, the population stable, and there are no uncertainties about human impacts (Wade, 1998). If assuming the population growth rate is in the middle range (R_{max} = 0.03), and using the conservative recover factor of 0.5, the total sustainable level of human-caused mortalities is 62 dugongs per year in Shark Bay and 4 dugongs per year in Exmouth Gulf.

Table 12. Estimated sustainable levels of human-caused mortalities of dugongs in Shark Bay and Exmouth Gulf using the Potential Biological Removal (PBR) method (Wade, 1998).

Area	N	SE	CV	N_{min}	PBR (RF = 0.5)			PBR (RF = 1)		
					R_{max}=0.01	R_{max}=0.03	R_{max}=0.05	R_{max}=0.01	R_{max}=0.03	R_{max}=0.05
Shark Bay	9347	1304	14.0%	8316	21	62	104	42	125	208
Exmouth Gulf	704	354	50.3%	472	1	4	6	2	7	12

DISCUSSION

Dugongs

Changes in dugong abundance

The dugong population estimate produced by this year's survey in Shark Bay is similar to results obtained during the 1999 (Gales *et al.*, 2004) survey according to the original Marsh and Sinclair (1989a) method of correcting for unseen animals (Table 10, Figure 7). According to this result it would appear that the population in Shark Bay has fluctuated in the last 13 years, increasing by 40% in between the 1994 and 1999 surveys, decreasing by 23% by the 2002 surveys, and increasing again by 27% before the current survey. In should be noted however, that the differences in estimates between surveys have never been tested statistically. The new Pollock *et al.* (2006) method for calculating correction factors produced a substantially lower estimate from the current survey (Table 10, Figure 7). The estimate using the new method is likely to be more accurate because the correction factors are based on more reasonable assumptions than the original method (Pollock *et al.*, 2006). However, it is difficult to compare this to previous abundance estimates, which were calculated using the original method. To reconcile the two results it would be helpful to recalculate population estimates from the 2002 survey using the new method (see Recommendations). In the interim I discuss possible explanations for the population estimates obtained here.

Table 13. Population estimates of dugongs in Shark Bay, Ningaloo Reef and Exmouth Gulf according to all surveys conducted to date.

Year (Date)	Reference	Estimate Method[1]	Shark Bay estimate (se)	Ningaloo Reef estimate (se)	Exmouth Gulf estimate (se)
1989 (4-11 July)	Preen *et al.* 1997	1	10146 (1665)	634 (127)[2]	1062 (321)
1994 (21-30 June)	Preen *et al.* 1997	1	10529 (1464)	968 (320)	1006 (494)
1999 (8-16 July)	Gales *et al.* 2004	1	13929 (1652)	163 (148)	174 (82)
2002 (4-10 February)	Holley *et al.* 2006	1	11021 (1357)	na	na
2007 (30 Mar – 16 June)	this report	1	14022 (1230)	tfs[3]	1411 (561)
2007 (30 Mar – 16 June)	this report	2	9347 (1204)	tfs	704 (354)

[1] Method 1 = Marsh and Sinclair, 1989; Method 2 = Pollock *et al.* 2006
[2] Survey only included the northern half of the Ningaloo Reef block
[3] tfs = too few sighted

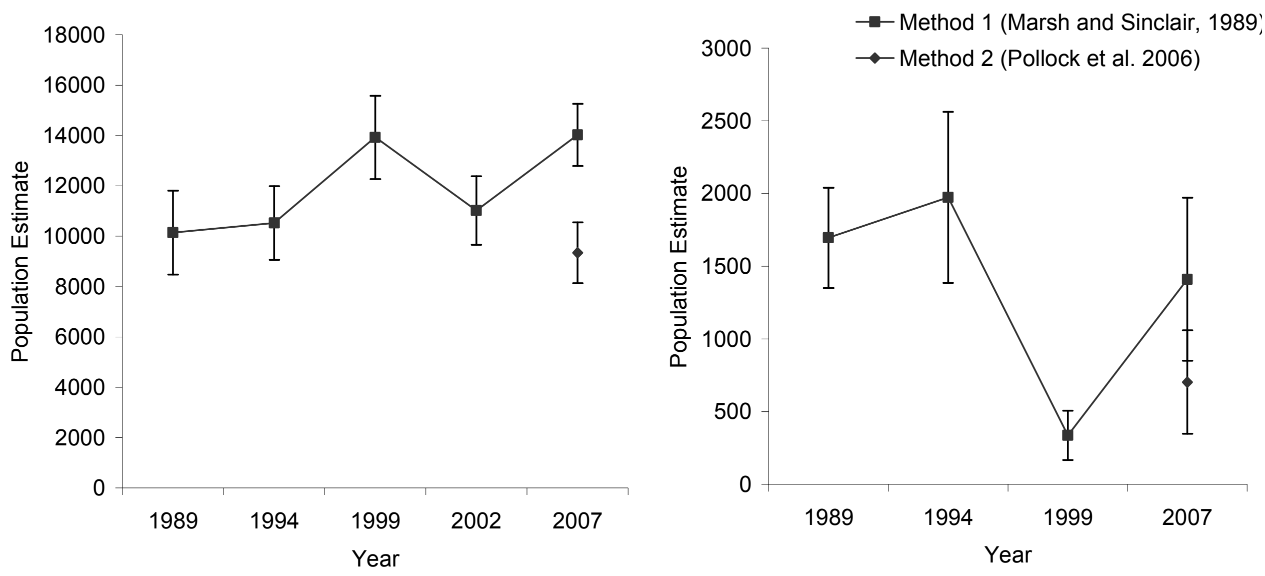

Figure 7. Population estimates for all aerial surveys for dugongs in (a) Shark Bay and (b) Ningaloo Reef and Exmouth Gulf combined, including results from the new estimate method used only for the current survey. Error bars represent standard errors.

Sampling methodology

The larger population estimate obtained from this survey using the Marsh and Sinclair (1989) method is unlikely to be an artefact of our sampling methodology because:

- all surveys to date have followed the same transect design and survey protocol;
- observers in each survey were trained and appear to have been consistently accurate according to the perception correction factors, which have been low in all surveys, demonstrating that the tandem observers on each side of the aircraft are producing matching results from their independent calls (Table 11);
- all surveys to date have been conducted under the same strict weather limit of a maximum Beaufort sea state of 2 to 3 to minimise the known effects of surface chop on the sightability of dugongs (Marsh & Sinclair, 1989b).

The 2002 surveys were the only surveys conducted during summer and confirmed a significantly different distribution pattern for dugongs within the Bay (Holley *et al.*, 2006). However, it is unlikely that the seasonal timing of the 2002 survey meant there were less dugongs in the Bay. In summer, dugongs move further into the shallow, southern regions of both sides of Shark Bay where their preferred seagrass forage is located (Anderson, 1986; Holley *et al.*, 2006). In winter the distribution of dugongs is defined by water temperatures and dugongs move from the colder, shallow waters in the southern bay, to the deeper north-western areas where the water temperatures are influenced by the warm Leeuwin Current (Marsh *et al.*, 1994; Preen *et al.*, 1997; Gales *et al.*, 2004, current study). Thus as dugongs are limited to accessing their preferred forage only during summer, it is unlikely dugongs move out of the bay during this time. Furthermore, the timing of the 2002 survey didn't appear to reduce the availability of dugongs to be counted as the availability correction factor was relatively low compared to other surveys (Table 11).

Changes in fecundity

The proportion of calves occurring in Shark Bay was significantly lower in 1999 and 2002 than during the earlier (1989 and 1994) surveys and the current survey. The suggested increase in the population since 2002 shown by the Marsh and Sinclair (1989) method is only possible through increased fecundity if the population growth rate has been at optimal levels of 5% every year since 2002. The high proportion of calves sighted during this survey (21.4%) suggests that this is possible. However, fecundity levels would have had to increase dramatically immediately after the 2002 survey when the calf ratio was only 3.6%, which is unlikely.

It is clearly not possible that the minimum four-fold increase in dugong abundance in Exmouth Gulf since the 1999 survey is a result of increased fecundity. Not only is this impossible in terms of dugong reproduction rates, there were no calves sighted during our survey. Although there may be some discrepancy in observers identification of calves, the two mid-seat observers were the same in both regions for this survey. Thus the large number of calves identified in Shark Bay compared to Exmouth Gulf was not an artefact of observer differences.

