GOVERNMENT OF
WESTERN AUSTRALIA

Browse LNG Precinct

Browse Liquefied Natural Gas Precinct
Strategic Assessment Report

(Draft for Public Review)

December 2010

Appendix C-9

Nearshore Regional Survey Dugong Report

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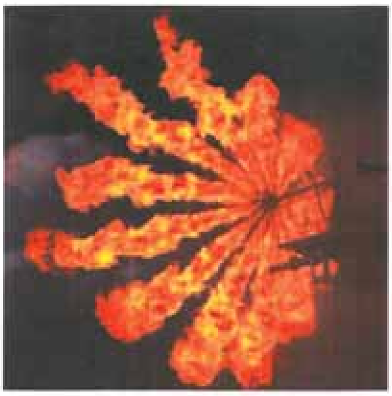
NEARSHORE REGIONAL SURVEY DUGONG REPORT

Browse MMFS 2009



RPS

NEARSHORE REGIONAL SURVEY DUGONG REPORT

Browse MMFS 2009

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EXECUTIVE SUMMARY

Woodside Energy Ltd. (Woodside) plans to develop several gas condensate fields of the Browse Basin, with onshore processing facilities located at the Browse Liquefied Natural Gas (BLNG) Precinct near James Price Point on the Dampier Peninsula. This location has been determined by the Department of State Development (DSD) (via the Northern Development Taskforce (NDT) and State (Western Australian) and Commonwealth Governments.

RPS was engaged by Woodside to undertake a series of marine megafauna baseline surveys to support the assessment and management of potential impacts to these fauna from the proposed LNG development. These surveys were:

- Nearshore Regional Survey (targeting dugongs)
- James Price Point (JPP) Migration Corridor Survey (targeting humpback whales)
- Reference Site Survey (targeting humpback whales at key locations over a regional area)
- Scott Reef Offshore Survey (targeting humpback whales)
- Vessel Transect Survey (to 'ground truth' species recorded)

The surveys were designed with an emphasis on sampling humpback whales and dugongs, but recorded most other marine megafauna that were visible from the air or surface.

This report describes the objectives, methods and results for the Nearshore Regional Survey which targeted dugongs. The Survey was undertaken in July and September, 2009, over the same survey area and using similar sampling methodology as a previous survey undertaken in March 2009 by SKM. A fixed wing aircraft and Strip Width Sampling method were utilised. Data from the Nearshore Regional Surveys, and the March 2009 survey, were analysed to determine the distribution and abundance of dugongs in inshore waters off the west coast of the Dampier Peninsula (La Grange Bay to Cape Leveque). This dataset was supplemented with dugong data from the other surveys, where applicable, to extend it spatially and temporally.

The surveys provide the first systematic assessment of west Kimberley coastal dugong populations, with standardised survey methodology applied across three survey periods, encompassing both dry and wet seasons. In total, 20 hours were spent on-transect during each of the two Nearshore Regional Survey sampling periods in addition to the survey conducted in March 2009. The Nearshore Regional Survey sampled an area of approximately 1,609 km^2 from a survey area of 9,353 km^2.

More dugongs were recorded during July (208) and September (155) than in March 2009 (103). The dugong population estimate in the late wet season (March) was found to be 930 (SE: ± 301) individuals (SKM 2009), and in the dry season the estimates were 1,774 (95% CI: 1,351 – 2,195) in July and 1,708 (95% CI: 1,188 – 2,205) in September. The substantial change in numbers between

the dry and wet seasons indicates a large scale regional movement of dugongs in the Kimberley. Whether dugongs move into the area from the north or south during the dry season cannot be determined. Because the water temperature in the Kimberley generally remains over 18°C, considered to be the lower thermal requirement for dugongs, the observed changes may be due to seagrass availability rather than a seasonal change in water temperature.

Dugongs were distributed along the whole west coast of the Dampier Peninsula, from Lagrange Bay in the south to Cape Leveque in the north. They were also found over the width of the survey area from the nearshore shallow waters to the limit of the Nearshore Survey area which lies along the 20 m isobath. However, their abundance was highly variable throughout the survey area. Three areas consistently provided higher numbers of dugong sightings during all three survey periods: an area to the west and south west of Carnot Bay, the waters between Beagle Bay and the Lacepede Islands and, in particular, Roebuck Bay. Most other areas of the coast were found to have lower abundances or sporadic occurrences of greater numbers. During the surveys that sampled out to greater depths (>20 m), the majority of dugongs were found in waters shallower than 20 m. Dugongs were occasionally recorded in offshore waters deeper than 20 m but these dugongs were considered to be in transit between foraging areas.

The densities and abundances of dugongs off James Price Point were highly variable and more typical of those found along the west Kimberley coast rather than at Roebuck or Carnot bays. Abundance around the James Price Point area was lowest in March when none were recorded and highest in July when several groups were recorded in state waters (3 Nm), and a dense aggregation of dugong groups found approximately 20 km from the shore.

Average densities across the survey area in March, July and September were 0.1, 0.19 and 0.18 dugongs per km^2 respectively. The higher densities are slightly lower than those previously recorded in Exmouth Gulf but substantially lower than those recorded in Shark Bay.

Key Findings Obtained from the Survey Data

#	Key Findings	Document Reference
	Distribution	
1	Dugongs in the region are primarily found in shallow coastal waters less than 20 m deep.	**4.1.2**
2	The James Price Point area was found to be fairly typical of the west coast of the Kimberley, with highly variable numbers of dugongs. Highest abundance was recorded in July (dry season) and lowest in March (wet season).	**4.1.2** **4.2.4**
3	The areas inshore of the Lacepede Islands (off Beagle Bay) around Carnot Bay and in Roebuck Bay were found to have greater numbers of dugongs than the rest of the area surveyed.	**4.1.2** **4.2.1**
4	The southern sections of the survey area, in particular Roebuck Bay, consistently had the highest population estimate and supported the greatest number of calves in all survey periods.	**4.1.2** **4.2.1**
5	A small number of dugongs were recorded from deep water areas and are considered to be transiting between key habitats.	**4.1.2** **4.2.1**
	Seasonal Abundance and Population	
6	Strip Width Sampling estimated that 930 dugongs were present in the survey area in March, 1,774 in July and 1,708 in September. Dugong densities ranged from 0.1 and 0.19 dugongs per km^2.	**4.1.3** **4.2.3**
7	The dugong population was substantially higher in the dry season (July and September) than in the wet season (March), suggesting large scale movement in and out of the area.	**4.2.1**
8	The estimated population of dugongs along the Dampier Peninsula coastline between Cape Leveque and Cape Bossut is larger than that in Exmouth Gulf but considerably smaller than Shark Bay.	**4.1.3** **4.2.1**
9	The average density of dugongs recorded along the Dampier Peninsula coastline between Cape Leveque and Cape Bossut is lower than Exmouth Gulf and substantially lower than Shark Bay.	**4.2.1**

ACRONYMS AND DEFINITIONS

Acronym	Definition
CITES	Convention on International Trade in Endangered Species
CMST	Centre for Marine Science and Technology
CWR	Centre for Whale Research
DEC	Department of Environment and Conservation
DEH	Department of Environment and Heritage
DEWHA	Department of the Environment and Water, Heritage and the Arts
DSD	Department of State Development
EEZ	Exclusive Economic Zone
EPA	Environmental Protection Authority
EIS	Environmental Impact Statement
EPBC Act	The Environment Protection and Biodiversity Conservation Act 1999
ERMP	Environmental Review and Management Program
IMCRA	The Interim Marine and Coastal Regionalisation of Australia
IUCN	International Union for the Conservation of Nature and Natural Resources (aka World Conservation Union)
IWC	International Whaling Commission
JPP	James Price Point
LNG	Liquefied Natural Gas
MTPA	Million Tonnes Per Annum
MNES	Matters of National Environmental Significance
NDT	Northern Development Taskforce
NMB	National Marine Bioregionalisation
UNEP	United Nations Environment Program

GLOSSARY

Baseline survey

A baseline survey provides information on the condition and ecology of an area prior to undertaking any activities. A baseline survey may include the collection of data for one or a number of environmental parameters.

Bathymetry

Bathymetry is the measurement of water depths.

Benthic

Benthic refers to the geological, topographical and biological conditions of the bottom or seabed of an aquatic environment.

Continental Shelf

The continental shelf is an area of the seafloor averaging less than 200 m deep and includes the underwater, extended edge of a continent and associated coastal plain that was generally exposed during past times of lower sea level.

Double count

Double counting refers to the same group or individuals of animals being surveyed that are counted (and thus recorded) twice by observers.

Double platforms (refer also to platform)

Double platforms refer to a method of survey that involves two locations of observers, for example; front seats versus rear seats of an aircraft (same deck, different seats).

Extant

Still in existence.

Gas condensate field

Is an area of land or seabed that is rich in an exploitable natural resource such as gas condensate.

Home range

An animal's home range is the size of the geographic area that is normally occupied and used by an individual or a species in which it gets its food, water and shelter.

Indonesian Throughflow

A warm oceanographic current that transports low salinity water between the Pacific Ocean and the Indian Ocean through the Indonesian Archipelago.

Marine megafauna

Megafauna are a group of marine fauna that are usually large and can normally be seen from the surface of the water. They can include animals such as whales, dolphins, dugong, sharks, rays and seabirds.

Matters of National Environmental Significance

MNES are matters of national environmental significance and are protected under the EPBC Act from actions likely to have a significant impact. Eight Matters of NES which are protected are:

- Listed threatened species and ecological communities.
- Migratory species protected under international agreements.
- Ramsar wetlands of international importance.
- The commonwealth marine environment.
- World heritage properties.
- National heritage places.
- Great barrier reef marine park.
- Nuclear actions.

Migratory species

Migratory species refers to a population which predictably travel from one place to another at regular times of year, often over long distances. It is also a conservation status listing under the EPBC Act.

Neap tides

Neap tides have the smallest tidal range which occurs every two weeks during the first and third quarter moons. Compare with spring tides.

Oceanography

Oceanography is the study of the ocean, its topography, and its inhabitants with emphasis on the physical and biological aspects of the oceans.

Oligotrophic

Oligotrophic refers to a body of water which is low in nutrients and in productivity.

Pipeline Corridor

The potential area in which the pipeline from the offshore (upstream) facilities to the onshore (downstream) facilities will be constructed.

Platform

The platform refers to a location or position of an observer, for example the bridge deck of a vessel or the seats of an aircraft.

Provincial bioregion

A provincial bioregion (also referred to as bioregion) is an area of the ocean which has similar types of plants, animals and ocean conditions when compared to other areas of a similar size.

Ramsar wetland

A Ramsar wetland is an area designated under the Ramsar Convention 1971 as a wetland of international importance because of its importance for preserving biological diversity (particularly in the case of waterfowl), or because it is a representative, rare and unique wetland type.

Recapture

Recapture is to capture/count something for a second or subsequent time.

Semi-diurnal

Occurs twice a day, for example two tidal regimes per day (as opposed to diurnal which occurs once a day).

Sirenia

Sirenia is the taxonomic group of animals in which the dugongs, sea cows and manatees belong.

Spring tides

The highest tidal range, occurring every two weeks during a full or new moon. Compare with neap tides.

Strip Width Sampling

Strip width sampling is a type of line transect sampling where the assumption is made that all animals out to a set distance are detected with equal probability however the distance of the detected animal from the line is not measured due to difficulties associated with correctly estimating the distance from the transect line.

Temperate

Temperate areas have a distinct summer and winter seasons of moderate temperature and rainfall.

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APPENDICES

1.0 INTRODUCTION

1.1 Browse Project Details

Woodside Energy Ltd. (Woodside) plans to develop the Torosa, Brecknock and Calliance gas condensate fields located offshore in the Browse Basin. Natural gas and condensate hydrocarbons from offshore facilities will be transported to onshore processing facilities in the vicinity of James Price Point located on the Dampier Peninsula approximately 60 km north of Broome. The Browse Liquefied Natural Gas (BLNG) Precinct encompasses the construction and operation of Liquefied Natural Gas (LNG) processing facilities and associated infrastructure.

The development will include export tanker facilities to receive and load LNG carriers (and potentially LPG carriers) and condensate tankers. An Integrated Marine Facility (IMF) will be constructed to provide vessel all-weather harbouring facilities (for tugs and support vessels) and materials offloading facilities (MOF). Dredging will be required to establish a shipping channel route, turning basin and berth pockets for tankers entering and departing the Marine Port Facilities. Dredging will also be required for establishment of the MOF and along designated sections of the pipeline route for protection of the gas pipelines. A single breakwater will also be constructed to provide a sheltered port for the export jetty and marine facilities.

The purpose of the BLNG Precinct is to provide a single onshore location for the various oil and gas operators in the Browse Basin. The central location is designed to eliminate the ad-hoc development of LNG facilities on the Kimberley coast and islands. The location of the Precinct has been determined to be within the James Price Point area development by the Department of State Development (DSD) (via the Northern Development Taskforce (NDT)) and State (Western Australian) and Commonwealth Governments (Figure 1).

Although Indigenous knowledge and anecdotal reports suggest the Kimberley is an important location for dugongs in WA (Prince 1986; Marsh et al. 2002; Holley and Prince 2008), there are no historical dugong abundance estimates or distribution data, and the region has not been systematically surveyed using the aerial survey techniques applied to determine dugong distribution and abundance elsewhere in Australia.

To help fill these gaps in knowledge, RPS Environment Pty Ltd (RPS) was commissioned by Woodside to design and conduct a series of Marine Megafauna Surveys (MMFS) in the winter (dry season) of 2009. This series of surveys followed preliminary aerial and vessel based surveys conducted in 2008 by Jenner and Jenner (2009) and in March 2009 by SKM (2009).