Movements

Gales *et al.* (2004) concluded that the most feasible hypothesis for the apparent increase in dugong abundance in Shark Bay between 1994 and 1999 was a result of large-scale regional movements of dugongs. Their simultaneous survey of Ningaloo Reef and Exmouth Gulf suggested that a decrease in dugong numbers had occurred in the region. Their survey followed a cyclone event that likely reduced the forage available to dugongs in the Ningaloo-Exmouth region, thus prompting a migration of dugongs from this habitat area to other habitats including Shark Bay. The subsequent decrease in the population estimate of dugongs in Shark Bay in 2002 is suggested, in the absence of simultaneous surveys in the Ningaloo-Exmouth region, to be a result of dugongs returning north (Holley *et al.*, 2006).

The increase in abundance indicated in this survey by the Marsh and Sinclair (1989) method is more difficult to explain simply by the link between the Shark Bay and Ningaloo-Exmouth populations. Although observers saw only two dugongs within the Ningaloo Reef survey area, a high number of dugongs in the Exmouth Gulf produced an overall population estimate well within previous estimates for the Ningaloo-Exmouth region (Figure 7). If population numbers in both regions have increased, it is likely that both populations are linked to those in dugong habitat further north. In the absence of regular dugong surveys or satellite tracking of dugongs further north than Ningaloo Reef, or genetic studies on dugong populations on the Western Australia coastline, it is difficult to determine how much movement occurs between the Western Australian dugong populations. However, aerial surveys conducted over a series of years in Queensland provide evidence of large scale movements between many habitat areas throughout the Torres Strait, Queensland, and Northern Territory (Marsh *et al.*, 1996; Marsh *et al.*, 1997; Marsh & Lawler, 2001b; Marsh *et al.*, 2003; Marsh *et al.*, 2004). However, recent genetic research using mitochondrial (maternally inherited) DNA shows regional differentiation of dugong populations along the east coast of Queensland (Blair *et al.*, in review). The data suggest two regional groups occur along the coastline of the mainland, with a third group in Torres Strait. This evidence supports the theory of interconnectivity of dugong populations along the Western Australian coastline, but a genetic study of dugongs on the west coast is needed together with further aerial survey work to determine whether boundaries exist between habitat areas.

Calculation of availability correction factor

The differences in the two methods of correcting for unseen animals are outlined in the methods section. The availability correction factor in the Marsh and Sinclair (1989a) method relies on observers assessing whether each dugong group sighted is ‘at the surface’. A high proportion of dugongs at the surface provides a high correction factor, and vice versa. The classification of ‘at the surface’ is difficult to determine, especially in clear water where dugongs can seen deeper in the water column than in turbid water, although observers show a high level of agreement in their assessment of groups ≤ 5 (Marsh & Sinclair, 1989b). In previous surveys of Shark Bay, the availability correction factor has been lower (ranging 2.19 – 2.75) than for the current survey (3.13, Table 11). There was a significant difference between the proportion of dugongs classified as at the surface in 2007 compared with all other years of surveys in Shark Bay. Therefore, either: (1) a higher proportion of dugongs were at the surface during this survey than in previous surveys, (2) turbidity levels were higher during this survey compared to previous surveys) or (3) observers made this assessment differently to previous observers. These possibilities are difficult to test. However, if the latter were true, the subjectivity of the observers’ calls on whether dugongs were ‘at the surface’ inflated the estimate from this Shark Bay survey. Using the availability correction factor from the 2002 survey reduces the estimate by 23%, bringing it more in line with the 2002 estimate and that obtained from the Pollock *et al.* (2006) method.

The Pollock *et al.* (2006) method improves the availability correction factor as it is derived from the proportion of dugongs that should be visible according to the environmental conditions (turbidity and Beaufort sea state) at the time of each sighting. It therefore, allows for changing conditions among sightings. This method also reduces the subjectivity of the availability correction factor as the classification of turbidity and Beaufort scales are clearly defined (Appendix 1) and it doesn’t rely on observers classifying whether dugongs are at the surface. The availability is calculated according to dugong dive profiles and the visibility of the dugongs in the various environmental conditions, and thus is a more reasonable estimate of the proportion of dugongs that should be ‘available’ (Pollock *et al.*, 2006) than the previous method which was based on the proportion of dugongs at the surface during one survey in one environment (Marsh & Sinclair, 1989a).

Table 14. Correction factors used to calculate population estimates for all surveys according to the Marsh and Sinclair (1989) method.

Survey[1]	Group size	Perception correction factor estimate (CV)		Availability correction factor estimate (CV)
		Port	Starboard	
Shark Bay				
1989	1.39 (0.597)	1.04 (0.015)	1.13 (0.08)	2.75 (0.139)
1994	1.23 (0.467)	1.09 (0.02)	1.19 (0.039)	2.19 (0.137)
1999	1.294 (0.035)	1.015 (0.002)	1.012 (0.002)	2.4891 (0.116)
2002	1.218 (0.036)	1.068 (0.01)	1.035 (0.006)	2.394 (0.12)
2007	1.519 (0.030)	1.015(0.002)	1.038(0.006)	3.129 (0.113)
Exmouth Gulf				
1989	1.48 (0.03)	1.03 (0.01)	1.04 (0.01)	2.45 (0.12)
1994	1.48 (0.14)	1.11 (0.09)	1.19 (0.11)	3.90 (0.15)
1999	1 (0)	1 (0)	1 (0)	2.489 (0.091)
2007	1.32 (0.095)	1.200 (0.107)	1.035 (0.016)	3.45 (0.181)

[1] Calculated according to published results of previous surveys in 1989, 1994, 1999 and 2002 (Preen *et al.*, 1997; Gales *et al.*, 2004; Holley *et al.*, 2006)

The status of dugongs in Shark Bay and Ningaloo-Exmouth

The method for determining the availability correction factor as described by Marsh and Sinclair (1989) is subject to the observers' interpretation of the proportion dugongs are 'at the surface'. If this proportion is over-estimated, the population estimate is inflated. The new Pollock *et al.* (2006) relies on fewer assumptions about dugong diving behaviour and their visibility in various environmental conditions, and therefore produces more accurate results. Therefore the best estimate of the Shark Bay dugong population is 9347 (± 1204 se) and the Ningaloo-Exmouth population is 702 (± 354 se). However, without having recalculated the 2002 survey estimate using the new method, I cannot rule out the possibility that the Shark Bay population has increased since the previous survey as suggested by the Marsh and Sinclair method (1989). The most likely explanation for this increase would be movement of dugongs from northern habitat areas, probably from areas further north than the Ningaloo-Exmouth region.

The Ningaloo-Exmouth population appears to have been re-established since the 1999 cyclone, suggesting that the seagrass beds, at least in the Exmouth Gulf, have recovered to some extent. The low numbers of dugongs on the Ningaloo Reef is noteworthy. There are some seagrass beds within the lagoon of the Reef including stands of *Amphibolis antarctica* and seasonal meadows of *Halophila ovalis* (Mike van Keulen, pers. comm., 2007). Larger dugong numbers have occurred within the Ningaloo survey area in previous years (Table 10). However, whether dugongs reside in this area throughout the year, or migrate out to the Reef from the Gulf to gain closer access to warmer deep waters off the Reef shelf, is unknown. If this movement does occur, it is possible that the earlier timing of the current survey compared to previous surveys meant water temperatures in the Gulf had not yet dropped enough for dugongs to move out to the Reef. Further information about the seagrass dynamics in the Gulf and Reef lagoon, and tracking data on dugong movements in this region (which would include temperature data), are needed to properly assess the ecology of dugongs in Ningaloo-Exmouth.

Further, the lack of calves sighted in Exmouth Gulf supports the theory that the response of dugongs to large-scale seagrass loss is not only to move (Preen & Marsh, 1995; Gales *et al.*, 2004), but also to reduce fecundity (Marsh & Kwan, in press). Our findings suggest that: (1) only single adults have re-populated Exmouth Gulf, and (2) reproductive rates have not yet recovered in this region. The calving rates in 1989 and 1994 were 24% and 20% respectively. It appears that the seagrass beds in Exmouth Gulf cannot yet sustain previous levels of fecundity.

Dolphins

The large number of dolphins sighted in Shark Bay was expected as there is a well known bottlenose dolphin population in the Bay, with an estimated 600 individuals in the eastern Bay alone (Mann & Watson-Capps, 2005). Of the 370 dolphins sighted, 256 were identified as bottlenose dolphins. In the western Bay observers also identified 27 Indo-Pacific humpback dolphins. The population of Indo-Pacific humpback dolphins is not recognised in the Shark Bay Management Plan (CALM, 1996) and only one individual was identified in the 1989 and 1994 surveys (Preen *et al.*, 1997). The recognised range of Indo-Pacific humpback dolphins in Western Australia extends from Exmouth Gulf northwards, and sightings in Shark Bay are considered rare (Parra *et al.*, 2004). However, research in Shark Bay is biased towards the eastern Bay where no Indo-Pacific humpback dolphins were sighted during this survey.