The James Price Point Marine Management Area (Figure 1) describes an area intended to include the marine infrastructure and dredging footprint of the Browse LNG Precinct. This area was identified for the purposes of the MMFS to examine fauna occurring

within or near the development area and is in no way intended to delineate any future Management Zone.

In March 2009, SKM, on behalf of Woodside, undertook a series of broad scale aerial surveys for dugongs (and other marine megafauna) covering the area between Cape Bossut and Cape Leveque (SKM 2009). The objectives were to:

1. Assess the suitability of the CASA 212-400 series aircraft (which differs from the aircraft normally used for Nearshore Regional Surveys) for (a) flying at low altitudes without eliciting a flight response from dugongs, and (b) provide enough opportunity for observers to be adequately trained to identify animals according to the altitude, flight speed and window size.

2. Understand the distribution and abundance of dugongs and other inshore marine megafauna along the Dampier Peninsula within the 20 m depth contour from Cape Leveque to Lagrange Bay during the late wet season.

The SKM survey obtained results in the late wet season, forming a basis for the study to be extended to sample during the 2009 dry season.

1.2 Study Objectives

The purpose of this project was to provide sufficient baseline information on dugongs to support an Environmental Impact Assessment (EIA) for the proposed LNG development. Associated objectives were to:

- Quantify the distribution and abundance of dugongs in inshore waters off the west coast of the Dampier Peninsula (Lagrange Bay to Cape Leveque) during two survey periods, in mid July and mid September.

- Establish a baseline for dugongs off the west coast of the Dampier Peninsula (Lagrange Bay to Cape Leveque), based on the data collected in the two survey periods described above and the March 2009 results, as well as records of dugong collected during other 2009 marine megafauna surveys.

It was recognised at the survey design stage that achieving these objectives would be dependent on prevailing conditions in the field and efficacy of survey method.

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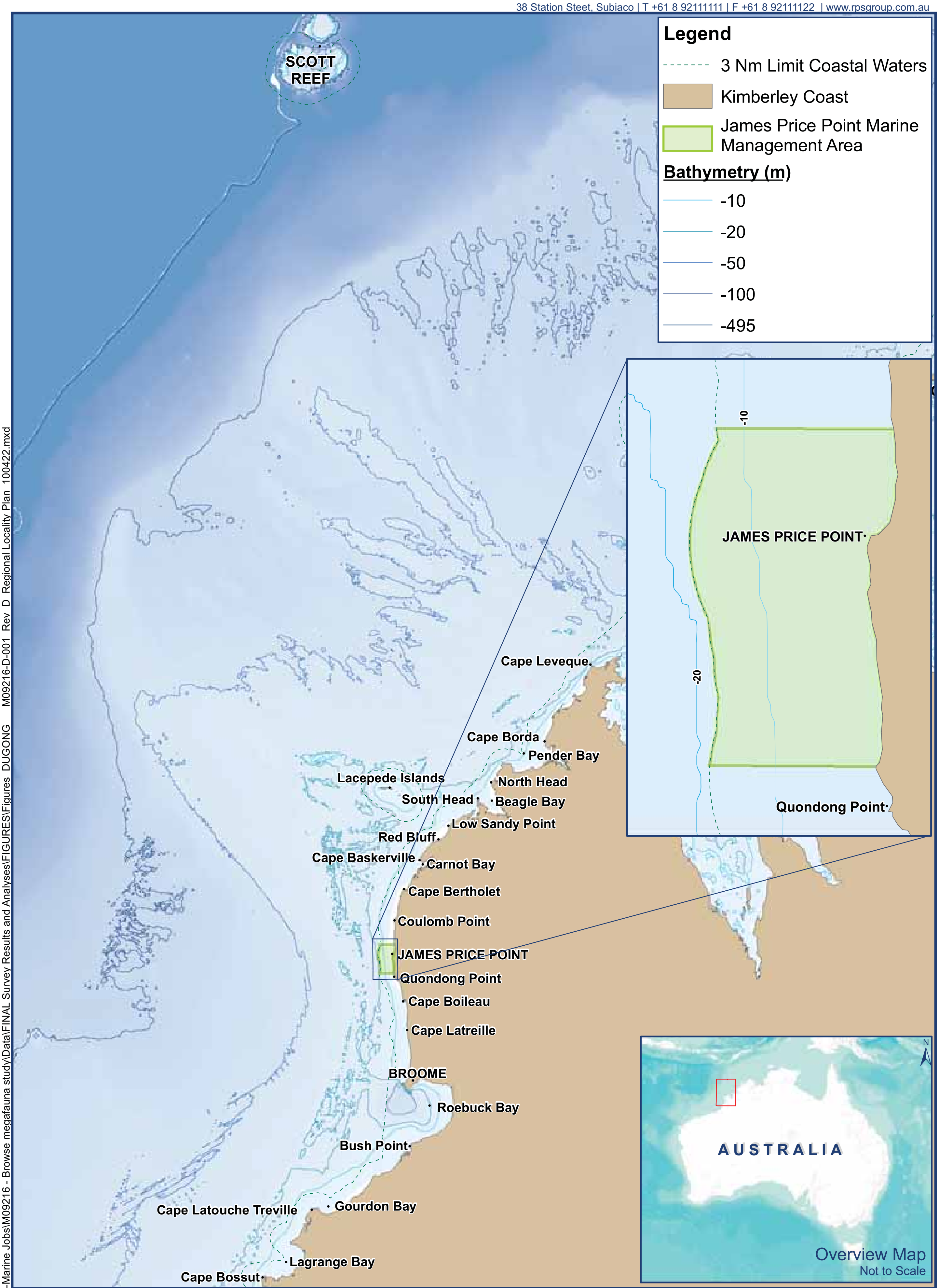

RPS woodside

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Date: 22/04/2010
Revision: D
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Source: RPS 2009

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Regional Locality Plan

Figure 1

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2.0 BACKGROUND INFORMATION

2.1 Regional Geography

The Kimberley is situated at the top of the North West Marine Region (NWMR) which extends north from Kalbarri, to the Western Australian - Northern Territory border, covering an area of more than 1 million km^2 (DEWHA 2008).

The region is characterised by shallow tropical marine ecosystems and has a unique combination of features including a large area of continental shelf, high tidal regimes and occurrence of cyclones, and unique current systems that create warm oligotrophic surface waters. These unique environment conditions create a mosaic of habitat types within the Region resulting in high species richness (Northwest Bioregional Plan DEWHA 2008). Due to the diverse range of habitats, eight provincial bioregions were identified based on benthic habitat and oceanographic data.

Waters within the NWMR range in temperature between 22 °C and 26 °C, and cover a large area of shallow continental shelf and slope, with more than half the area having water depths of less than 500 m (Baker et al. 2008). The region experiences high tidal ranges and strong surface currents. Tides are semi-diurnal with daily tides ranging between 3 m during neap tides and 10 m during spring tides (Northwest Bioregional Plan DEWHA 2008). Prevailing currents of the region are the Leeuwin Current and the Indonesian Throughflow Currents, which are seasonally variable (Northwest Bioregional Plan; DEWHA 2008).

Biological productivity may also be influenced by oceanography characteristics such as a combination of internal tides and associated internal waves and bathymetry, where canyons in the region are thought to 'support rich and dynamic communities' (Brewer et al. 2007). Bathymetry features typical for the NWMR include terrace and steps reflecting ancient coastlines when sea levels were lower than today. These are believed to be important migratory pathways for marine megafauna (DEWHA 2008).

The Woodside marine megafauna survey was conducted at the northern extent of the North West Shelf Province within the NWMR, from Cape Bossut to Cape Leveque, and extending out to Scott Reef.

2.2 Regional Habitat Characteristics

In relation to dugongs, the habitat features of greatest importance are seagrass beds. Tropical seagrass beds are important foraging areas for dugongs, a largely herbivorous marine mammal. Surveys undertaken by DEC in November 2007 indicated that there was a patchy distribution of seasonally-abundant seagrass along the Dampier Peninsula coast from the lower intertidal zone out to the 20 metre depth (DSD 2009).

CSIRO and AIMS undertook a benthic habitat survey of various locations in the Kimberley Region on behalf of the Northern Development Taskforce in 2008. Results pertaining to seagrass (Fry et al. 2008) are provided in Table 1.

Table 1: Results of Western Kimberley Benthic Habitat Surveys Pertaining to Seagrass, as Recorded by Fry et al. (2008) during June 2006

Location	Dominant Substratum	Seagrass Presence
Gourdon Bay	Fine sand.	Relatively high percentage coverage of *Halophila sp*. in very nearshore transects.
Quondong Point to Coulomb Point (includes JPP coastal area)	Fine sand (some areas of reef in the northern section).	Some patches of seagrass coverage offshore (but very little habitat overall).
Perpendicular Head	Fine sand (some areas of rubble in the northern section and some reef inshore of the rubble).	Small isolated patches of seagrass present on sandy substratum.
Packer Island	High and low reef with coarse sand in between.	Relatively high coverage of seagrass within small bays in the northern section.

The area between Quondong Point to Coulomb Point including the James Price Point area, has not been found to support any significant seagrass beds. Unlike the highly productive, sheltered embayments of Roebuck, Carnot, Pender and Beagle Bays (DEWHA 2008) James Price Point is exposed to wave energy and winds which are adverse conditions for the establishment of seagrass. In comparison, Roebuck Bay supports extensive *Halophyla ovalis* and *Halodule uninervis* beds, seagrass species known to be favoured by foraging dugongs (DEWHA 2010).

2.3 Dugong Biology and Ecology

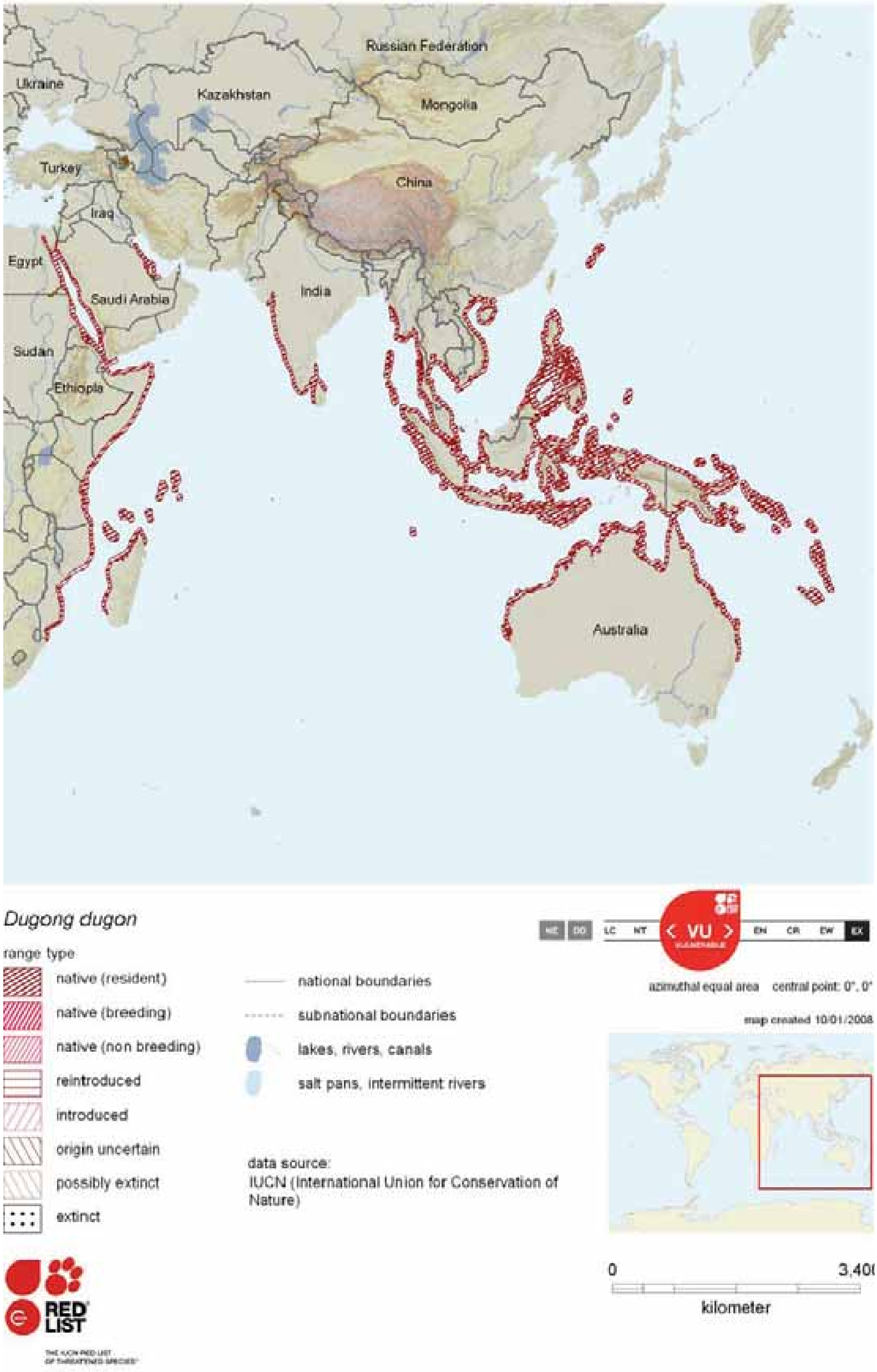
The dugong (*Dugong dugon*) is a marine mammal belonging to the order Sirenia and is the only extant member of its family, Dugongidae. The species is recognised internationally as threatened and is listed by the International Union for Conservation of Nature (IUCN) as Vulnerable on its Red List of Threatened Species (IUCN 2009). The species is listed as a threatened (Vulnerable) and migratory species under the EPBC Act and as Specially Protected under the Western Australian *Wildlife Conservation Act 1950*.

The dugong is a long-lived mammal with a lifespan of around 60 years (Marsh 1995) Immature male and female dugongs are generally less than 2.2 m in length, while dugongs over 2.5 m are generally mature (Limpus and Chatto 2004). Mature dugongs can weigh up to 450 kg (NAILSMA 2006).

Dugongs are threatened by indigenous harvest, entanglement in fishing nets, and habitat degradation. Habitat can be degraded by both anthropogenic factors and natural phenomenon, such as cyclones. Given that the maximum attainable rate of increase for any dugong population is about 5% per year (Marsh 1999), even low levels of anthropogenic adult mortality can have a significant impact at the population level. In 2002, the United Nations Environment Program (UNEP) released the '*Dugong Status Report and Action Plan for Countries and Territories*' (Marsh et al. 2002) providing dugong management recommendations.

2.3.1 Population Structure and Distribution

Dugongs occur in the tropical and sub-tropical shallow waters of the Indian and Pacific oceans (Figure 2), but are most abundant in the marine waters of northern Australia that support the *Halodule* and *Halophyla* seagrasses on which they feed. It is generally accepted that Australia supports the most abundant dugong population in the world (Parks and Wildlife Service 2003).



(IUCN 2008)

Figure 2: Known Range of Dugongs

Dugongs are generally spread across the northern half of Australia, in coastal waters off the NT, Queensland and Torres Strait, and northern WA. On the west coast, Shark Bay is the southernmost area of their range and, on the east coast, the coastal waters of northern New South Wales (NAILSMA, 2006). The total Australian dugong population is estimated at more than 80,000 individuals (Saafield and Marsh, 2004).

Important dugong aggregation areas in Western Australia include the Shark Bay and Exmouth Gulf regions (Marsh et al. 2002). Table 2 shows the population estimates of dugongs in Shark Bay, Ningaloo Reef and Exmouth based on surveys conducted to date. The largest aggregation of dugongs occurs in Shark Bay. This area is considered to be internationally significant for this species and believed to be home to more than 10% of the world's dugongs (Hodgson 2007).

Exmouth Gulf is recognised as an important feeding and breeding area (Jenner and Jenner 2005) for this species, with critical dugong habitat present (Prince 2001). Surveys between 1989 and 2007 indicate that Exmouth Gulf also generally supports a large dugong population, although numbers can vary substantially in response to natural perturbation, as evidenced following the destruction of seagrass beds by tropical cyclone Vance in 1999 (Prince, 2001). Gales et al. (2004) acknowledged evidence of large-scale movements of dugongs that reside in the Exmouth Gulf and Ningaloo Reef area to areas north in response to natural habitat changes.

Table 2: Population Estimates with Standard Error (se±) of Dugongs in Shark Bay, Ningaloo Reef, Exmouth Gulf and the Pilbara Coastline

Year (Date)	Shark Bay	Ningaloo Reef	Exmouth Gulf	Pilbara Coast	Reference
1989 (4–11 July)	10,146 (se±1,665)	634 (se±127)	1,062 (se±321)	-	*Preen et al. (1997) *cited in* Hodgson (2007)
1994 (21–30 June)	10,529 (se±1,464)	968 (se±320)	1,006 (se±494)	-	*Preen et al. (1997) *cited in* Hodgson (2007)
1999 (8–16 July)	13,929 (se±1,652)	163 (se±148)	174 (se±82)	-	*Gales et al. (2004) *cited in* Hodgson (2007)
2000 (6–16 April)	-	-	95 (se±62)	2046 (se±376)	*Prince (2001)
2002 (4–10 Feb.)	11,021 (se±1,357)	-	-	-	*Holley et al. (1997) *cited in* Hodgson (2007)
2007 (30 March–16 June)	14,022 (se±1,230)	-	1,411 (se±561)	-	*Hodgson (2007)
2007 (30 March–16 June)	9,347 (se±1204)	-	704 (se±354)	-	#Hodgson (2007)

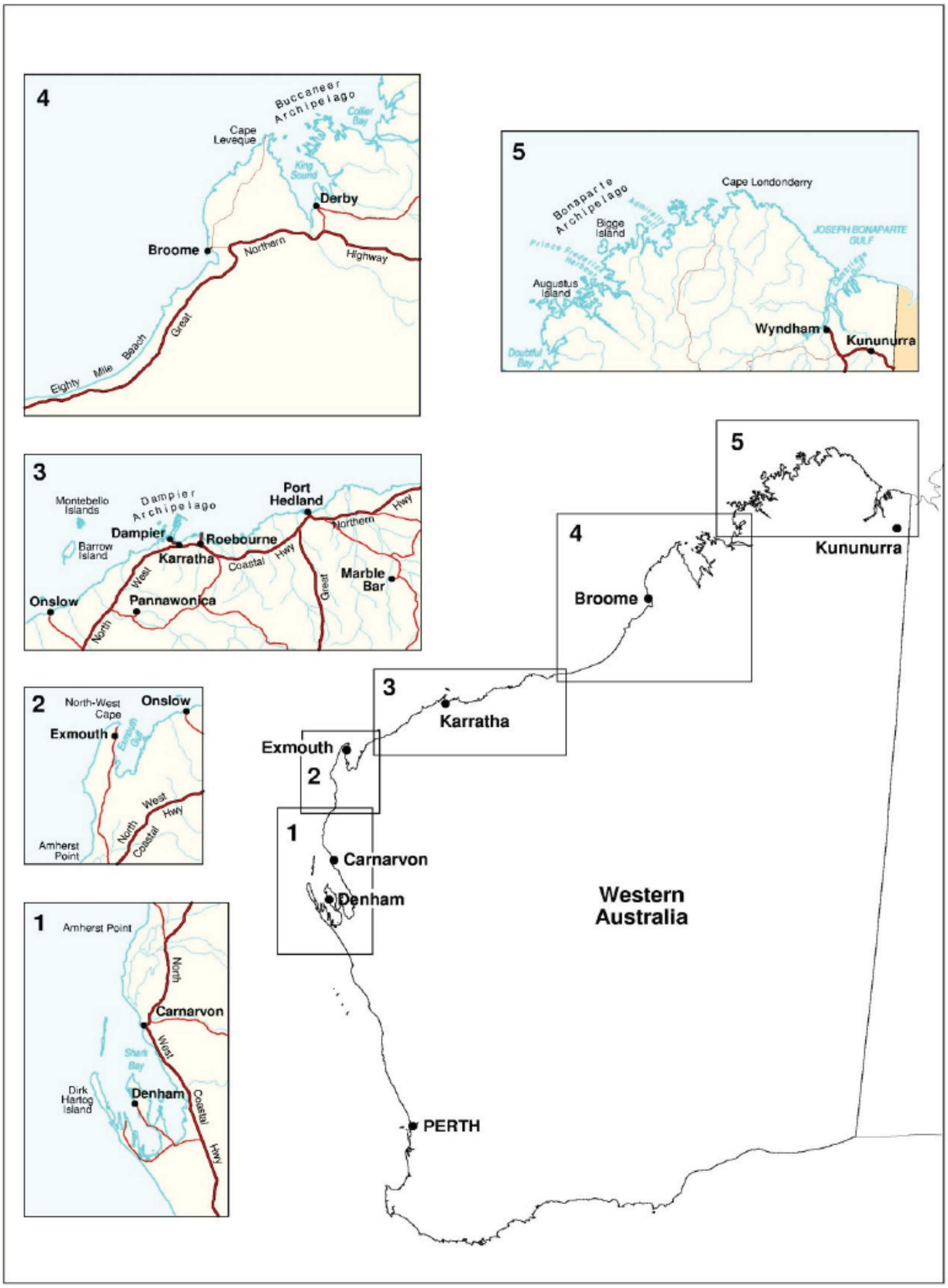
*Marsh and Sinclair (1989) method
Marsh and Sinclair (1989) as refined by Pollock et al. (2006) method

For the purpose of managing the dugong, the Western Australian coastline has been divided into Dugong Management Units (Holley and Prince, 2008). Unit 4 (Figure 3) is relevant to this report.

There is little is known about the population trends of dugongs on the Kimberley Coast. Resident populations are thought to occur at Beagle Bay and at the Montgomery Islands (Mustoe and Edmunds 2008). Holley and Prince (2008) compiled and reviewed historical datasets of dugong observations in the Kimberley, but concluded they provided little insight into abundance.

Population numbers in the Kimberley could be considerable as suitable dugong feeding grounds and large bays and gulfs occur throughout this region (Mustoe and Edmunds 2008; Prince 1986). The area may also host calving females, with Ashmore Reef to the north known to be associated with a small population of dugongs that includes calves (Limpus and Chatto 2004).

In March 2009, SKM undertook a Nearshore Regional Survey along the west coast of the Dampier Peninsula and sampled the dugong population at the end of the wet season. The results indicated that there were an estimated 930 dugongs (standard error of $\pm$301) in the population. The highest densities of dugongs were in Roebuck Bay immediately south of Broome.



(Holley and Prince, 2008)

Figure 3: Dugong Management Units for Western Australia (Unit 4 is Relevant to this Report)

2.3.2 Migration

While dugong seasonal movements are little understood, they are known to be migratory in certain areas of their range. This is thought to be mostly a search for suitable foraging grounds or warmer waters (Marsh et al. 2002; Gales et al. 2004).

Dugongs are sensitive to temperatures below approximately 20 ˚C and tend to be found in warmer waters in the range of 21–27 ˚C (Sleeman et al. 2007). Gales et al. (2004) acknowledged evidence of large-scale movements of dugongs that reside in Exmouth Gulf and at Ningaloo Reef to areas north in response to natural habitat changes, such as those associated with storm events. Dugongs typically either travel solitary, in pairs or in small groups (around three to six individuals) but can be found in large herds of twenty or more.

Dugong migratory movements have been monitored during a number of Australian studies. Sheppard et al (2006) reported great range in movement behaviours in a study in the Northern Territory; 37 per cent of dugongs moved less than 15 km away from where they were tagged whilst 62.8 per cent travelled further and up to 560 km away. In a preliminary report on four satellite tracked dugongs in Beagle Bay, Campbell and Holley (2010) highlight the variation in migratory behaviour. Whilst three dugongs demonstrated site fidelity, the fourth undertook a large scale migration, travelling almost 500 km south to east of Port Hedland (Campbell and Holley, 2010).

2.3.3 Breeding

Dugongs have a very slow and highly inconsistent reproductive rate (Lanyon 2007). Both males and females are believed to reach sexual maturity at nine to 10 years but females are unlikely to calf until they are 15–17 years old (Marsh 1995). The period between calving varies from three to seven years between and within individual females (Marsh, 1995).

Breeding can occur at any time of the year (Marsh 1999) although neither males nor females are constantly in breeding condition (Marsh 1995). It is believed that when dugongs do not have a sufficient food supply breeding may be delayed (NAILSMA 2006).

Mating behaviour may differ in different regions of Australia. Anderson (1996) observed 'lekking' mating behaviour in Shark Bay where an aggregation of males engaged in sexual displays in order to attract females. In other areas, such as the Queensland coast, male dugongs actively compete for females on heat (NAILSMA 2006) which is then followed by courtship and mating in male-female pairs (Anderson 1996).

Gestation lasts approximately thirteen to fifteen months (NAILSMA 2006). The period of August / September to November has been recorded as the dugong calving season in northern Australia (Townsville to Cairns) (Marsh et al. 1984 *cited in* Marsh, 1995) but calving seasons within Western Australia are unconfirmed. Protected shallow waters such as tidal sandbanks and estuaries are considered important sites for calving (Limpus and Chatto 2004). Calves suckle for a period of at least fourteen months (NAILSMA 2006) although they begin grazing seagrass almost as soon as they are born (Marsh, 1995).

2.3.4 Diet and Foraging Habitat

Dugongs are a largely herbivorous marine mammal, feeding on seagrass particularly of the genera *Halodule* and *Halophyla*. Dugongs also consume marine algae although this feeding behaviour is thought to be exhibited only when seagrass is not readily available (Parks and Wildlife Service 2003; Chatto and Limpus 2004). Macroinvertebrates may form part of a dugong's diet, especially for those at higher latitude limits (Limpus and Chatto 2004), including in Western Australia (NAILSMA 2006). Estimates put dugong seagrass consumption per day at 28–40 kg (Limpus and Chatto 2004). Originally it was thought that dugongs grazed on the seagrasses that were readily available, however there is some indication that these mammals graze according to the nutritional quality of the seagrass (Limpus and Chatto 2004).

While dugongs frequent coastal waters, they also use estuarine creeks and streams and have been observed travelling upstream of creeks for several kilometres (Lawler et al. 2002). Dugongs tend to aggregate in wide, shallow protected bays and mangrove channels, and on the sheltered side of large inshore islands (Heinsohn et al. 1979), which typically coincide with seagrass beds. However, they are occasionally found up to 70–100 km offshore.

2.3.5 Dive Patterns

Dugongs spend most of their time at the bottom of the water column, feeding on seagrass, but must regularly surface for at least one or two seconds to breathe (Anderson 1981). In contrast to other marine mammals which are much deeper divers, dugongs limit their diving to shallower depths, relating to areas where seagrass may grow (Chilvers et al. 2004). Chilvers et al. (2004) studied the dugong diving behaviour at Shark Bay, the Gulf of Carpentaria and Shoalwater Bay (Queensland) and characterised five types of dugong dives. The dominant patterns exhibited were feeding dives, reported as 'square and U-shaped' (67% of dugongs) and travelling dives which were slow and erratic (22% of dugongs) (Chilvers et al. 2004). Exploratory dives (reported as 'V-shaped') were exhibited by 8% of dugongs and shallow resting dives were exhibited by 3 per cent. Campbell and Holley (2010) have so far found that the 'square and U-shaped' foraging pattern was exhibited by a satellite tracked dugong throughout its entire 500 km trip from Beagle Bay to east of Port Hedland.