Only six bottlenose dolphins were sighted along Ningaloo Reef, while in the Gulf observers saw similar numbers of dolphins as in the 1989 and 1994 surveys (41, 59, and 24 respectively, Preen *et al.*, 1997). As in previous surveys, the species were bottlenose and Indo-Pacific humpback dolphins, in similar proportions. Observers sighted 6 Indo-Pacific humpback dolphins, compared to 1 in 1989 and 6 in 1994. (Preen *et al.*, 1997).

There is little known about the distribution, abundance or status of Indo-Pacific humpback dolphins in Australia, however, populations appear to be small, localised, and in many cases, declining (Parra *et al.*, 2004). Abundance estimates exist for only two Indo-Pacific humpback dolphins populations in Queensland: Moreton Bay where there are less than 200 individuals (Corkeron *et al.*, 1997), and Cleveland Bay where the population is less than 100 (Parra *et al.*, 2006). In Shark Bay the Indo-Pacific humpback dolphins are afforded protection by the Marine Park status of the Bay and have relatively few threats compared to the two known populations in Queensland, which occur along an urban coastline (Brisbane and Townsville respectively). The most likely threat to all dolphins in Shark Bay is boat traffic, including boat strikes and disturbance from both passing boats and tourism directed towards these species (Bejder *et al.*, 2006). In Exmouth Gulf these dolphins are not afforded that same level of protection and are threatened by the possible impacts of prawn trawlers (Parra *et al.*, 2004), and proposed mining developments. Our survey suggests there could be a relatively large population of Indo-Pacific humpback dolphins both in Shark Bay and Exmouth Gulf. Further research is needed on both these populations to determine their distribution and abundance in order to effectively assess potential human impacts.

Turtles

A total of 546 turtles in Shark Bay equates to 50% more than were seen in 1989 (326) and 1994 (365). As in previous years, large numbers were sighted in the eastern Bay, but the distribution more closely followed that of 1989 where the turtles were mainly in the deeper waters rather than on the shallow sand banks. In the western Bay the turtles were in higher concentrations in the southern part of the Bay than in previous years. The turtles were not identified to species but green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles are known to be the most abundant species in Bay with the former species occurring in higher densities than the latter (CALM, 1996; Heithaus *et al.*, 2005).

Along Ningaloo Reef sighting rates of turtles were twice those of 1989 and 1994 (313, 162 and 119 respectively). Numbers in Exmouth Gulf were similar to 1989 (this survey: 286, 1989: 262) but higher than 1994 (115, Preen *et al.*, 1997). There are higher abundances of green turtles than loggerheads in both locations and thus a high proportion of our sightings were likely green turtles. The distribution of turtles in Exmouth Gulf follows that of the 1989 survey where most were sighted in the southern and eastern parts of the Gulf.

Conservation of dugongs in Western Australia

Overall it appears that both the Shark Bay and Ningaloo-Exmouth dugong populations fluctuate over time, and it is proposed that changes in numbers reflect dugong movements between these areas, and possibly habitats further north. The known human impacts on the Shark Bay dugongs are minimal as the population is isolated from urban development, suffers low levels of indigenous hunting (Gales *et al.*, 2004; Holley *et al.*, 2006), and is protected by the Marine Park and World Heritage status of the Bay. The variation in the proportions of calves sighted among survey years probably reflect the effects of natural variation in environmental conditions on fecundity. Further research on dugong movement patterns and behaviour within the Bay would increase our ability to predict such effects. In addition, dugong movements between habitat areas in WA reduce the predictability of human or natural impacts on the WA population as a whole. Thus with the current knowledge, it is appropriate to use a medium level of population growth and conservative recovery factor is to estimate the maximum sustainable level of human-caused mortalities. The PBR method (Wade, 1998) gives a maximum of 62 dugongs per year in Shark Bay, and four dugongs per year in Ningaloo-Exmouth. The monitoring of human-caused mortalities should be considered a high priority for management as this provides more immediate and consistent feedback on the sustainability of direct human impacts on these dugong populations. However, indirect impacts, such as possible disturbance from boats, and particularly in Shark Bay, tourist vessels, as well as potential impacts of mining developments on dugong habitat, cannot be monitored from mortality rates. Aerial surveys provide information on the structure, distribution, and abundance of dugong populations, and as such, allow managers the only opportunity to monitor the large-scale impacts of habitat degradation.

Ultimately, the conservation and management of human impacts on dugongs in Western Australia would be best achieved by combining the approaches used during this project to assess population trends, i.e., regular surveys to assess population distribution and abundance and comparing PBR and with actual levels of anthropogenic mortality. However, this information also needs to be combined with an understanding the ecological and social factors affecting the behaviour and movements of individual animals. Predicting the impacts of habitat modification *before* they threaten the survival of dugongs presents a great challenge. Estimating the levels of these impacts requires not only demographic knowledge of the population and the identification of important habitat areas (Marsh *et al.*, 2002), but also a quantitative assessment of these impacts on the behaviour and movements of dugongs. A number of techniques can by employed to assess behaviour and movement patterns, including satellite tagging, genetic studies and direct observations. In combination, these tools provide a complete understanding of the dynamics of a population. Knowledge of the demographics and population trends is essential for determining how variations in behaviour and movement patterns will affect population levels, while developing a baseline understanding of the behaviour of individual dugongs and the evolutionary processes governing their behaviour allows predictions of population responses that cannot be assessed by simply monitoring population levels or assessing mortality rates.

RECOMMENDATIONS

RECOMMENDATION 1

That a Research and Monitoring Strategy be developed for dugongs in WA.

The possibility of links between dugong populations along the WA coastline suggests that the management of these populations requires a single coordinated approach by DEC. Knowledge of the dugong population in WA is limited to the Shark Bay / Ningaloo / Exmouth region and research needs to be extended northward of this region. An overarching Research and Monitoring Strategy for Dugongs in WA should be developed with input from all stakeholders, ideally through a workshop to determine research and monitoring needs. This Plan could feed into a national Wildlife Conservation Plan for Dugongs.

RECOMMENDATION 2

That the biologically and logistically feasible spatial scale upon which to manage dugongs be investigated through population genetic techniques.

Recent genetic research using mitochondrial (maternally inherited) DNA shows regional differentiation between dugong populations along the east coast of Queensland (Blair *et al.*, in review). A similar study of dugong populations along the WA coastline would enhance our knowledge of the interconnectedness between the these populations and provide a baseline for determining the best spatial scale at which to manage dugongs in WA.

RECOMMENDATION 3

That the program of aerial surveys in Shark Bay, Ningaloo Reef and Exmouth Gulf be continued, but extended to include dugong habitat northward of the Ningaloo-Exmouth region, to provide the basis for a spatial risk assessment of dugongs in WA.

Following Recommendation 2, the current aerial survey monitoring program of Shark Bay should be redesigned at a spatial scale consistent with the movements and relatedness between dugong populations along the WA coastline. This program would need to take into account logistical constraints of large scale aerial surveys. The logistical and funding requirements to implement an expansive monitoring program are potentially prohibitive. However, aerial survey methodology continue to be developed and new technologies such as unmanned aerial vehicles (UAVs) need to be investigated in an effort to reduce these logistical and funding issues. Knowledge of dugong distribution and abundance along the WA coastline would provide the basis for a spatial risk assessment to be conducted to determine the extent to which dugongs are at risk from human activities in WA.

RECOMMENDATION 4

That dugongs occurring along Ningaloo Reef and in Exmouth Gulf be satellite tagged to determine the habitat use in this area and movement between these habitats and those further north.

Little is known about the habitat and movements of dugongs between Ningaloo Reef and Exmouth Gulf. During this survey only two dugongs were sighted along the Reef even though the population in the Gulf was similar to pre-1999 levels. Dugongs may only frequent the Ningaloo Reef seasonally to gain access to warm waters. The use of seagrass beds within the Ningaloo Marine Park needs to be investigated by tracking the movements of dugongs in this region. Satellite tags now provide fine scale movement data from which it is possible to obtain detailed habitat use patterns (e.g. Sheppard *et al.*, 2006). This would allow managers to identify important dugong habitat areas within the marine park and provide protection from tourism impacts.

RECOMMENDATION 5

That the 2002 survey data be reanalysed using the improved Pollock *et al.* (2006) method for calculating correction factors to allow more accurate comparisons with the current survey.

The current survey highlights the importance of using correction factors that are based on realistic assumptions about dugong diving behaviour and the effects of sighting conditions on the availability of dugongs to be counted. The new Pollock *et al.* (2006) method addresses biases within the Marsh and Sinclair (1989) approach to calculating correction factors used in previous surveys. Comparisons between the current results and the 2002 survey data, recalculated using the new method, would allow a more accurate assessment of whether dugong numbers in Shark Bay have changed in the last five years.