There is great variation in all aspects of dive patterns for each individual dugong (Chilvers et al. 2004; Whiting, 2002; Sheppard et al. 2006). Chilvers et al. 2004 recorded a mean maximum dive depth of 4.8 $\pm$ 0.4 metres and a mean dive time of 2.7 $\pm$ 0.17 minutes for their study sites. This time was significantly less than the mean submergence time (6 $\pm$ 2 minutes) reported by Whiting (2002) for dugongs in Darwin Harbour which has a tidal range of 8 metres. Whiting has not provided depth or tidal data which would enable comparisons of this area to the Kimberley which also experiences high tidal movements. However, Campbell and Holley (2010) provide a preliminary report that the mean dive time (2.01 minutes $\pm$ 2.17) for their tracked dugong in nearshore coastal

waters of the Kimberley was more consistent with Chilvers et al. (2004) observations. Campbell and Holley (2010) also report that the majority of diving exhibited by the same dugong was to depths less than 5 metres, reflecting the importance of intertidal and shallow water habitats in the area.

Surfacing regularly renders dugongs vulnerable to hunting and boat strike (Anderson, 1981) and repetitive deep diving during travel may cause heightened susceptibility to entrapment in bottom set gill nets (Sheppard et al. 2006). Spending most of their lives on the sea bottom, dugongs can be difficult to detect. Correction factors are applied within survey methods to account for this 'unavailability'.

3.0 METHODS

3.1 Survey Area

The Nearshore Regional Survey area covered the west coast of the Kimberley from Cape Bossut near LaGrange Bay in the south to Cape Leveque in the north. The survey covered an area from the coastline to the 20 m isobath (Figure 4). Two aerial surveys were conducted, one in July and the other in September. The survey used the same transect lines and sampling method as that conducted in March 2009 (SKM, 2009).

A systematic series of parallel line transects were established perpendicular to local bathymetry (i.e. cross-shelf transects), to minimise sampling bias and to ensure that the probability of coverage was high (SKM 2009). Transect lines were placed 2.5 nautical miles (4.6 km) apart which corresponds to a survey sampling area of 1,609 km^2 providing a sampling intensity of 17% over the 9,353 km^2 study area (Figure 4).

The spatial extent of the surveys targeted dugong distribution and abundance along the west coast of the Kimberley and included the James Price Point Marine Management Area. Additional transects were established and sampled in the September survey in order to sample the area to the north of Pender Bay and out to the Lacepede Islands (Figure 4). This increased the study area to 10,403 km^2.

A series of surveys for humpback whales were also conducted through July to mid-October. These surveys focussed on the James Price Point Marine Management Area and out to Scott Reef along the potential pipeline corridor. Anecdotal information on dugongs collected during those surveys is reported within, as supplementary information.

3.1.1 Methods Overview

The most effective method to detect and count dugongs over regional spatial scales (1,000 km^2) is by aerial survey. The established sampling method for dugongs in Australia is Strip Width Sampling, as described by Marsh and Sinclair (1989) and refined by Pollock et al. (2006). This method can provide data to assess distribution, relative abundance, density, and population size for dugongs in the survey area.

3.1.2 Aerial Survey Method

All nearshore regional aerial surveys were conducted from a CASA 212-400 fixed wing aircraft. The sequence of surveys was modified on a daily basis during the period of survey to account for prevailing weather conditions. A trial flight was conducted on 30 June 2009 to test equipment in the aircraft and to ensure observers were familiar with sampling protocol and target species identification.

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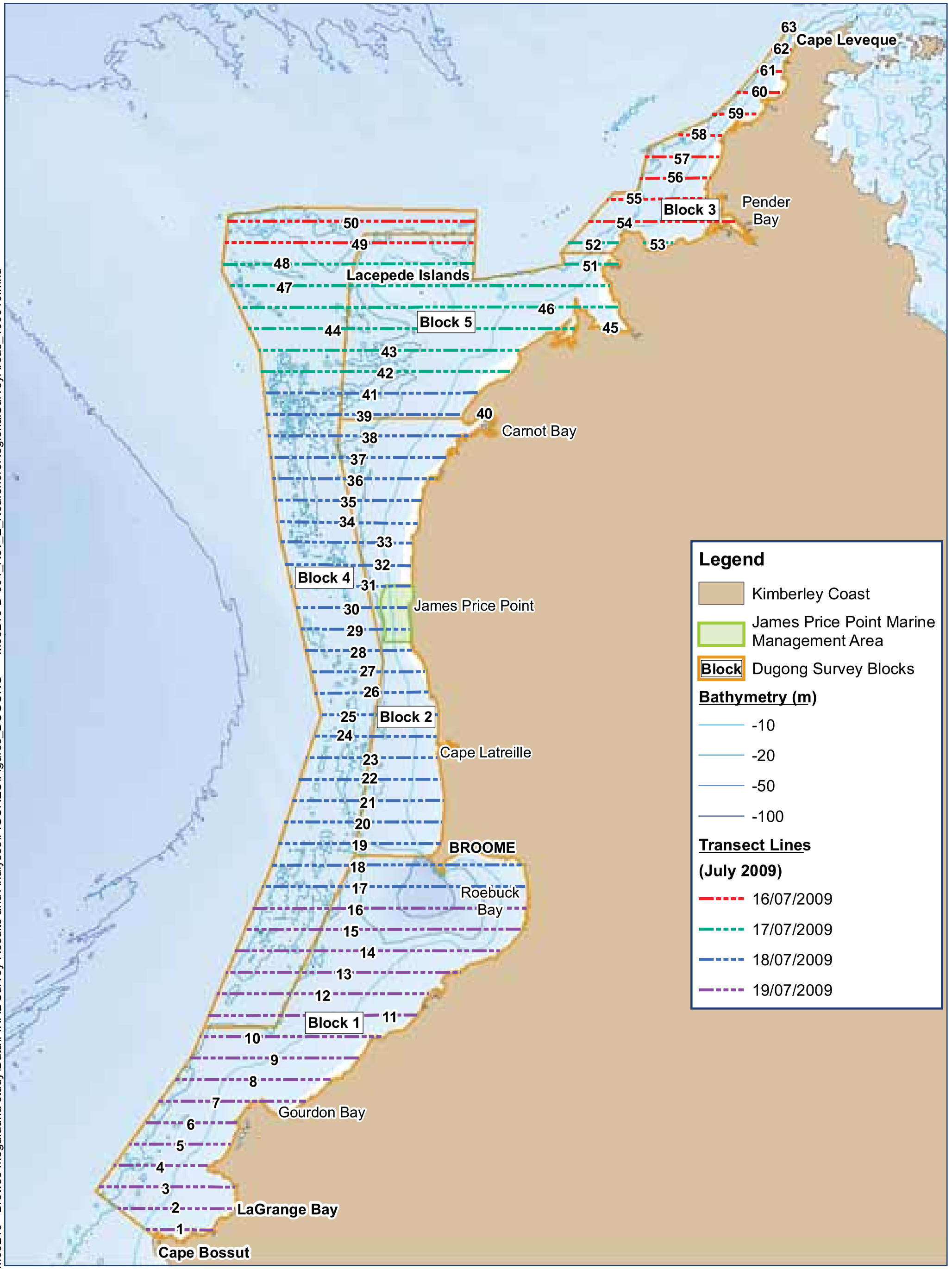

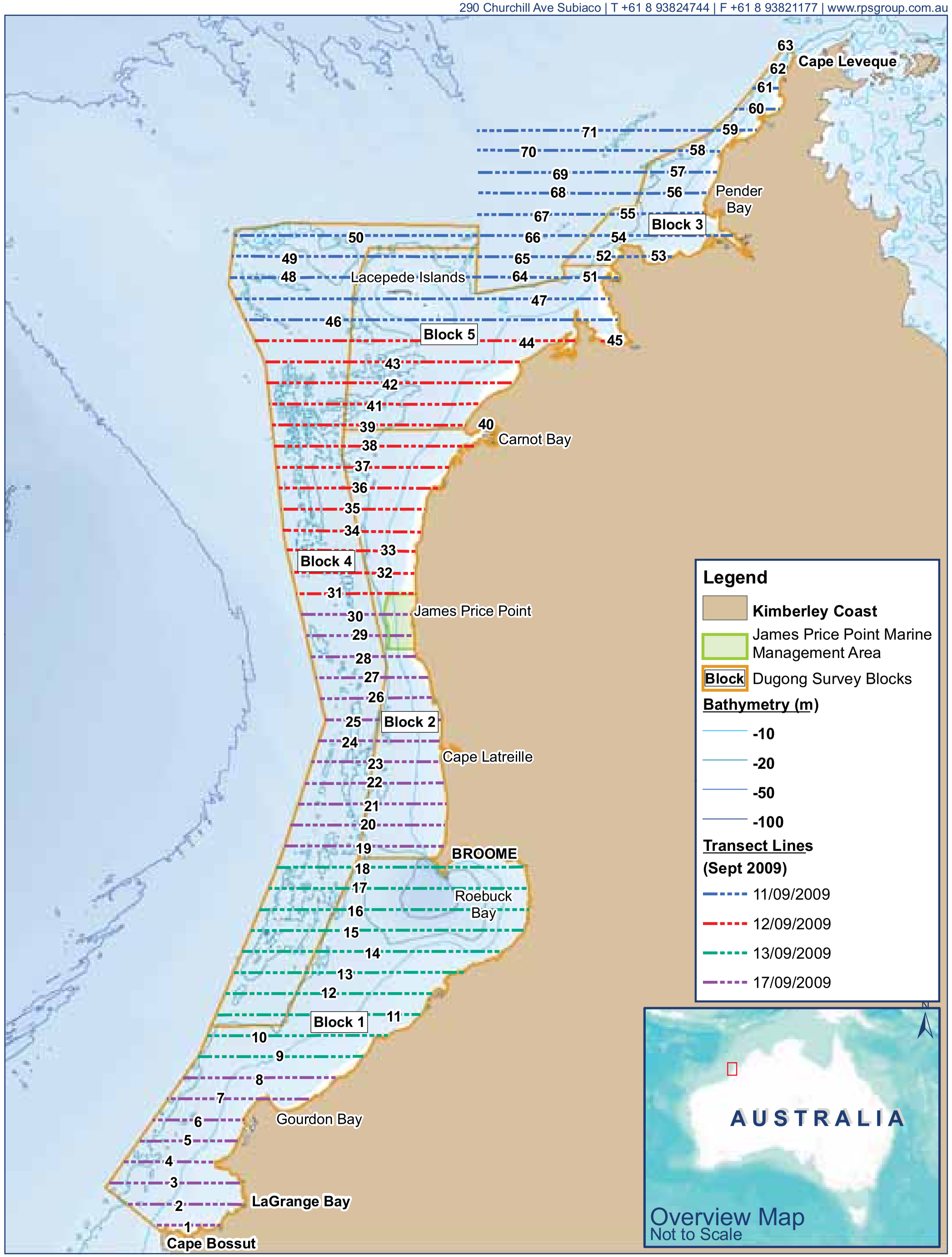

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Nearshore Regional Survey Areas

Figure 4

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To estimate the number of animals that were missed by the observers but at the surface (observer bias), a dual-platform, double-count method was used. This involved two observers on each side of the aircraft (four observers in total), one sitting behind the other and isolated visually and acoustically from each other. Both platforms on either side of the aircraft collected data for recapture sightings to be established after the flight. The ratio of records that had been observed by both and those observed by only one of the observers, was the parameter used in estimating observer bias.

By applying the same aerial survey methods as those used in March 2009 (SKM 2009), comparisons could be made between distribution of dugongs in the region through time. The altitude of the aircraft was 900 feet (274 m) with the surveys conducted at a constant speed of 110 kts (204 km/h). Although the most common altitude for dugong survey is 450 feet (137 m), the higher altitude was selected to sample a larger area more efficiently. SKM undertook a comparison between the two altitudes during the March 2009 survey and found no significant difference between the sampling efficiencies for dugong (SKM, 2009).

The survey area was sampled in the shortest time period that the weather and flight restrictions permitted (approximately four days). When weather conditions permitted, transects were surveyed sequentially from north to south. This pattern was used to minimise recounts between transects and minimise spatial autocorrelations.

To maximise sightability of dugongs, aerial surveys were conducted as close to the period of neap tides as possible when water turbidity was at its lowest, and in good weather (Beaufort Sea State (BSS) <4) with minimal glare (i.e. avoiding early and midday high glare) (Marsh and Sinclair 1989; Lanyon 2003). The scales of environmental factors affecting visibility are provided in Appendix 1.

A transect strip width of 400 m was surveyed on each side of the aircraft. This was demarcated into low, middle, high and very high zones each of 100 m width and the outside zone which included everything outside the sampling strip (either between the sampling strip and the aircraft or beyond the sampling strip). The viewing zones were marked on windows prior to each flight using geometry provided in Marsh and Sinclair (1989). The markings were based on individual observer seating position and survey flight height. The zones were used to help identify recaptures between tandem observers (Marsh and Sinclair 1989; Lanyon 2003). This resulted in approximately 17% of the study area being surveyed.

The survey team consisted of two pilots, a dedicated Team Leader, and a team of tandem Observers (front and rear) on either side of the aircraft. The forward two observers were the more experienced personnel and termed Platform 1, and the two rear observers, Platform 2. Traditional Owners (TOs) were also involved, when available, to help identify additional animals and help establish sightings to species.

The Team Leader and Observers communicated via aviation headsets connected to an eight channel audio management system which was also used to make audio records of the data for subsequent transcription to a database. The audio system was comprised of a Steinberg MR816x Audio Interface and Behringer HA4700 HeadPhone Amplifier linked to a laptop loaded with Cubase 5 recording software. All voice data were digitally recorded on the laptop via the hardware and Cubase 5 software interface. Independent recordings were also made to a Zoom H4n 4 channel digital recorder for backup should the audio management system or laptop fail. The audio management system gave the Team Leader control as to which observers he could communicate with. The audio system maintained acoustic isolation between front and rear observers.