RECOMMENDATION 6

That the dugong population estimates obtained from all surveys in the Shark Bay / Ningaloo / Exmouth region be compared statistically to determine if the apparent fluctuations in numbers are real.

Although dugong population estimates across years appear to have fluctuated, the differences in these estimates were only tested statistically for 1989 and 1994. Thus the fluctuations between subsequent years cannot be assumed to be real as they may be accounted for by the error incorporated in the estimates. A statistical comparison of survey data obtained across all years (1989 - 2007) is needed to determine whether the changes in population estimates are significant.

RECOMMENDATION 7

That photo-identification studies and/or boat-based surveys be conducted of the Indo-Pacific humpback dolphin populations in Shark Bay and Exmouth Gulf to determine their abundance and distribution.

This survey is the first reported evidence that a substantial population of Indo-Pacific humpback dolphins occurs in western Shark Bay. This survey also provides further support for a persistent population of Indo-Pacific humpback dolphins in Exmouth Gulf. Nothing is known of either of these populations, or most other Indo-Pacific humpback dolphin populations in Australia (Parra *et al.*, 2004). The location of these dolphins makes them among the most accessible for research on a species about which very little is known. Surveys to determine their distribution and abundance, by way of boat-based transect surveys and/or photographic identification studies, should be conducted to provide managers with the baseline knowledge needed to affect suitable conservation actions to protect this species.

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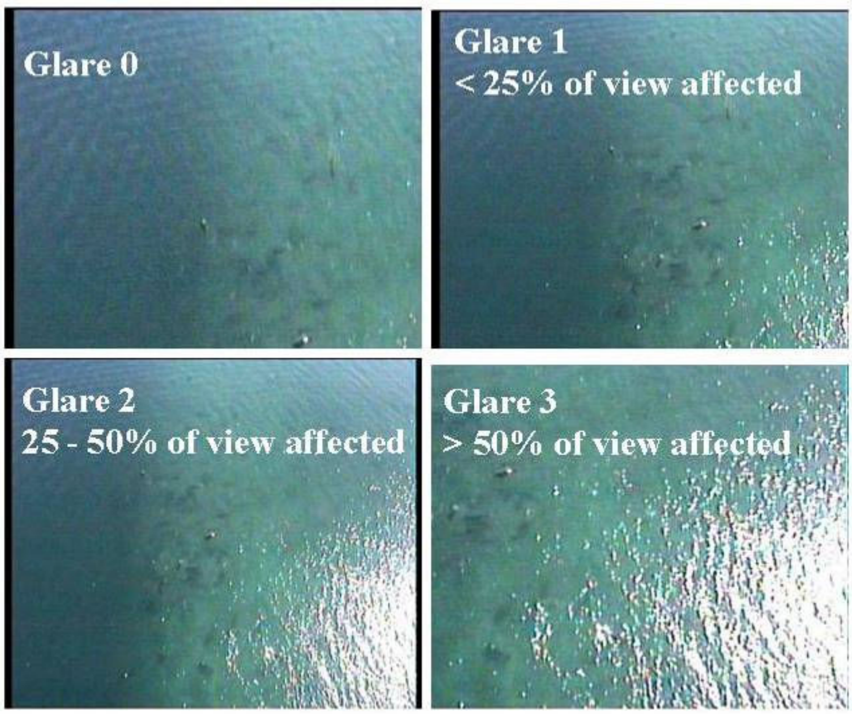
APPENDIX 1: Scales for environmental conditions

Turbidity Scale

Turbidity	Water Quality	Depth Range	Visibility of Sea Floor
1	Clear	Shallow	Clearly visible
2	Variable	Variable	Visible but unclear
3	Clear	>5m	Not visible
4	Turbid	Variable	Not visible

Glare Scale



APPENDIX 2: Details of transect lengths and areas

Block	Transect	Length (km)	Area (km2)
EG1	1	8.41	3.36
EG1	2	10.65	4.26
EG1	3	7.25	2.90
EG1	4	27.69	11.08
EG1	5	25.05	10.02
EG1	6	23.94	9.58
EG1	7	32.36	12.94
EG1	8	33.59	13.43
EG1	9	36.80	14.72
EG1	10	38.37	15.35
EG1	11	42.86	17.14
EG1	12	46.32	18.53
EG1	13	41.68	16.67
EG1	14	45.88	18.35
EG1	15	49.38	19.75
EG1	16	51.50	20.60
EG1	17	51.04	20.42
EG1	18	51.03	20.41
SB3	6	29.56	11.82
SB3	9	14.47	5.79
SB3	10	51.96	20.78
SB3	11	50.14	20.06
SB3	12	48.17	19.27
SB3	13	47.58	19.03
SB3	14	46.19	18.47
SB3	15	46.10	18.44
SB3	16	49.93	19.97
SB3	17	45.19	18.07
SB3	18	47.34	18.94
SB3	19	47.17	18.87
SB4	37	5.11	2.04
SB4	38	6.27	2.51
SB4	39	6.87	2.75
SB4	40	12.05	4.82
SB4	41	21.38	8.55
SB4	42	24.59	9.84
SB4	43	29.49	11.79
SB4	44	33.09	13.23
SB4	45	38.00	15.20
SB4	46	36.40	14.56
SB4	47	35.73	14.29
SB4	48	37.58	15.03
SB4	49	39.67	15.87
SB4	50	44.57	17.83
SB4	51	49.01	19.60
SB4	52	52.02	20.81
SB4	54	53.71	21.48
SB4	56	51.21	20.48
SB4	350	4.05	1.62
SB4	360	6.66	2.66

Block	Transect	Length (km)	Area (km2)
SB4	370	6.81	2.73
SB5	20	46.20	18.48
SB5	53	45.57	18.23
SB5	55	44.21	17.69
SB5	57	40.76	16.30
SB6	58	48.71	19.48
SB6	59	39.26	15.70
SB6	60	47.06	18.82
SB6	61	38.91	15.56
SB6	62	45.39	18.16
SB6	63	36.79	14.72
SB6	64	42.24	16.90
SB6	65	34.68	13.87
SB6	66	41.64	16.66
SB6	67	33.09	13.24
SB6	68	40.19	16.08
SB6	69	31.10	12.44
SB7	71	62.88	25.15
SB7	73	58.12	23.25
SB7	75	55.78	22.31
SB7	77	55.05	22.02
SB7	79	54.02	21.61
SB7	80	53.77	21.51
SB7	81	48.76	19.51
SB7	82	47.21	18.88
SB7	83	47.63	19.05
SB7	84	46.23	18.49
SB7	85	19.49	7.79
SB7	86	20.24	8.10
SB7	87	19.23	7.69
SB7	88	19.60	7.84

APPENDIX 3: Beaufort sea state, glare and turbidity for each transect

See Appendix 1 for turbidity and glare scales.

Block/ Transect	Beaufort Sea State			Turbidity			Glare South			Glare North		
	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
SB0												
21	0	1	1	0	2	1	0	1	0	2	3	3
22	0	1	0	0	2	1	0	0	0	1	2	1
23	0	1	1	0	3	1	1	2	1	2	3	3
24	0	1	0	0	3	1	0	0	0	1	2	1
25	0	1	1	0	3	2	1	2	1	3	3	3
26	0	1	1	0	3	1	0	0	0	1	3	
27	0	1	1	0	3	0	0	2	1	1	3	2
28	0	1	1	0	3	2	0	0	0	0	2	
SB1												
29	0	1	0	0	3	0	2	3	3	1	2	2
30	0	0	0	0	3	2	0	0	0	0	3	
31	1	3	2	0	4	2	0	1		3	3	3
36	1	3	2	0	4	1	0	0	0	3	3	
38	1	4	1	0	4	1	1	1	1	3	3	3
39	1	4	2	0	4	2	0	0	0	3	3	3
40	1	4	2	0	4	0	0	1	1	0	1	1
41	3	4	3	0	4	2	0	0	0	2	2	2
42	1	2	2	0	2	2	0	0		3	3	
43	3	3	3	1	2	2	0	0		0	0	
44	1	3		0	2	0	3	3	3	0	1	
370	1	3	2	0	4	2	0	0	0	3	3	3
SB2												
1	1	2	1	0	2	1	0	0		3	3	
2	1	4	1	0	2	0	0	0		3	3	
3	1	4	3	0	2	2	0	0	0	3	3	3
4	2	4	2	1	2	2	0	0	0	3	3	3
5	1	3	2	1	2	2	0	0	0	3	3	3
7	1	4	3	0	2	2	0	0		3	3	
8	1	4	2	0	3	1	0	0		3	3	
1001	1	3	2	0	2	0	1	1	1	1	2	
1002	1	4	4	0	2	0	0	1		0	2	2
1003	1	4	1	0	3	1	1	1	1	2	3	3
1004	1	4	2	0	2	2	1	1	1	2	3	3
1005	1	4	3	0	1	1	1	1	1	2	3	3
1006	2	4	2	1	4	2	1	1		3	3	
1007	1	4	2	0	2	2	1	2		3	3	3
SB3												
6	0	1	0	0	2	1	0	1	0	2	2	2
9	1	1	1	0	1	0	0	1		1	2	2
10	0	1	0	0	2	1	0	0	0	1	3	3
11	0	0	0	0	2	1	0	1	0	2	2	2
12	0	1	1	0	2	1	0	0	0	3	3	3
13	0	2	2	0	2	2	0	0	0	1	2	1
14	0	2	1	0	3	1	0	0		3	3	
15	0	2	2	0	3	3	0	3		1	2	
16	0	3	2	0	3	3	0	0	0	2	3	3

Block/ Transect	Beaufort Sea State			Turbidity			Glare South			Glare North		
	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
17	1	2	2	0	3	3	0	0	0	3	3	3
18	1	3	2	0	3	3	0	1	0	2	3	2
19	1	3	2	0	3	3	0	0	0	3	3	3
SB4												
37	3	3		1	3		0	0	0	3	3	
38	1	3		0	2	0	1	1		3	3	
39	1	2	1	0	4	2	0	0		3	3	
40	1	3	1	0	4	0	0	0		0	0	
41	1	3	3	0	4	2	0	0		1	1	
42	1	2	1	1	4	2	1	1		3	3	
43	1	2	2	1	4	2	0	0	0	2	2	2
44	2	3	2	0	4	2	0	0		0	0	
45	1	2	2	0	3	1	0	0	0	1	2	
46	1	3	3	0	4	0	1	1	1	3	3	3
47	1	2	1	0	3	1	0	0		2	2	
48	1	3	2	0	4	0	2	3	3	1	1	1
49	1	2	2	0	3	3	0	0	0	2	2	2
50	1	3	2	0	3	2	1	1	1	2	3	3
51	1	3	3	0	3	2	1	1	1	1	2	
52	2	3	2	0	4	2	1	1	1	2	2	2
54	2	4	3	0	4	2	1	1	1	2	2	2
56	2	3	2	0	4	2	0	0	0	3	3	3
350	1	1		1	1		0	0		3	3	
360	1	3		0	3	0	0	0		3	3	
370	1	2	1	0	1	1	0	0		3	3	
SB5												
20	1	3	3	1	3	2	0	0	0	3	3	3
53	1	3	3	1	3	2	0	0		3	3	
55	1	3	2	0	3	0	0	1		2	3	3
57	1	3	2	0	3	3	0	0	0	3	3	3
SB6												
58	2	3	3	0	3	2	2	3	3	0	0	0
59	1	4	3	0	3	3	0	0	0	3	3	3
60	1	2	2	0	4	3	0	0	0	3	3	3
61	1	1	1	1	3	3	0	0	0	3	3	3
62	1	2	1	0	3	3	0	0	0	3	3	3
63	1	1	1	0	4	2	0	0	0	2	2	2
64	1	1	1	0	3	2	0	0	0	3	3	3
65	1	1	1	0	4	3	0	0	0	3	3	3
66	1	2	1	1	3	3	0	0	0	3	3	3
67	1	1	1	0	4	2	0	0	0	3	3	3
68	1	3	2	0	3	3	0	0	0	3	3	3
69	1	2	1	0	3	2	0	0		2	3	
SB7												
71	0	1	0	0	3	2	0	1	1	3	3	3
73	0	2	1	0	4	2	0	0	0	1	1	1
75	0	1	0	0	3	3	0	1	1	2	3	2
77	0	1	1	0	3	3	0	0	0	1	1	1
79	0	1	1	0	3	3	1	1	1	2	2	2
80	0	1	0	1	3	3	0	0	0	1	1	1
81	1	4	4	0	4	2	0	1	1	1	2	2
82	2	4	4	0	4	3	0	0	0	3	3	3

Block/ Transect	Beaufort Sea State			Turbidity			Glare South			Glare North		
	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
83	1	4	4	0	4	3	0	1		2	3	
84	2	4	3	0	4	4	0	0	0	3	3	3
85	1	3	3	3	4	4	0	1		3	3	3
86	2	3	3	3	4	4	0	0	0	3	3	3
87	1	4	3	0	4	3	0	1		2	4	3
88	2	4	3	0	4	4	0	0	0	3	3	3
NR1												
1	1	1		1	2		0	0		2	2	
2	1	1		2	2		0	0		1	1	
3	1	1		0	1		0	0		2	2	
4	1	1		2	2		0	0		2	2	
5	1	1		0	2		0	0		2	2	
6	1	1	1	1	3		0	0	0	2	2	2
7	1	1		1	3		0	0		2	2	
8	1	1	1	2	2	2	0	0		1	1	
9	1	1		1	3	2	0	0		2	2	
10	1	1	1	1	3	3	0	0		2	2	
11	1	1		1	3		0	0		2	2	
12	1	2	1	0	2	2	0	0		3	3	
13	1	1	1	1	3	2	0	0		2	2	
14	1	2	1	1	2	1	0	0		3	3	
15	1	1	1	0	3	1	0	0		2	2	
16	1	1	1	1	3	1	0	0		3	3	
17	1	1		0	3	2	0	1		2	2	
18	1	2	1	1	3	2	0	0		1	1	
19	1	2	2	2	3	2	1	1		2	2	
20	1	2	1	0	3	3	0	0		1	1	
21	1	1		1	2		0	0		2	2	
22	1	2	1	0	3	2	0	0		3	3	
23	1	2	2	0	3	2	0	0		2	3	
24	1	1		1	2		0	0		3	3	
25	1	2		1	2	2	0	0		3	3	
26	1	2		1	3	2	0	0		3	3	
27	2	3	2	0	3	2	0	0		3	3	
28	1	3		0	3	2	0	0		3	3	
29	1	3		1	3	2	0	0		3	3	
30	3	3	3	2	3	2	0	0		3	3	
31	1	3	3	1	2	2	0	0		3	3	
32	3	3		0	2	2	0	0		3	3	
33	1	2		1	2	1	0	0		3	3	
34	1	3		0	3		0	0		0	3	
35	1	3		1	2		0	0		3	3	
36	3	3		1	2		0	0		3	3	
37	1	3		0	3	0	0	0		3	3	
38	1	3		0	3	1	0	0		3	3	
39	2	3		1	3	1	0	0		3	3	
40	2	2	2	1	2	1	0	0		3	3	
41	1	3		1	3		0	0		3	3	
42	2	3		2	3		0	0		0	0	
43	2	3		1	3	3	3	3		0	0	
EG1												
1	1	2		0	4	4	0	0		0	1	

Block/	Beaufort Sea State			Turbidity			Glare South			Glare North		
Transect	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode	Min	Max	Mode
2	1	2	2	0	4	4	0	0	0	2	2	2
3	1	2	1	0	4	2	0	0		2	2	
4	1	3	2	0	4	2	0	0	0	0	2	1
5	0	1	0	1	4	4	0	0	0	1	2	1
6	1	1	1	0	4	1	0	0	0	0	4	0
7	0	1	1	0	4	4	0	0	0	2	2	2
8	0	1	1	0	4	4	0	0	0	0	1	
9	0	2	1	0	4	4	0	1	0	2	2	2
10	0	1	1	0	4	4	0	0	0	0	1	
11	0	2	1	0	4	4	0	1	0	2	3	3
12	1	2	1	0	4	4	0	0	0	1	1	1
13	2	2	2	0	4	4	0	0	0	0	2	
14	1	2	2	0	4	4	0	0	0	2	2	2
15	1	2	2	0	4	4	0	0	0	2	3	
16	1	3	2	0	4	3	0	1	0	2	2	2
17	1	2	2	0	4	4	0	0	0	1	2	2
18	2	2	2	0	4	3	0	0	0	2	2	2

APPENDIX 4: Raw data for sightings of dugongs used for population estimates

See Appendix 1 for Turbidity scale
Observer: P = Port, S = Starboard, F = Front, R = Rear, B = Both