Forward platform observers were visually isolated from rear platform observers with a curtain fixed between the top of the seats and the aircraft bulkhead. To reduce observer bias and maintain consistency over the course of the survey, a core team of six observers were used.

Position fixes of the aircraft were obtained every second and constantly downloaded to laptop from a Garmin GPSMAP 60CSx with external antennae located in the cockpit of the aircraft. A backup GPS was also placed in the cockpit, and set to record fixes every second to internal memory. The audio management system, GPS and watches were synchronised prior to every flight so that records of sightings and environmental conditions could be allocated to positions after the flight from within the aerial database.

The Team Leader was responsible for monitoring survey progress, recording environmental conditions through the survey period, and informing the observers when to start and stop surveying. The Team Leader monitored progress of the survey using a moving map facility on a laptop computer loaded with OziExplorer, and managed the GPS data stream of time, position and altitude for later downloading.

Environmental parameters collected by the Team Leader included wind speed (knots) and direction (degrees), cloud cover (oktas), Beaufort Sea State (BSS) (1–12), turbidity (1–4), visibility (1–9), other weather conditions (e.g. rain), transect start and finish time, and sighting data with associated viewing zone.

Tandem observers on each side of the aircraft independently recorded their observations in a standard format. Observers reported glare at the start of each transect and any changes that occurred while on transect. Sightings of other marine megafauna were acquired during the surveys but priority was given to dugongs. Observers recorded megafauna according to a specific sequence defined on a laminated chart:

- Dugongs
- Humpback whales
- Other cetaceans
- Whale sharks

- Turtles
- Crocodiles
- Other sharks, rays, sea snakes
- Vessels
- Bird and fish feeding aggregations
- Other biological and oceanographic features of interest

3.2 Nearshore Regional Survey Schedule

The Nearshore Regional Survey was designed to extend the temporal dataset from March 2009 (late in the summer monsoonal season) over the drier winter months to account for seasonal variation. The timing of these surveys is shown in Table 3: below.

Table 3: Timing of each Nearshore Regional Survey

Survey name and reference	Season	Survey Dates
March 2009 Megafauna Survey (SKM)	Late wet season	19/03/2009 20/03/2009 22/03/2009 24/03/2009 25/03/2009 26/03/2009
July 2009 Nearshore Regional Survey (NR1)	Early dry season	16/07/2009 17/07/2009 18/07/2009 19/07/2009
September 2009 Nearshore Regional Survey (NR2)	Late dry season	11/09/2009 12/09/2009 13/09/2009 17/09/2009

3.3 Analytical and Mapping Methods

All dugong data gathered during the aerial surveys were transcribed into an Access database. The data acquired for dugongs were analysed (where sample number permitted) using a range of software to provide:

- Summary statistics.
- Mapping.
- Spatial and temporal distribution.
- Abundance (population estimates).
- Density Mapping.

All analytical methods included consideration of calves.

3.3.1 Summary Statistics

A summary of all successful survey effort conducted throughout the survey period is provided, with a summary of the dugong data acquired. Any issues with the survey method or limitations of the data have been identified in the discussion of results. Data presented in the results and interpreted in the discussion were extracted from the database under the following parameters:

- Include records from both the front and rear platforms.
- Include observations from within the strip width area.
- Exclude observations from outside the strip width area.
- Exclude recaptures.
- Use maximum recorded number of individuals in a group rather than averaging the minimum and maximum best estimate.

3.3.2 Mapping

Sightings of dugongs and calves acquired from the aerial surveys were plotted in ArcMap 9.3.1 and projected to estimated positions of the sightings based on the central distance of the zone in which they were observed (port or starboard). Recaptures were not plotted to avoid displaying bias due to duplicates. Only sightings of dugongs inside of the strip width were plotted. Sightings figures show 'actual' flights flown and not data from abandoned flights.

Kernel estimators of 5, 10 and 20 km were applied to the data of which the 20 km was the most informative and suitable for the data and sampling effort. Density maps for the lower estimators maintained artefact patterns from the sampling transect lines whereas the 20 km estimator smoothes these effects out. Because the densities are dugongs spotted within the strip width and have been averaged out across the whole survey area, the densities shown on Figure 7 are to be used as relative densities within and between figures only: they are not compatible with the density estimates produced when estimating the population. The density estimates produced when estimating population, are based on numbers of sampled animals adjusted to account for perception bias, availability bias and area outside of the strip width that fell within the survey area. These two different methods of density estimation are not compatible with each other.

It must also be remembered that the data from the Nearshore Regional Survey were acquired over several days and therefore double counting of the same group of animals may have occurred on transects that lie adjacent to one another which were sampled on consecutive days.

3.3.3 Spatial and Temporal Distribution

The mapped data and density maps (see Density Mapping section below) from the surveys conducted in 2008, March, July and September 2009 were inspected and a descriptive overview of the distributions provided. Any high densities and clusters of sightings identified are discussed according to the frequency of use by the species. Tables and bar charts were produced to help describe the changes in dugong numbers over time. Wherever possible, calves were also described separately.

3.3.4 Abundance (Population Estimates)

The procedure to estimate dugong population in the survey area followed that given by Marsh and Sinclair (1989) and refined by Pollock et al. (2006). The broad process involved five steps based on the number of marked and recaptured sightings obtained within the sampling strip:

1. Correction for perception/observer bias – animals at the surface but missed by the observers.

2. Correction for availability bias – number of animals in the area but not available at the surface to be recorded.

3. Multiply the estimate from the density of the sampling strip to the whole survey area.

4. Add the estimated number of animals within groups of more than ten individuals.

5. Estimate the confidence intervals for the resultant mean population estimate using bootstrapping.

The above five steps were conducted in a similar fashion to those described in Marsh and Sinclair (1989) and Pollock et al. (2006). Corrections for perception/observer bias (i.e. groups of dugongs visible on the transect line that were missed by observers) were calculated from the number of animals sighted by either the front or rear platform or both, using the MARK program. This determined whether observers detected the same groups of animals (Barlow et al. 2008). Observer bias correction factors were calculated separately for port and starboard observers using data for July and September flights. The MARK program was used to calculate the perception bias with Huggins closed capture data and assuming the probability of an individual observer sighting an animal was the same regardless of whether or not it had been previously marked (i.e. probability of each observer sighting an animal was independent of whether or not it had been previously sighted by the other observer in the team).

Estimates for the animals present at the surface were adjusted according to the adjustment factors shown in Table 4 as reported by Pollock et al. (2006). These authors have demonstrated that the availability of dugongs to be spotted is dependent upon the marine conditions, in particular a combination of turbidity, water depth and sea state as shown in Table 4.

Table 4: Correction Factors for the Combined Effects of Turbidity, Water Depth and Sea State

Class	Water Turbidity	Beaufort Sea State	Probability
1	1 – Clear & shallow	≤ 2	1
2	2 – Turbid & shallow	≤ 2	0.65
3	3 – Clear & deep	≤ 2	0.46
4	4 – Turbid & deep	≤ 2	0.47
5	1 – Clear & shallow	≥ 3	1
6	2 – Turbid & shallow	≥ 3	0.47
7	3 – Clear & deep	≥ 3	0.30
8	4 – Turbid & deep	≥ 3	0.47

(from Pollock et al. 2006)

The strip width represents approximately 17% of the overall survey area and therefore the densities acquired on either side of the aircraft were multiplied according to the proportion of the survey area not sampled.

Perception and availability bias were not applied to herds of dugong ≥10 individuals because the probability of sufficient animals being available and being perceived by both observers was considered to approach one. Previous studies have omitted large herds when extrapolating the estimated strip width density to the entire survey area. There is however, no logical reason to not apply the probability of sampling large groups to the area outside of the strip width. Failure to do this makes the assumption that herds will only be seen in the strips sampled, rather than representing a sample of the total number of herds across the entire block. In confirmation of this, a large group was spotted outside the strip width by a non survey team member during a flight. For this reason, herds of dugongs were also corrected for area and then added to the final population estimate. The survey area had previously been divided into five blocks for analysis (SKM 2009). These were used again to ensure compatibility with the population estimate from the March survey.

Monte Carlo analysis was performed on September and July survey estimates separately. Each time, 10,000 simulations were run for the overall estimate of population. To calculate confidence intervals within blocks, 1,000 additional simulations were run for each separately. Confidence interval estimates were calculated from the distributions of the Monte Carlo outputs directly, rather than using associated estimates of variances from the simulations to calculate standard errors (Manly 1991).

3.3.5 Density Mapping

A kernel density estimator was applied to the dual platform data from each of the surveys using the Home Range Tool (HRT) extension for ArcGIS. Pre-processing to remove sampling bias was not required as the sampling effort was uniform across the survey area for the two surveys and for the sampling periods. A grid of 442 x 442 m was placed over the study area and several iterations using various search radii (smoothing values) were used. Results were inspected and the most logical and smoothest scale was selected for the final outputs. Densities were grouped into percentiles.

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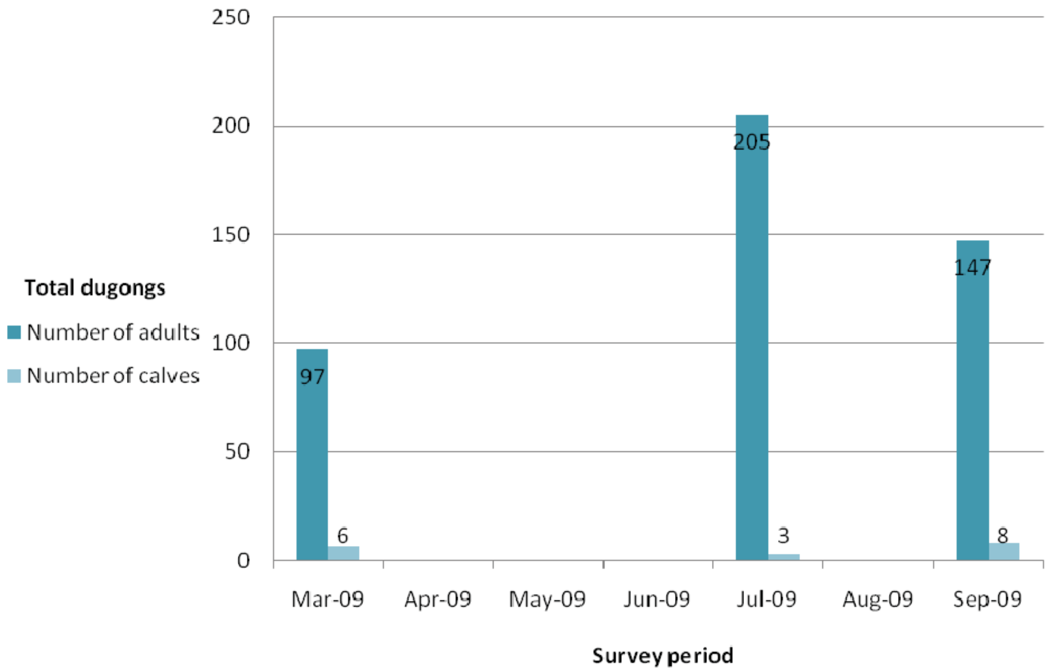
4.0 RESULTS AND DISCUSSION

4.1 Survey Data

4.1.1 Dugongs Recorded During the Nearshore Regional Survey

Figure 5 presents the number of adult and calf dugongs recorded in each of the surveys. A total of 124 groups of dugongs were recorded during the July survey which comprised of 205 adults and 3 calves. During the September survey, a total of 90 groups were recorded, comprising of 147 adults and 8 calves.



Note: Observations from within the strip width area with recaptures excluded.

Figure 5: Total Number of Dugong Adults and Calves Recorded During Each Nearshore Regional Survey (March Survey data from SKM 2009)

The July and September Nearshore Regional Surveys recorded, respectively, 1.6 and 1.3 times as many adults as the March survey did. The lowest proportion of calves (1.9%, n=3) was recorded during the July survey (6.2%, n=6 recorded in March; 6.5%, n=8 in September).

The largest groups recorded and included in the analyses were of an estimated 10 individuals in July and 12 in September; both lower than the herd of 20 recorded in March (Figure 6). Similarly, the mean group size in March of 1.91 individuals was higher than in July (1.68) and September (1.72). Larger groups were recorded as recaptures (10 - 25 individuals on the 1 July), on an aborted Nearshore Regional Survey flight (20 – 30 animals) and other surveys (10 - 25 individuals).

The percentage of recaptures was recorded for both the July and September surveys. July had a 46% recapture rate whilst September had a 48% recapture rate. The percentage of recaptures indicates how robust the Mark Recapture analyses will be. Surveys with a high number of recaptures will provide a more accurate and precise estimation than those with a low recapture rate.

Although a correction factor has been applied to account for the ‘unavailability’ of dugongs (present but not be seen), an underestimation of the number of calves present is possible: calves are only 100 to 200 centimetres long (Marsh, 1995), and therefore are more difficult to sight than adults. This difficulty could have been exacerbated in this survey by the turbid waters of the Kimberley and the observations being made at an altitude of 900 ft, in comparison to the 450 ft used for the Shark Bay, Ningaloo Reef and Exmouth Gulf survey in 2007 (Hodgson, 2007).

4.1.2 Spatial and Temporal Distribution and Densities

Figure 6 presents the distribution of dugongs as recorded during each of the March, July and September surveys. All three surveys recorded a spread of dugongs along the entire coastline surveyed, from Cape Bossut in the south to Cape Leveque in the north and around the Lacepede Islands. Dugongs were largely restricted to water less than 10 m deep in March, whereas they were dispersed more widely across the bathymetry in July and September. This can be seen in the offshore areas of Blocks 1 and 5 in Figure 6. Dugongs were recorded in greater abundance in the southern parts of the survey area in March, but were sparse or absent in several large areas. In particular, they were absent across an area that extended from approximately 15 km north of James Price Point to Broome. During the March survey, most dugongs were recorded in Roebuck, and off Pender, Beagle and Lagrange bays. The largest herd was recorded off Beagle Bay.

Dugongs were more evenly distributed across the survey area in July than in either March or September. Greatest numbers were in Roebuck Bay and the waters off Carnot, Beagle and Pender bays. A large aggregation was also recorded approximately 20 km off James Price Point in water between 10 and 20 m deep. The largest herd, of around 10 individuals, was found approximately 5–10 km north of Cape Latreille in very shallow waters (less than 10 m) within 5 km of the shoreline. The majority of dugongs were observed as individuals or pairs and were between the 10 m depth contour and the shoreline.

In September, dugongs were recorded along the entire length of the surveyed coastline but were present in greater numbers approximately 5–20 km offshore from Carnot Bay around the 20 m isobath. The largest herd recorded in September was of around 12 individuals just outside of Beagle Bay.

The other aerial surveys recorded a dugong sighting 80 km offshore west of James Price Point in water of around 70 to 80 m depth. Sightings were also occasionally obtained between the 20 and 50 m isobaths (Appendix 2). It is possible that these animals were in transit as there is no seagrass on which they graze in waters this deep.

Changes in dugong abundance over time were apparent, with almost twice the number of dugongs recorded in July than in March. Slightly fewer dugongs were recorded in September than in July but the sighting conditions across the survey area were slightly better in July. The population estimates discussed in Section 4.1.4 adjust the number of animals spotted to account for environmental conditions and remove negative bias created by sub-optimal conditions.

Figure 7 represents relative densities of dugongs calculated for March, July and September surveys. These densities are relative only and should not be compared with the absolute densities calculated using Strip Width Analysis. Dugong densities varied along the coastline and between the survey periods. Areas that consistently recorded more animals throughout the season include Roebuck Bay, and waters west of Carnot and Beagle Bays. The highest relative density occurred in September due west of Carnot Bay (Figures 6 and 7).

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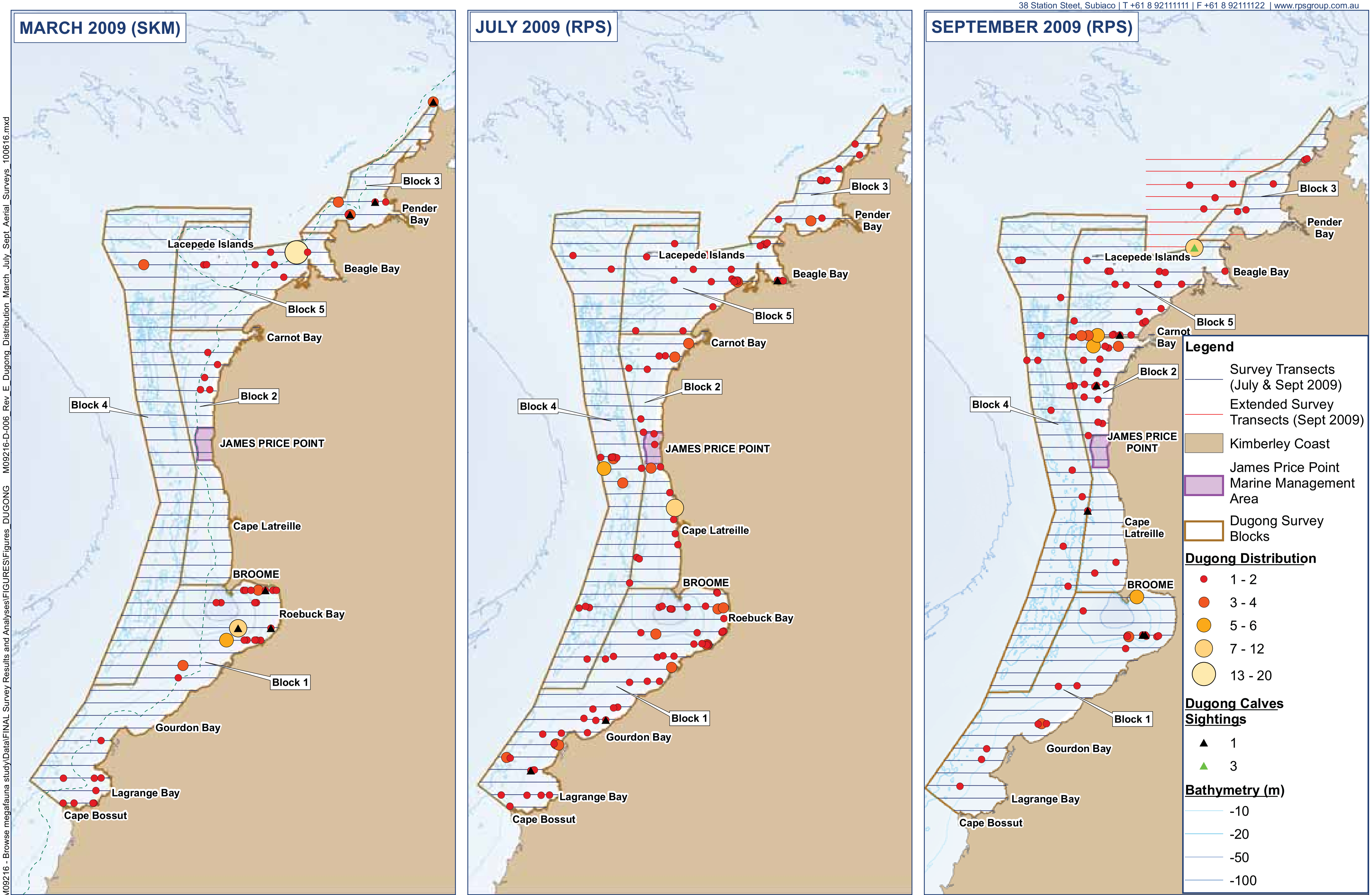

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Distribution of Dugongs as Recorded During the March 09 (SKM), July 09 and September 09 (RPS) Surveys

Figure 6

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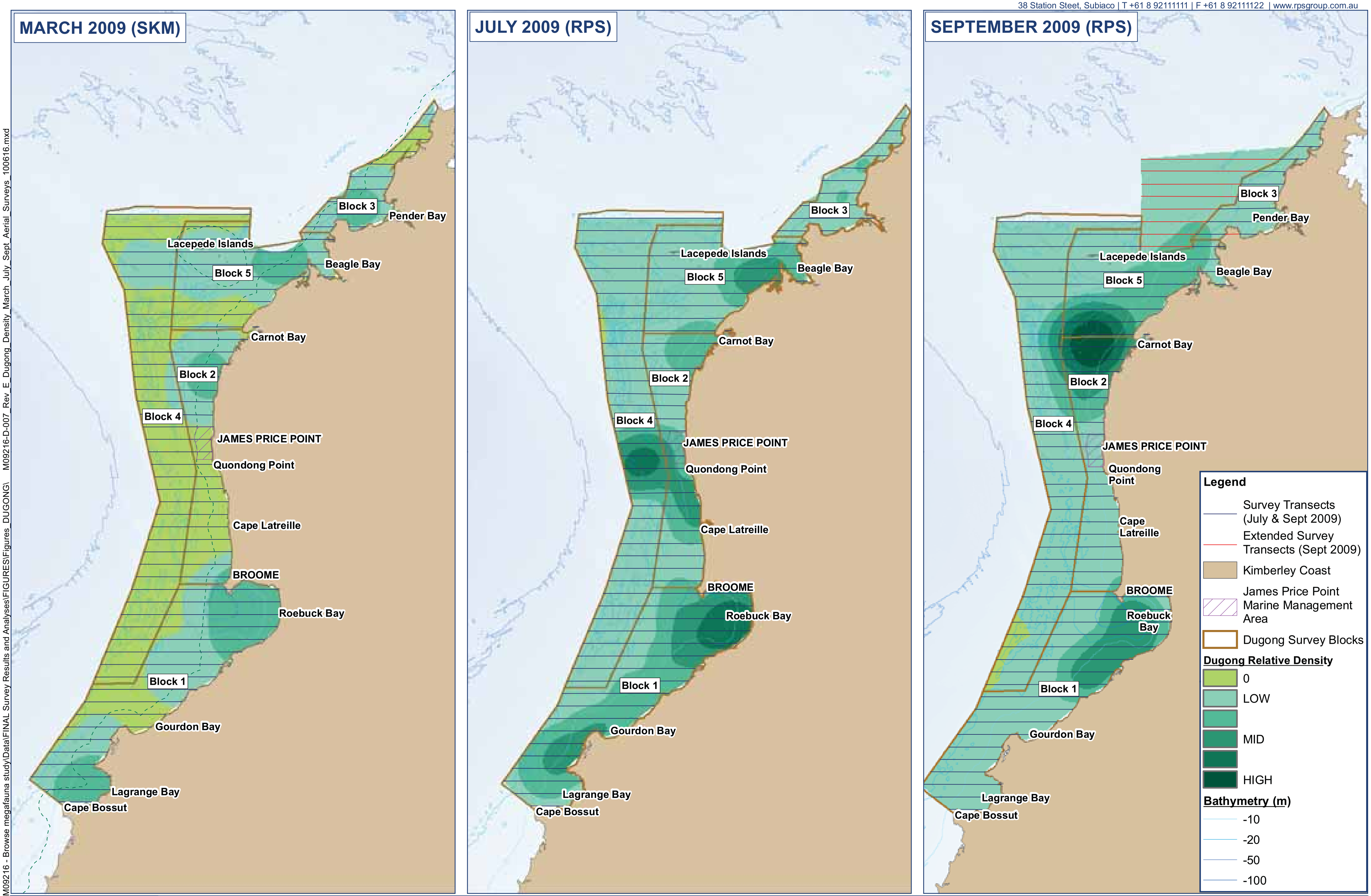

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Dugong Density in March 09, July 09 & September 09 Surveys

Figure 7

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Densities were estimated across the whole Nearshore Regional Survey area, as presented in Figure 8. Overall, higher densities were recorded during the July and September surveys (0.19 and 0.18 dugongs per km^2, respectively) than during the March survey (0.1 dugongs per km^2).

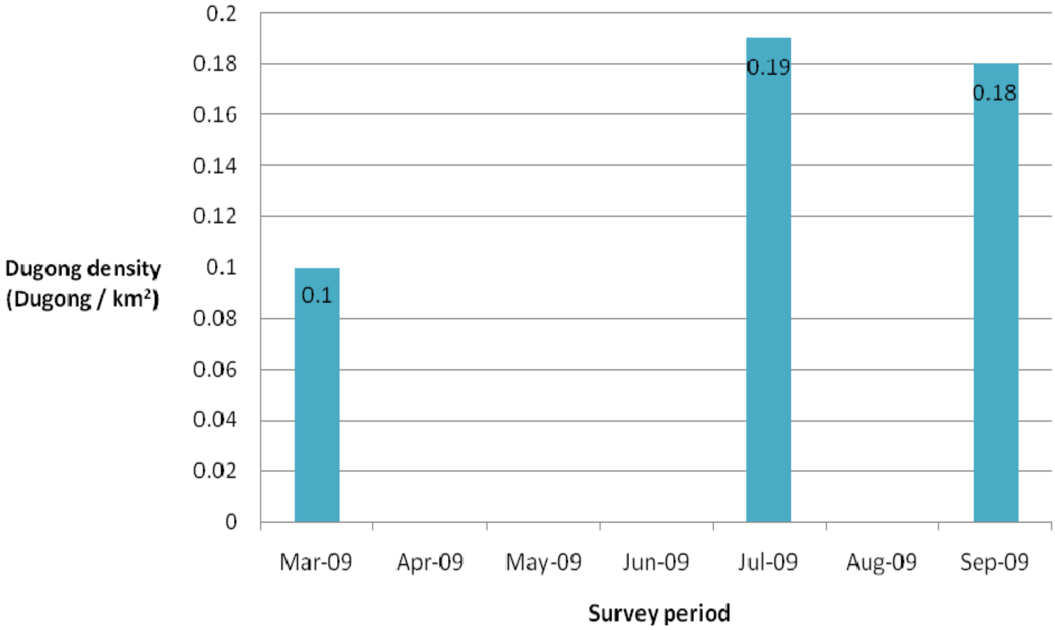


Figure 8: Estimates of Dugong Density for each of the Nearshore Regional Surveys.

4.1.3 Population Estimates

The data from the Nearshore Aerial Survey were analysed in accordance with the method described in Section 3.1.2. Population estimates were calculated and results are shown in Table 5 and Figure 9. Block 1, which includes Roebuck Bay, consistently contained the greatest number of dugongs. Block 2, which includes the James Price Point Marine Management Area, had a large proportion of the overall population in all three surveys. The majority of animals in this block were found in waters north of James Price Point, particularly the waters offshore of Carnot Bay.

The dugong population estimated from the March survey was 930 (SE of ± 301) (SKM 2009). In comparison, the total estimated dugong population for July was 1,774 (95% CI: 1,351-2,195) and for September, 1,708 (95% CI: 1,188 – 2,205)(Figure 9). The wider confidence intervals in the September data are probably a result of the environmental conditions, which were not as good in September as in July.

Table 5: Dugong Population Estimates and Confidence Intervals for the Nearshore Regional Survey.

See Figure 4 for the Block Boundaries. Direct Comparison between Population Estimates for each of the Blocks is not possible due to the different areas of each Block.