Date	Block	Transect	Direction	Beaufort	Turbidity	Observer	Number	Calves	Latitude	Longitude
15/06/2007	EG1	2	E	2	2	PR	1		-22.4574	114.1791
16/06/2007	EG1	5	W	1	4	PB	2		-22.3742	114.3327
16/06/2007	EG1	5	W	1	4	PB	1		-22.3750	114.2851
16/06/2007	EG1	6	E	1	4	SB	1		-22.3317	114.2803
16/06/2007	EG1	7	W	1	2	PF	1		-22.2927	114.3743
16/06/2007	EG1	8	E	1	4	SB	1		-22.2499	114.3392
16/06/2007	EG1	8	E	1	4	SB	1		-22.2501	114.3498
16/06/2007	EG1	8	E	1	4	SB	3		-22.2501	114.3551
16/06/2007	EG1	9	W	1	1	SB	1		-22.2108	114.4242
16/06/2007	EG1	9	W	2	2	SB	1		-22.2105	114.4090
16/06/2007	EG1	10	E	1	2	SB	1		-22.1650	114.3801
12/06/2007	EG1	15	E	2	2	SF	1		-21.9579	114.5347
12/06/2007	EG1	15	E	2	4	PF	1		-21.9576	114.5178
12/06/2007	EG1	15	E	2	2	SF	2		-21.9579	114.5294
12/06/2007	EG1	16	W	2	2	PF	1		-21.9177	114.5729
12/06/2007	EG1	16	W	2	2	SB	1		-21.9178	114.5688
12/06/2007	EG1	16	W	2	2	SF	1		-21.9179	114.5626
12/06/2007	EG1	16	W	2	2	PB	1		-21.9177	114.5739
12/06/2007	EG1	16	W	2	2	SR	2		-21.9179	114.5626
12/06/2007	EG1	16	W	2	3	SB	3		-21.9177	114.5729
12/06/2007	EG1	16	W	2	2	PB	1		-21.9179	114.5636
12/06/2007	EG1	16	W	2	2	PR	2		-21.9179	114.5626
12/06/2007	EG1	16	W	2	4	SB	1		-21.9181	114.5535
12/06/2007	EG1	16	W	2	2	SF	1		-21.9181	114.5473
12/06/2007	EG1	16	W	2	2	PR	1		-21.9181	114.5332
13/06/2007	NR1	8	E	1	2	SB	1		-23.2590	113.7498
13/06/2007	NR1	20	E	2	2	SF	1		-22.7472	113.7213
31/05/2007	SB1	42	W	2	2	PB	2	1	-25.9211	113.3737
30/05/2007	SB1	370	E	1	3	SR	1		-26.1247	113.3627
4/06/2007	SB3	11	E	0	1	PF	1		-25.9178	113.8075
4/06/2007	SB3	14	W	2	1	PB	1		-25.7913	114.1141
8/06/2007	SB3	17	E	2	3	SB	1		-25.6660	113.7186
8/06/2007	SB3	18	W	1	2	PR	1		-25.6315	113.9687
8/06/2007	SB3	18	W	2	3	SB	2	1	-25.6326	113.8437
8/06/2007	SB3	19	E	2	3	PB	2		-25.5839	113.8415
8/06/2007	SB3	19	E	2	3	PF	1		-25.5844	113.8008
30/05/2007	SB4	39	E	1	2	PR	1		-26.0400	113.2378
30/05/2007	SB4	39	E	1	2	SB	1		-26.0400	113.2328
30/05/2007	SB4	39	E	1	4	PF	2		-26.0400	113.2378
31/05/2007	SB4	42	W	2	4	SB	2	1	-25.9190	113.2120
31/05/2007	SB4	42	W	2	2	PB	2		-25.9185	113.1944
31/05/2007	SB4	42	W	2	4	PB	5	2	-25.9193	113.2178
31/05/2007	SB4	42	W	1	4	PB	2	1	-25.9196	113.2296
31/05/2007	SB4	42	W	2	3	PR	1		-25.9185	113.1944
31/05/2007	SB4	42	W	2	2	SR	2	1	-25.9185	113.1944
31/05/2007	SB4	42	W	2	3	PR	1		-25.9183	113.1885
31/05/2007	SB4	42	W	2	4	PB	1		-25.9190	113.2120

Date	Block	Transect	Direction	Beaufort	Turbidity	Observer	Number	Calves	Latitude	Longitude
31/05/2007	SB4	42	W	2	1	PB	2		-25.9183	113.1885
31/05/2007	SB4	43	E	2	4	SB	1		-25.8731	113.1819
31/05/2007	SB4	43	E	2	2	PB	3	1	-25.8751	113.2988
31/05/2007	SB4	43	E	2	4	PB	2	1	-25.8733	113.1711
31/05/2007	SB4	43	E	2	4	PB	1		-25.8731	113.1872
31/05/2007	SB4	43	E	2	4	PB	2	1	-25.8731	113.1872
31/05/2007	SB4	43	E	1	4	PB	1		-25.8731	113.1605
31/05/2007	SB4	43	E	2	2	SB	2	1	-25.8732	113.1926
31/05/2007	SB4	43	E	2	2	SB	1		-25.8744	113.2670
31/05/2007	SB4	43	E	2	2	PB	1		-25.8751	113.2988
31/05/2007	SB4	43	E	2	2	SB	2	1	-25.8754	113.3095
31/05/2007	SB4	43	E	2	4	SB	2	1	-25.8733	113.2033
31/05/2007	SB4	43	E	2	4	PB	2	1	-25.8735	113.2298
31/05/2007	SB4	43	E	2	2	SF	1		-25.8757	113.3309
31/05/2007	SB4	44	E	2	3	PF	1		-25.8379	113.2654
31/05/2007	SB4	44	E	2	3	PF	1		-25.8361	113.2174
31/05/2007	SB4	45	E	1	2	SB	1		-25.7869	113.0997
31/05/2007	SB4	45	E	1	1	SR	1		-25.7915	113.3440
31/05/2007	SB4	45	E	1	3	PB	1		-25.7889	113.1193
31/05/2007	SB4	45	E	2	3	PB	3		-25.7906	113.1810
31/05/2007	SB4	45	E	2	3	PB	1		-25.7911	113.2222
31/05/2007	SB4	45	E	1	2	SF	1	1	-25.7915	113.3602
31/05/2007	SB4	45	E	2	3	SB	2	1	-25.7911	113.2170
31/05/2007	SB4	46	W	2	3	SF	2	1	-25.7516	113.3521
31/05/2007	SB4	46	W	3	4	PB	2	1	-25.7507	113.1304
31/05/2007	SB4	46	W	3	3	SB	1		-25.7506	113.1133
31/05/2007	SB4	46	W	3	4	PF	1		-25.7509	113.1645
31/05/2007	SB4	47	E	1	2	PR	3	1	-25.7095	113.0913
31/05/2007	SB4	47	E	2	3	SB	1		-25.7098	113.2108
31/05/2007	SB4	47	E	2	3	PF	1		-25.7096	113.2320
31/05/2007	SB4	47	E	2	1	PB	2	1	-25.7084	113.3551
31/05/2007	SB4	47	E	2	1	PB	4	2	-25.7090	113.3227
31/05/2007	SB4	47	E	1	1	PB	2	1	-25.7088	113.3334
31/05/2007	SB4	48	E	2	3	PB	2	1	-25.6663	113.2334
31/05/2007	SB4	48	E	2	1	PB	1		-25.6663	113.3042
31/05/2007	SB4	48	E	2	3	PB	1		-25.6660	113.2445
31/05/2007	SB4	48	E	2	2	PB	1		-25.6666	113.3373
31/05/2007	SB4	48	E	2	3	PF	2		-25.6660	113.2389
31/05/2007	SB4	49	E	1	2	PR	1		-25.6263	113.0733
31/05/2007	SB4	49	E	2	3	PB	1		-25.6270	113.2188
31/05/2007	SB4	49	E	2	3	PF	1		-25.6268	113.2796
31/05/2007	SB4	49	E	2	3	SB	2	1	-25.6274	113.2472
31/05/2007	SB4	49	E	2	3	SB	2		-25.6272	113.2367
31/05/2007	SB4	49	E	2	3	SB	2	1	-25.6272	113.2403
31/05/2007	SB4	50	W	3	1	SB	2		-25.5830	113.3567
31/05/2007	SB4	50	W	3	1	PB	1		-25.5829	113.3185
31/05/2007	SB4	50	W	2	3	PB	2	1	-25.5838	113.2055
31/05/2007	SB4	50	W	3	1	PF	1		-25.5835	113.3837
31/05/2007	SB4	50	W	3	1	SF	1		-25.5831	113.3077
31/05/2007	SB4	50	W	2	3	PB	1		-25.5836	113.2274
31/05/2007	SB4	50	W	3	1	PB	3	1	-25.5832	113.3691
31/05/2007	SB4	50	W	3	1	PB	2	1	-25.5831	113.3621
31/05/2007	SB4	50	W	2	3	SB	3	1	-25.5835	113.2330