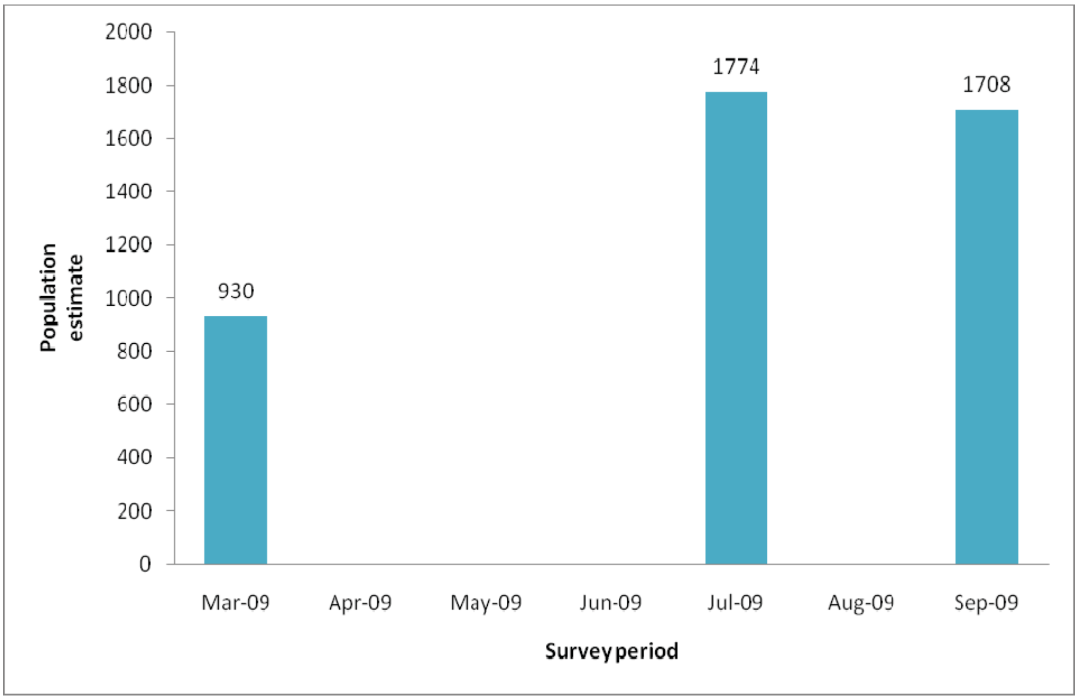
Block	Total Area (km^2)		March		July		September	
			Population Estimate	Std Error	Popn. Estimate	Conf. Level (U/L)	Popn. Estimate	Conf. Level (L/U)
1	2580		542	216	709	951.7	531	810.7
						455.2		273.9
2	2987*	1388ˆ	210	108	325	477.7	417	632.6
						170.3		202.8
3	650		177	181	118	202.8	35	76.3
						40.2		0
4	3137		N/Aˇ	N/Aˇ	287	468.0	223	341.7
						121.8		114.0
5	N/A*	1598ˆ	N/A*	N/A*	336	568.9	503	851.9
						108.3		151.1
Total	**9353**		**930**	**301**	**1774**	**2194.5**	**1708**	**2204.5**
						1351.4		**1187.9**

*The March survey combined blocks two and five to obtain results, hence the larger area (km^2) for block two (SKM 2009)

ˆThe July and September surveys kept blocks two and five as separate areas in order to obtain more definitive results

ˇInsufficient numbers of dugongs were recorded in block four of the March survey for the abundance to be calculated.

The dugong population in the survey area increased substantially from the wet to the dry season and remained fairly constant between July and September (dry season). The differences in the raw data for the three periods (as shown in Figure 5), are reduced in Figure 9 because of the correction for surveying conditions. It should also be noted that data from the additional transects flown in September were not included in the September population estimate (although four dugong were recorded in this additional survey area).



Note: Error bars and confidence intervals not displayed in the bar chart as they were calculated differently between March and July/September.

Figure 9: Mean Dugong Population Estimate per Survey (March Data taken from SKM 2009)

4.1.4 Results Specific to the James Price Point Area

No sightings of dugongs occurred within or near the James Price Point Area in March or September.

Two herds of one to two animals were recorded within the James Price Point Marine Management Area in July. Four more groups of one to two individuals and one group of three to four dugongs were recorded within 5 km of the James Price Point Marine Management Area, again in July. In September, three sightings of one to two animals were recorded approximately 10 km north and north-west of James Price Point. During other aerial surveys, only a single sighting, comprising two dugongs, was recorded from within the James Price Point Marine Management Area, and was obtained in October.

No calves were recorded in or in close proximity to the James Price Point Marine Management Area during the Nearshore Regional Survey, but it is acknowledged that calves may have been under represented in the data due to their small size. The James Price Point area was fairly typical of the majority of the west Kimberley coastline for dugong distribution: numbers were generally fairly low in comparison with Roebuck Bay and Carnot Bay, but sporadic, and therefore dugongs may be relatively more abundant at certain times of the year. This trend however, is based on data from within one year only, and any greater abundance observed in any one season or time period may not be reflected in another year.

A moderately high density of dugongs was present approximately 15 km offshore from Quondong Point, between the 10 and 20 m isobaths in July (approximately 15 km from James Price Point. This related to several groups of animals recorded 15-20 km offshore. Five herds of dugong formed this high density area: three herds of one to two animals; one herd of three to four animals, and one herd of five to six animals. A herd of three to four animals was also sighted approximately 15 km south of the James Price Point area.

4.2 Discussion of Results

4.2.1 Dugong Distribution and Density

Dugongs were widely distributed over the survey area during the 2009 surveys, although with considerable variation in distributions between different survey periods. The majority of dugongs were recorded in shallow, nearshore waters less than 20 metres deep, and often in less than 10 metres water depth. This is as expected given the species primarily food source (seagrass) and known behavioural patterns. However, dugongs were also occasionally recorded further offshore during the humpback whale surveys (Appendix 2). Whilst the majority of dugongs recorded by these other surveys were in waters less than 20 m deep, 11 sightings were recorded from waters between 20 and 50 m deep and two sightings occurred in waters between 50 and 100 m deep. As this is too deep for the presence of seagrass, and therefore unsuitable for dugong foraging, it is expected that these few animals are transiting through the area.

Areas inshore of the Lacepede Islands (off Beagle Bay), offshore of Carnot Bay and in Roebuck Bay appear to be the most important for dugongs. These areas are sheltered and known localities for dense seagrass habitat.

Densities of dugongs in the overall (regional) survey area were lower than those reported from both the Exmouth and Shark Bay regions of Western Australia (Table 6).

Table 6: Comparison of Population Estimates*and Densities of Dugongs as Recorded in Western Australia

*using method described by Marsh and Sinclair (1989) as refined by Pollock et al. (2006)

Timing	Location	Population Estimate	Density (Dugongs / km^2)	Reference
19–26 March 2009	Dampier Peninsula	930 (se±301)	0.1 / km^2	(SKM, 2009)
16–19 July 2009	Dampier Peninsula	1,774 (1,351.4 –2,195: 95% CI)	0.19 / km^2	This report
11–17 September 2009	Dampier Peninsula	1,708 (1,187.9– 2,204.5: 95% CI)	0.18 / km^2	This report
30 March– 16 June 2007	Exmouth Gulf	704 (se±354)	0.24 / km^2	(Hodgson 2007)
30 March– 16 June 2007	Shark Bay	9,347 (se±1204)	0.64 km^2	(Hodgson 2007)

Note: Population estimates have been rounded up to the whole number.
Note: Dates are not inclusive

Dugong densities off the west coast of the Kimberley were slightly lower than those estimated for Exmouth Gulf and substantially lower than densities in Shark Bay. Dugong numbers recorded in the coastal area from Broome north to Carnot Bay (which includes the James Price Point area), were lowest in March (0.1 dugongs per km^2), increasing in both July (0.19 dugongs per km^2) and September (0.18 dugongs per km^2). These results indicate a substantial influx of animals from outside of the area during the winter. It cannot be ascertained from the data whether this is from the north or south.

There is a lack of information available on local or large scale dugong migration, particularly for the Kimberley. A preliminary report of four satellite tracked dugongs has shown that, in six weeks from late July, one of these animals migrated from Beagle Bay 500 km south towards Port Hedland, passing through the nearshore habitat off James Price Point (Campbell and Holley 2010). This study also concluded that dugongs in the west Kimberley exhibit variation in site fidelity. Seasonal dugong migration patterns are believed to be based primarily on searching for suitable foraging grounds or warmer waters (Marsh et al. 2002; Gales et al. 2004). Since the water temperature in the Kimberley stays above the threshold temperature for dugongs of 18°C, it is more likely that seagrass availability is the reason for this movement.

4.2.2 Distribution and Proportion of Dugong Calves

A total of 17 calves were sighted during the surveys conducted in March, July and September 2009. Calves were recorded in all coastal sections of the survey area, but only the southern-most section of the survey area had calves recorded in all three survey periods. Calves were typically recorded in inshore waters. Several were also recorded in water deeper than 20 m and on one occasion out to 70 - 80 metres during the surveys targeting humpback whales (Appendix 2).

Overall, the proportion of calves to adults was low, with the lowest proportion of calves recorded during July (1.9%, n=3) and a higher proportion apparent in both March and September (6.2%, n=6 recorded in March; 6.5%, n=8 in September) and comparable with the lower levels in Shark Bay. Although dugong breeding could occur at any time of the year (Marsh 1999), more calves are likely to be born late in the year (Boyd et al. 1999 cited in Saalfeld and Marsh 2004) so the relatively higher numbers in the September survey could be consistent with a similar reproductive pattern. The reason for the higher proportion of calves apparent in March is unclear, but might involve sightings of older calves born the previous season in the March survey.

The low number of calves recorded overall precludes the confident identification of any trends over time or across areas. This could be an underestimation due to turbid conditions of the Kimberley and observations undertaken at 900 ft altitude (in comparison to 450 ft in the Hodgson 2007 survey). However, the low numbers and proportion of calves to adults during September survey is comparable to the lower levels recorded elsewhere. Adult to calf ratios have been recorded between 3.7 and 27% in Shark Bay and up to 33% in Exmouth Gulf (Preen et al 1997; Gales et al. 2004; Holley et al. 2006 in Hodgson 2007).

4.2.3 Population Estimates

The July and September 2009 surveys indicate an estimate of the dugong population in the survey area of approximately 1,700 animals. For comparison, the population in the Shark Bay Marine Park is believed to number approximately 10,000 individuals (Holley and Prince 2008) over 15,625 km^2.

The total number of dugongs (208 and 155) recorded in the survey area during the dry season surveys (July and September respectively) were higher than that recorded (103) in the wet season (March 2009), corresponding to a mean population estimate change from approximately 930 to 1,774 animals, and overall population densities increasing from 0.10 dugongs per km^2 to 0.19 per km^2. Anecdotal information supports that observations of dugongs are higher in the Kimberley during the dry season than in the wet. Furthermore, migratory linkages with the Kimberley population have been speculated for the Ashmore Reef population (Limpus and Chatto 2004) and the Exmouth Gulf population (Gales 2004). This is consistent with evidence that shows some dugongs may undertake large scale movements of up to 600 km in just a few days (Marsh and Rathburn 1990 in Saalfeld and Marsh 2004). It is evident from these surveys that a significant proportion of the Kimberley population undertakes regional scale migration. The MMFS was not designed to sample the movements of dugongs along the coast (see Section 3.1.2) and therefore movement patterns remain unknown.

4.2.4 Significance of the James Price Point Area

The area offshore of James Price Point does not appear to have any particular significance for the distribution, density or abundance of dugongs. Records acquired during July comprised a total of eight dugongs in five groups, within 15 km of James Price Point. In September a total of three isolated dugongs were recorded within 15 km (north) of James Price Point. Through the three surveys, a small number of calves were recorded close to James Price Point, all during the dry season.

This is in contrast to other areas of the coast such as Roebuck, Beagle or Carnot bays, where larger numbers of dugongs were observed during all three surveys. These areas are known to support beds of seagrass (DEWHA 2008), which is the probable reason for greater dugong abundance in these areas. Studies conducted by CSIRO have shown that the region supports relatively little seagrass coverage outside of the embayments (Fry et al. 2008). Consequently, dugongs may need to forage widely in the region for the sparse seagrass resources, leading to a sporadic dugong presence along the coastline, including the James Price Point area.

The data presented here suggests that dugongs may be present sporadically in and around the James Price Point area during the dry season but in very low numbers. Areas that support larger numbers of dugongs during both the wet and dry seasons e.g. Roebuck and Beagle bays, lie to the south and north of James Price Point.

4.3 Survey Effort

Aerial surveys were conducted across a total of thirty days between 1 July and 14 October 2009 during the Nearshore Regional Survey campaign and Humpback Aerial Survey campaign, amounting to 85 hours and 21 minutes of survey effort. During this time approximately 18,000 linear kilometres of transect were sampled. Flights were scheduled to coincide with neap tides when turbidity is at its lowest and avoid glare associated with the midday sun reflecting directly off the water's surface as it reduces sighting efficiency.

Two Nearshore Regional Survey flights targeting dugongs were completed in the periods 12–19 July and 11–17 September during neap tides. Complete coverage of transects 1 - 62 was obtained, resulting in survey data from the entire strip width survey area of 1,609 km^2 within the overall 9,353 km^2 Nearshore Regional Survey area. Additional fill-in transects (64–71) were surveyed during the second survey period to record the occurrence of marine megafauna to the west of Pender Bay (NB. Transect 63 just marks the northern boundary of the survey area, refer to Figure 4). These additional survey transects increased the sampled area for the second Nearshore Regional Survey to approximately 10,403 km^2. Results are also supplemented with data acquired from a survey conducted in March 2009 by SKM.

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5.0 CONCLUSIONS

Dugong aerial surveys were completed in the periods 12–19 July 2009 and 11–17 September 2009 during neap tides and generally good conditions (i.e. BSS <4), providing reliable survey data from the entire Cape Leveque to Cape Bossut survey area. Combined with the aerial survey conducted over the area using the same methodology in March 2009 (SKM 2009), the 2009 Nearshore Regional Surveys represent the first systematic assessment of the west Kimberley coastal dugong populations using contemporary survey methodology applied across three survey periods, encompassing both dry and wet seasons.