Date	Block	Transect	Direction	Beaufort	Turbidity	Observer	Number	Calves	Latitude	Longitude
31/05/2007	SB4	50	W	2	3	SB	1		-25.5836	113.2274
31/05/2007	SB4	50	W	2	3	PB	3		-25.5838	113.1559
11/06/2007	SB4	51	W	2	3	SR	2	1	-25.5406	113.3395
11/06/2007	SB4	51	W	3	3	PB	3		-25.5409	113.2191
11/06/2007	SB4	51	W	3	3	PB	2		-25.5411	113.2077
11/06/2007	SB4	51	W	2	3	PF	2	1	-25.5411	113.4653
11/06/2007	SB4	51	W	3	3	PR	2	1	-25.5405	113.2702
11/06/2007	SB4	51	W	3	3	SR	1		-25.5412	113.2021
11/06/2007	SB4	51	W	3	3	SR	1		-25.5406	113.2589
11/06/2007	SB4	51	W	3	3	PB	2		-25.5414	113.1850
11/06/2007	SB4	51	W	3	3	SR	1		-25.5414	113.1792
11/06/2007	SB4	51	W	3	3	PF	1		-25.5414	113.1792
11/06/2007	SB4	52	E	3	3	PR	2	1	-25.4976	113.2165
11/06/2007	SB4	52	E	3	3	SR	1		-25.4977	113.1742
11/06/2007	SB4	52	E	3	3	SB	1		-25.4976	113.1902
11/06/2007	SB4	52	E	3	3	SF	2	1	-25.4976	113.2009
11/06/2007	SB4	52	E	3	3	PF	1		-25.4977	113.1582
11/06/2007	SB4	52	E	2	3	SB	2	1	-25.4982	113.3592
11/06/2007	SB4	52	E	2	3	SF	1		-25.4983	113.3645
11/06/2007	SB4	52	E	2	4	SB	1		-25.4989	113.4285
11/06/2007	SB4	52	E	3	3	SF	1		-25.4977	113.1795
11/06/2007	SB4	52	E	2	4	SB	1		-25.4986	113.4017
11/06/2007	SB4	52	E	2	4	SB	3	1	-25.4986	113.4017
11/06/2007	SB4	52	E	2	2	PF	2		-25.4986	113.3911
11/06/2007	SB4	54	W	2	2	PB	3		-25.4538	113.3355
11/06/2007	SB4	54	W	3	2	SF	1		-25.4543	113.2951
11/06/2007	SB4	54	W	2	3	SR	1		-25.4530	113.4074
11/06/2007	SB4	54	W	2	3	SR	1		-25.4534	113.3661
11/06/2007	SB4	54	W	3	2	PF	1		-25.4543	113.2951
11/06/2007	SB4	56	E	3	3	SR	3	1	-25.4172	113.3152
11/06/2007	SB4	56	E	2	3	PB	2	1	-25.4173	113.3314
11/06/2007	SB4	56	E	2	3	SR	1		-25.4173	113.3479
11/06/2007	SB4	56	E	2	3	SB	1		-25.4171	113.3752
11/06/2007	SB4	56	E	2	3	SF	2	1	-25.4173	113.3369
11/06/2007	SB4	56	E	2	3	SF	2		-25.4173	113.3424
30/05/2007	SB4	350	E	1	1	PF	1		-26.1833	113.2536
30/05/2007	SB4	360	W	1	1	SF	2	1	-26.1416	113.1839
30/05/2007	SB4	370	E	1	1	SF	1		-26.1254	113.2524
30/05/2007	SB4	370	E	1	1	PF	1		-26.1246	113.2713
8/06/2007	SB5	20	W	2	2	SB	1		-25.5419	113.8355
8/06/2007	SB5	20	W	2	3	PB	1		-25.5419	113.8355
8/06/2007	SB5	20	W	3	3	SB	1		-25.5422	113.7719
8/06/2007	SB5	20	W	3	3	PB	1		-25.5422	113.7653
8/06/2007	SB5	53	E	2	3	PF	1		-25.4968	113.7211
8/06/2007	SB5	53	E	3	3	PR	1		-25.4971	113.7800
8/06/2007	SB5	53	E	3	3	PR	2	1	-25.4972	113.7842
8/06/2007	SB5	53	E	2	3	SB	2	1	-25.4966	113.6947
8/06/2007	SB5	53	E	3	3	SB	2		-25.4971	113.7789
8/06/2007	SB5	53	E	3	3	SB	1		-25.4972	113.7853
8/06/2007	SB5	53	E	3	3	SF	1		-25.4953	113.5308
8/06/2007	SB5	53	E	2	3	SR	2	1	-25.4966	113.6999
8/06/2007	SB5	55	W	2	3	PB	1	1	-25.4617	113.7843
8/06/2007	SB5	55	W	2	3	PB	2		-25.4616	113.7832

Date	Block	Transect	Direction	Beaufort	Turbidity	Observer	Number	Calves	Latitude	Longitude
8/06/2007	SB5	55	W	3	1	SR	1		-25.4595	113.5558
8/06/2007	SB5	55	W	2	3	PB	2	1	-25.4618	113.7941
8/06/2007	SB5	55	W	2	3	SR	2	1	-25.4616	113.7788
8/06/2007	SB5	55	W	2	3	PB	1		-25.4609	113.7460
8/06/2007	SB5	55	W	2	3	PB	1		-25.4614	113.7679
8/06/2007	SB5	55	W	2	3	PF	1		-25.4613	113.7668
8/06/2007	SB5	55	W	2	3	PB	1		-25.4599	113.5840
8/06/2007	SB5	55	W	3	2	PB	1		-25.4594	113.5345
8/06/2007	SB5	57	E	2	3	SB	1		-25.4180	113.6958
8/06/2007	SB5	57	E	2	3	PB	1		-25.4178	113.6634
8/06/2007	SB5	57	E	2	3	PB	1		-25.4180	113.7011
8/06/2007	SB5	57	E	2	3	PR	2	1	-25.4174	113.7589
8/06/2007	SB5	57	E	2	3	SR	2	1	-25.4175	113.7654
8/06/2007	SB5	57	E	2	2	SB	2	1	-25.4175	113.7708
8/06/2007	SB5	57	E	2	3	SB	4	2	-25.4174	113.7536
8/06/2007	SB5	57	E	2	3	SF	1		-25.4175	113.7697
11/06/2007	SB6	58	E	2	3	SB	1		-25.3714	113.4267
11/06/2007	SB6	58	E	3	2	PB	1		-25.3711	113.3547
11/06/2007	SB6	58	E	2	3	SR	1		-25.3734	113.5089
11/06/2007	SB6	58	E	2	3	PB	1		-25.3723	113.4788
11/06/2007	SB6	58	E	2	3	PR	1		-25.3731	113.1014
8/06/2007	SB6	59	W	4	3	PB	1		-25.3750	113.7607
8/06/2007	SB6	59	W	4	3	PB	3	1	-25.3753	113.7341
8/06/2007	SB6	59	W	3	3	PB	1		-25.3750	113.7673
8/06/2007	SB6	59	W	4	3	PB	1		-25.3751	113.7563
8/06/2007	SB6	59	W	4	3	PB	1		-25.3753	113.7216
8/06/2007	SB6	59	W	4	3	SR	1		-25.3754	113.7160
8/06/2007	SB6	59	W	4	3	PB	1		-25.3752	113.7386
8/06/2007	SB6	59	W	4	3	PB	2	1	-25.3753	113.7284
11/06/2007	SB6	60	E	2	3	SB	1		-25.3321	113.3127
11/06/2007	SB6	60	E	2	3	PR	1		-25.3327	113.4436
11/06/2007	SB6	60	E	2	2	PB	2	1	-25.3330	113.4596
11/06/2007	SB6	60	E	2	2	PB	2		-25.3340	113.2106
11/06/2007	SB6	60	E	2	2	PB	1		-25.3339	113.2268
11/06/2007	SB6	60	E	2	3	SR	1		-25.3337	113.2429
11/06/2007	SB6	60	E	2	2	PB	1		-25.3319	113.3183
11/06/2007	SB6	60	E	1	3	PF	1		-25.3317	113.3843
11/06/2007	SB6	61	W	1	3	SR	2		-25.3345	113.7491
11/06/2007	SB6	61	W	1	3	SB	1		-25.3346	113.7379
11/06/2007	SB6	61	W	1	2	PB	1		-25.3341	113.7771
11/06/2007	SB6	61	W	1	3	SB	2	1	-25.3346	113.7379
11/06/2007	SB6	61	W	1	3	PB	1		-25.3346	113.6591
11/06/2007	SB6	61	W	1	3	SB	1		-25.3345	113.7546
11/06/2007	SB6	61	W	1	3	PB	1		-25.3345	113.7491
11/06/2007	SB6	61	W	1	3	SB	1		-25.3346	113.7435
11/06/2007	SB6	61	W	1	3	SB	2	1	-25.3346	113.6984
11/06/2007	SB6	61	W	1	3	PB	1		-25.3346	113.6927
11/06/2007	SB6	61	W	1	3	SF	1		-25.3346	113.7153
11/06/2007	SB6	61	W	1	3	PB	2	1	-25.3346	113.6704
11/06/2007	SB6	62	E	1	2	SB	1		-25.2928	113.2303
11/06/2007	SB6	62	E	1	3	SB	1		-25.2920	113.4206
11/06/2007	SB6	62	E	2	3	SB	1		-25.2948	113.1279
11/06/2007	SB6	62	E	1	3	PB	1		-25.2919	113.3618