Habitat studies did not form part of this study, and therefore, discussion of the relative importance of the survey area, or selected locations within it, to dugongs is based on consideration of the distribution, abundance and relative densities of dugong sightings acquired in the area involved.

The Dampier Peninsula coastline between Cape Leveque and Cape Bossut provides dugong habitat and supports a population estimated to fluctuate between 930 and 1,774 individuals. This population is greater than the estimated population in Exmouth Gulf, but considerably smaller than that recorded for Shark Bay (circa 10,000 individuals). Conversely, average densities were higher in Exmouth Gulf indicating the population is distributed across a larger area on the west Kimberley coast.

The population size along the west coast of the Kimberley increased substantially from the wet to the dry season. It is not known whether dugongs move into the area from the south or north. Migratory links to other areas have been confirmed by preliminary satellite tagging by Campbell and Holley (2010); a dugong tagged at Beagle Bay travelled almost 500 km south to east of Port Hedland.

Dugongs in the region were primarily found in shallow coastal waters less than 20 m deep and often less than 10 m deep. Certain locations were found to contain higher numbers of dugongs during all three surveys, in particular Roebuck, Beagle and Carnot bays. The southern portions of the survey area (Block 1) consistently had the largest population and supported the highest number of calves in all survey periods. Of particular note was Roebuck Bay which appeared to have the most stable population of dugongs, including calves, within the survey area.

Dugongs were absent from the James Price Point area in March but were recorded nearby in July and September. In July, a relatively higher density of dugongs was apparent approximately 15 km offshore from Quondong Point, between the 10 and 20 m isobaths.

The data suggests that dugong presence is sporadic along much of the west Kimberley coast. They are likely to be present offshore of James Price Point at any time during the dry season but in relatively low numbers compared to other areas along the west Kimberley coastline.

Table 7: Key Findings Obtained from the Survey Data

#	Key Findings	Document Reference
	Distribution	
1	Dugongs in the region are primarily found in shallow coastal waters less than 20 m deep.	**4.1.2**
2	The James Price Point area was found to be fairly typical of the west coast of the Kimberley, with highly variable numbers of dugongs. Highest abundance was recorded in July (dry season) and lowest in March (wet season).	**4.1.2** **4.2.4**
3	The areas inshore of the Lacepede Islands (off Beagle Bay) around Carnot Bay and in Roebuck Bay were found to have greater numbers of dugongs than the rest of the area surveyed.	**4.1.2** **4.2.1**
4	The southern sections of the survey area, in particular Roebuck Bay, consistently had the highest population estimate and supported the greatest number of calves in all survey periods.	**4.1.2** **4.2.1**
5	A small number of dugongs were recorded from deep water areas and are considered to be transiting between key habitats.	**4.1.2** **4.2.1**
	Seasonal Abundance and Population	
6	Strip Width Sampling estimated that 930 dugongs were present in the survey area in March, 1,774 in July and 1,708 in September. Dugong densities ranged from 0.1 and 0.19 dugongs per km^2.	**4.1.3** **4.2.3**
7	The dugong population was substantially higher in the dry season (July and September) than in the wet season (March), suggesting large scale movement in and out of the area.	**4.2.1**
8	The estimated population of dugongs along the Dampier Peninsula coastline between Cape Leveque and Cape Bossut is larger than that in Exmouth Gulf but considerably smaller than Shark Bay.	**4.1.3** **4.2.1**
9	The average density of dugongs recorded along the Dampier Peninsula coastline between Cape Leveque and Cape Bossut is lower than Exmouth Gulf and substantially lower than Shark Bay.	**4.2.1**

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APPENDIX 1

Scales of Environmental Factors Affecting Visibility

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APPENDIX 1: Scales of Environmental Factors Affecting Visibility

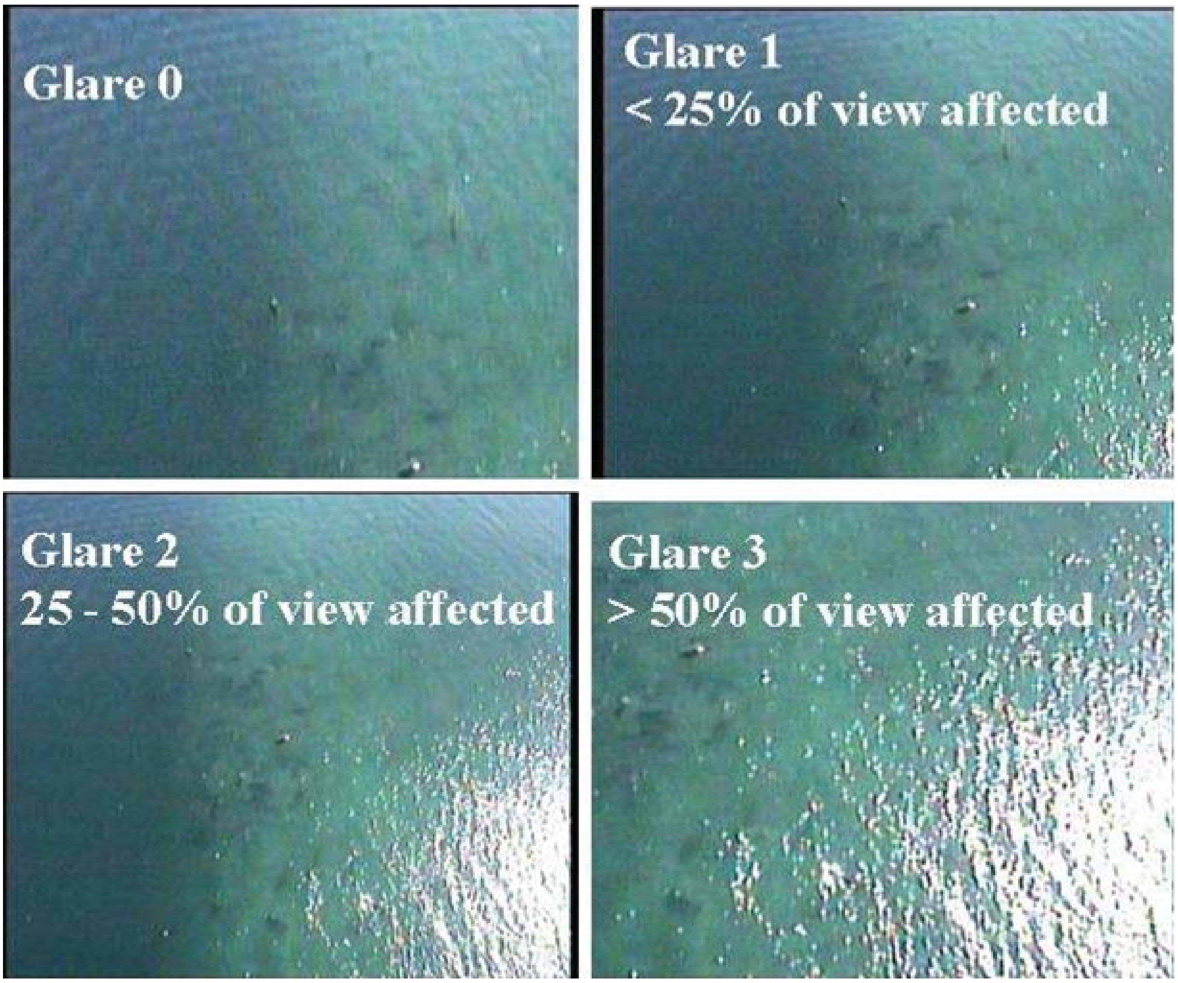
Turbidity Scale

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

Force	Description	Sea Description	Speed Knots	Range	Forecast Description	Sea State	Waves in metres
0	Calm	Sea like a mirror	0	<1	Calm	Calm	0
1	Light air	Ripples with the appearance of scales are formed, but without foam crests.	2	1-3	Light	Smooth	0.1
2	Light breeze	Small wavelets, still short but more pronounced. Crests have a glassy appearance and do not break.	5	4-6	Light	Smooth	0.2
3	Gentle breeze	Large wavelets. Crests begin to break. Foam of glassy appearance. Scattered white horses.	9	7-10	Light	Slight	0.6
4	Moderate breeze	Small waves, becoming longer, fairly frequent white horses.	13	11-16	Moderate	Moderate	1
5	Fresh breeze	Moderate waves taking a more Pronounced long form; many white horses are formed. Chance of some spray.	19	17-21	Fresh	Rough	2
6	Strong breeze	Large waves begin to form; white foam crests are more extensive everywhere. Probably some spray.	24	22-27	Strong	Very rough	3
7	Near gale	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	30	28-33	Strong	High	4
8	Gale	Moderately high waves of greater length; edges of crests begin to break into spindrift. The foam is bown in well-marked streaks along the direction of the wind.	37	34-40	Gale	Very high	5.5
9	Strong gale	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.	44	41-47	Severe gale	Very high	7
10	Storm	Very high waves with long over-hanging crests. The resulting foam, in great patches, is blown in dense white streaks along the direction of wind. On the whole the surface of the sea takes a white appearance. The 'tumbling' of the sea becomes heavy and shock-like. Visibility is affected	52	48-55	Storm	Phenomenal	9
11	Violent storm	Exceptionally high waves (small & medium sized ships might be lost to view for a time behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Every-where the edges of the wave crests are blown into froth. Visibility is affected.	60	56-63	Violent storm	Phenomenal	11.5
12	Hurricane	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected	64+		Hurricane		14

Visibility Scales

Glare



Visibility Range

1	<50 m
2	50–200 m
3	>200–500 m
4	>500–1000 m
5	>1–2 km
6	>2–4 km
7	>4–10 km
8	>10 km
9	Not available

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APPENDIX 2

Dugongs Recorded During Other Browse Surveys

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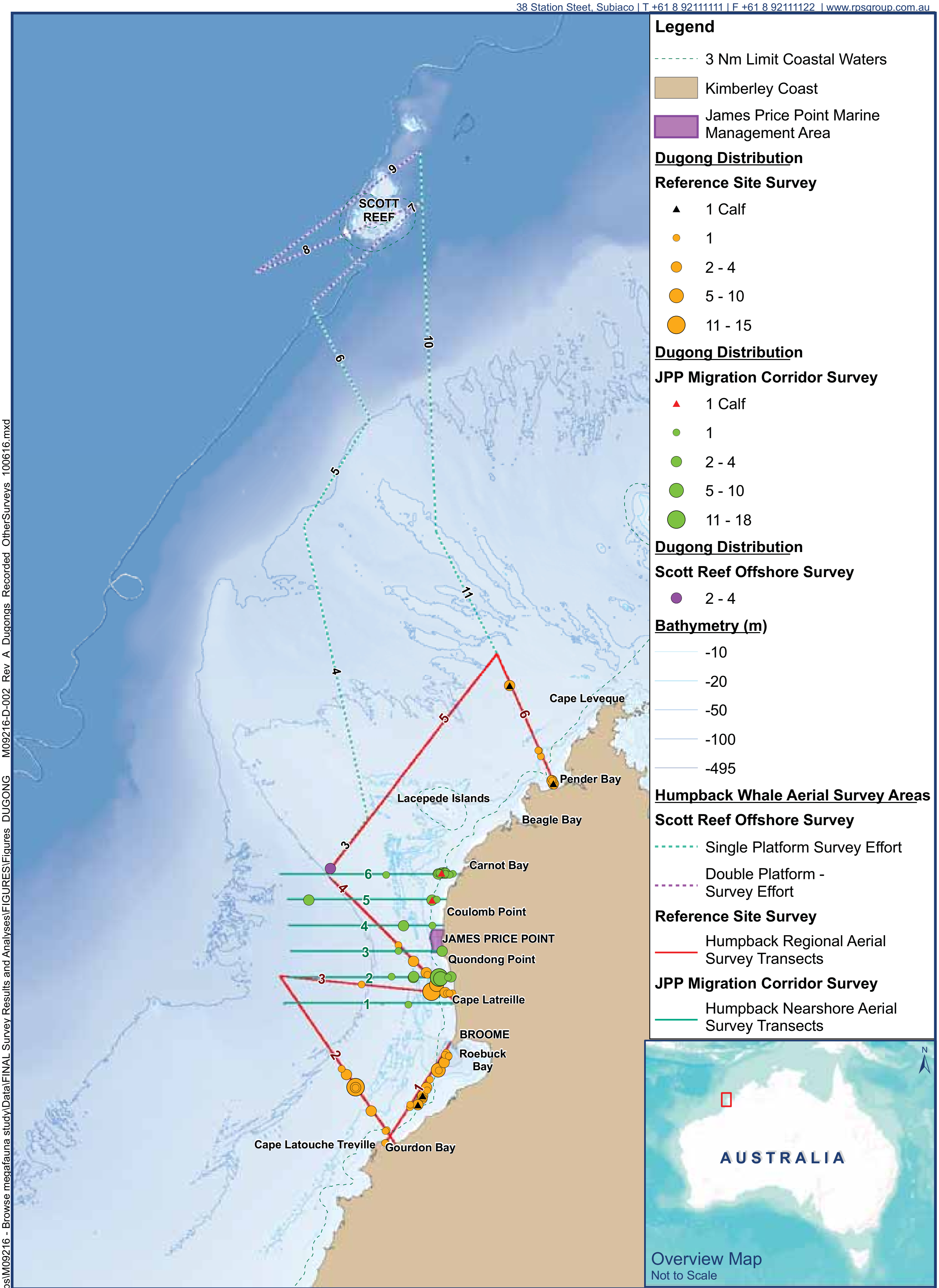

Dwg Number: M09216-D-002
Date: 16/06/2010
Revision: A
Scale: Not to Scale @ A4
Drafted by: M Angove
Source: RPS 2009

0 15 30 60 km

Dugongs Recorded During JPP Migration Corridor, Reference Site & Scott Reef Offshore Surveys

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