Date	Block	Transect	Direction	Beaufort	Turbidity	Observer	Number	Calves	Latitude	Longitude
11/06/2007	SB6	62	E	1	3	SB	1		-25.2918	113.4314
11/06/2007	SB6	62	E	1	3	PB	1		-25.2915	113.4424
11/06/2007	SB6	62	E	1	3	PB	2	1	-25.2915	113.4424
11/06/2007	SB6	63	E	1	3	PB	2	1	-25.2916	113.5013
11/06/2007	SB6	63	E	1	3	PB	2	1	-25.2895	113.6175
11/06/2007	SB6	63	E	1	3	PB	1		-25.2899	113.6341
11/06/2007	SB6	63	E	1	3	PB	2	1	-25.2895	113.6175
11/06/2007	SB6	63	E	1	3	PB	1		-25.2896	113.6230
11/06/2007	SB6	63	E	1	3	SB	1		-25.2896	113.6230
11/06/2007	SB6	63	E	1	3	SF	1		-25.2898	113.6285
11/06/2007	SB6	63	E	1	3	SB	1		-25.2901	113.6452
11/06/2007	SB6	63	E	1	3	PR	1		-25.2902	113.6618
11/06/2007	SB6	63	E	1	1	SF	1		-25.2906	113.7658
11/06/2007	SB6	64	W	1	3	SB	1		-25.2498	113.4670
11/06/2007	SB6	64	W	1	3	PB	1		-25.2500	113.4560
11/06/2007	SB6	64	W	1	2	PB	2	1	-25.2492	113.5046
11/06/2007	SB6	64	W	1	2	PB	2	1	-25.2498	113.2179
11/06/2007	SB6	64	W	1	1	SB	3	1	-25.2494	113.1080
11/06/2007	SB6	64	W	1	3	PB	1		-25.2497	113.4723
11/06/2007	SB6	64	W	1	3	PB	1		-25.2497	113.4776
11/06/2007	SB6	64	W	1	3	SR	2	1	-25.2072	113.4540
11/06/2007	SB6	64	W	1	2	PB	4	1	-25.2501	113.2736
11/06/2007	SB6	65	W	1	3	SB	3		-25.2476	113.6772
11/06/2007	SB6	65	W	1	3	SB	2	1	-25.2487	113.6044
11/06/2007	SB6	65	W	1	3	SB	1		-25.2486	113.6211
11/06/2007	SB6	65	W	1	4	SB	2	1	-25.2473	113.7105
11/06/2007	SB6	65	W	1	2	PB	1		-25.2474	113.6995
11/06/2007	SB6	67	E	1	3	SB	1		-25.2077	113.6014
11/06/2007	SB6	67	E	1	3	SB	1		-25.2077	113.6068
11/06/2007	SB6	67	E	1	3	SB	2	1	-25.2078	113.6231
11/06/2007	SB6	67	E	1	3	PB	2	1	-25.2078	113.6286
11/06/2007	SB6	67	E	1	3	SB	2	1	-25.2076	113.5960
11/06/2007	SB6	67	E	1	3	PB	2		-25.2078	113.6122
11/06/2007	SB6	67	E	1	3	SB	1		-25.2078	113.6286
11/06/2007	SB6	68	W	2	3	SB	2	1	-25.1667	113.3745
11/06/2007	SB6	68	W	1	2	PB	1		-25.1671	113.3128
11/06/2007	SB6	68	W	1	3	SB	1		-25.1670	113.3293
11/06/2007	SB6	68	W	1	3	SB	1		-25.1671	113.3183
11/06/2007	SB6	69	W	1	3	PB	2	1	-25.1673	113.6054
11/06/2007	SB6	69	W	1	3	SB	1		-25.1676	113.6334
11/06/2007	SB6	69	W	1	3	SB	1		-25.1671	113.6000
11/06/2007	SB6	69	W	1	2	PB	1		-25.1682	113.6619
11/06/2007	SB6	69	W	1	3	PB	2	1	-25.1669	113.5669
11/06/2007	SB6	69	W	1	3	PF	1		-25.1677	113.6391
5/06/2007	SB7	73	E	1	2	SB	1		-25.0822	113.5195
5/06/2007	SB7	73	E	2	1	PB	1		-25.0817	113.6572
5/06/2007	SB7	75	W	0	3	PB	1		-25.0414	113.1574
5/06/2007	SB7	75	W	0	3	PB	1		-25.0414	113.1563
5/06/2007	SB7	75	W	0	3	PB	2		-25.0414	113.1510
5/06/2007	SB7	75	W	0	3	PB	1		-25.0414	113.1510
5/06/2007	SB7	75	W	0	3	PB	2	1	-25.0414	113.1510
5/06/2007	SB7	75	W	0	2	PF	1		-25.0413	113.1405
5/06/2007	SB7	77	E	0	3	SB	1		-24.9998	113.2801

Date	Block	Transect	Direction	Beaufort	Turbidity	Observer	Number	Calves	Latitude	Longitude
5/06/2007	SB7	77	E	0	3	PB	2		-25.0000	113.2681
5/06/2007	SB7	77	E	0	3	SB	2		-24.9998	113.1344
5/06/2007	SB7	77	E	0	3	PB	1		-25.0001	113.1409
5/06/2007	SB7	77	E	0	3	SB	1		-24.9998	113.2790
5/06/2007	SB7	77	E	0	3	SR	1		-24.9998	113.2790
5/06/2007	SB7	77	E	0	3	SB	2	1	-24.9998	113.2801
5/06/2007	SB7	77	E	1	2	SB	2	1	-25.0001	113.5163
5/06/2007	SB7	77	E	0	3	SB	2	1	-25.0004	113.1679
5/06/2007	SB7	77	E	0	3	PB	2		-25.0000	113.2691
5/06/2007	SB7	77	E	0	3	PB	5		-24.9999	113.2735
5/06/2007	SB7	77	E	0	3	PF	2		-24.9999	113.2746
5/06/2007	SB7	77	E	0	3	PF	1		-25.0001	113.1409
5/06/2007	SB7	77	E	1	2	PB	1		-25.0004	113.5700
5/06/2007	SB7	77	E	1	1	PB	1		-24.9978	113.6198
5/06/2007	SB7	79	W	1	2	PB	3	1	-24.9550	113.5761
5/06/2007	SB7	79	W	1	2	SB	1		-24.9551	113.5696
5/06/2007	SB7	79	W	1	2	SB	2	1	-24.9551	113.5599
5/06/2007	SB7	79	W	1	2	SB	2	1	-24.9551	113.5589
5/06/2007	SB7	79	W	1	2	PB	1		-24.9551	113.5589
5/06/2007	SB7	79	W	1	2	PB	2		-24.9551	113.5707
5/06/2007	SB7	79	W	1	2	PB	1		-24.9550	113.5642
5/06/2007	SB7	79	W	1	2	SF	2	1	-24.9550	113.5491
5/06/2007	SB7	79	W	1	3	SB	1		-24.9577	113.3190
5/06/2007	SB7	79	W	1	2	PB	1		-24.9550	113.5653
5/06/2007	SB7	80	E	1	2	SB	1		-24.9168	113.5280
5/06/2007	SB7	80	E	0	3	SB	2		-24.9184	113.1650
5/06/2007	SB7	80	E	0	2	PF	1		-24.9183	113.1696
5/06/2007	SB7	80	E	0	3	PB	2	1	-24.9194	113.2781
5/06/2007	SB7	80	E	0	3	SB	3	1	-24.9192	113.2728
5/06/2007	SB7	81	W	4	3	SF	1		-24.8753	113.2119