RPS

HUMPBACK WHALE SURVEY REPORT

Browse Marine Megafauna Study 2011

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Report No: N1119903
Version/Date: Rev 0, April 2012

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Document Status

Version	*Purpose of Document*	*Orig*	*Review*	*Review Date*	*Format Review*	*RPS Release Approval*	*Issue Date*
Draft A	*Draft for Client Review*	*EmmSom*	*PetBar*	*21.12.11*	*DC 21.12.11*		
Draft B	*Draft for Client Review*	*CraSty*	*BarShe*	*12.02.12*	*DC 17.02.12*		
Rev 0	*Final for Issue*	*BarShe*	*WarChi*	*04.04.12*	*SN 10.04.12*	*D. Sim*	*11.04.12*

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SUMMARY

Woodside Energy Limited (Woodside) plans to develop several gas and condensate fields in the Browse Basin, with onshore processing facilities located at the Browse Liquefied Natural Gas (LNG) Precinct near James Price Point on the Dampier Peninsula. The proposed development will involve establishing offshore infrastructure near Scott Reef, with a pipeline extending to an onshore LNG plant near James Price Point. The location of the Browse LNG Precinct was 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 conduct an extensive series of marine megafauna baseline surveys over three years, 2009–2011, to support the assessment and management of potential impacts to these fauna from the proposed Browse LNG Precinct development.

A series of aerial and vessel surveys for humpback whales (*Megaptera novaeangliae*) and other marine megafauna was undertaken by RPS during the 2009 winter–spring season (RPS 2010) and aerial surveys were also conducted during the winter–spring season in 2010 (RPS 2011). Aerial surveys were again undertaken from June–September 2011.

Aerial surveys were conducted to assess humpback whale use of the James Price Point coastal area and were conducted with a fixed wing aircraft following a distinct flight plan. The flight plan was consistent between the three baseline years. Humpback whales were sampled from the air with a dual platform, double-count method. Throughout the three years of baseline studies 57 hours were spent in total sampling along 12,695 km of transects during the Migration Corridor Survey. Other aerial and vessel surveys were also undertaken in 2009 and 2010, the results of which have also been used in the summary.

Data obtained from the aerial surveys were used to quantify the distribution, abundance and density of humpback whales within the James Price Point coastal area. The 2011 survey season provides a third year of baseline monitoring of humpback whales in the area and was used to investigate inter-annual variation in key characteristics of humpback whale activities during their annual migration along the Dampier Peninsula.

A summary of data from 2009 – 2011 is provided in Table 1.

Table 1: Summary of Survey Effort from all Three Years of Baseline Survey

	2009	2010	2011
Survey Period	1 July–10 Oct	8 June–30 Oct	28 June–21 Sept
Number of Flights	8	10	7
Total survey effort for transects 1-6	19.07h (Mean: 2.38h)	22.28h (Mean: 2.23h)[¥]	16.25h (Mean: 2.32h)
Total length of transects 1-6 (Average length sampled per flight)	4,095 km (Mean: 512 km)	5,067 km (Mean: 507 km)	3,533 km (Mean: 505 km)

¥: Last three flights were conducted at 130 knots rather than 110 knots, hence shorter flight time.

Conclusions from 2009, 2010 and 2011 Baseline Surveys

The key findings of the three years of baseline studies for humpback whales are presented in Table 2.

Whales occur off the Dampier Peninsula for a five month period each winter (dry season) between June and October inclusive (RPS 2010 and 2011). From their initial arrival around the beginning of June, the humpback whale abundance increases to a peak from late July to mid August. Whale abundance then decreases until the last whales leave the area by the end of October or early November. The extreme limits of the whale season has not been sampled but is based on third party information and anecdotal information from tour operators and local people. The majority of whales (80%) are likely to occur between 5 July and 16 September.

Their general spatial distribution is focussed in a band along the coast from between 9 and 46 km from the western shore of the Dampier Peninsula. Whale abundance outside of this migration corridor becomes sparse. A significantly greater number of whales and calves were sampled off Pender Bay than off James Price Point in 2009 and 2010 and supports the conclusion that the area from Pender Bay to Camden Sound is a major calving area. A small number of whales have also been recorded around Scott Reef and in 2009 and 2010 two calves were also recorded at this location. Few whales were recorded between Scott Reef and the mainland.

Distance analysis has estimated that 11,364 (95% CI: 2,721–31,567) and 9,256 (95% CI: 2,088–25,634) individual whales pass along the west coast of the Dampier Peninsula on their way north in 2009 and 2010 respectively (RPS 2010, 2011). Because of the relatively wide confidence intervals around population estimates, nothing can be surmised about what proportion this constitutes of the west coast humpback whale population (Group IV) of 28,830 (95% CI: 23,710-40,100) individuals as estimated by Hedley et al (2011) from data collected off the North West Cape in 2008.

While off the west coast of the Dampier Peninsula, humpback whales have been observed travelling, resting and nursing their young, whilst many whales were also frequently observed breaching and tail and pectoral fin slapping. Some courting and mating activity has also been observed. Very small calves have also been observed towards the south of the Migration Corridor survey area in the early part of the season suggesting that some calves are born to the south and move north through the area. Calf abundance has been shown to peak in September and thus later than adults.

Table 2: Key Findings from the Humpback Whale Survey in the Browse Marine Megafauna Study for 2009, 2010 and 2011

Category	Key Finding	Section
Temporal distribution	Humpback whales are present offshore of the west Kimberley coast from early June to early November.	3.2.1.1
	The peak in adult humpback whales offshore from James Price Point occurred in late July in 2011, early August in 2010 and mid-August in 2009.	
	The peak in calf numbers offshore of the James Price Point coastal area occurred mid-September in 2011, late August in 2010 and in early September in 2009.	
	The peak in northbound whales in 2009, 2010 and 2011 occurred at the end of July to early August, with a peak in southbound whales from September to October.	
	80% of all whales that occur in the survey area offshore of James Price Point can be expected to be present between the 5 July and 16 September based on data from 2009 and 2010.	
	No evidence of significant variation in abundance among years during the main period of time when whales are migrating	
Spatial distribution	Humpback whales were recorded throughout the survey area with most occurring within approximately 50 km of the coast and within the 50 m isobath. Low numbers of whales use the deeper offshore areas, including around Scott Reef.	3.2.1.2 3.2.1.3 RPS 2010; RPS 2011
	Most humpback whale calves were seen within 40 km of the coast.	3.2.1.2
	The median distances from shore for individual adult humpback whales were 22.3 km in 2011, 23.1 km In 2010 and 23.4 km in 2009.	3.2.1.2 3.2.3.2
	The median distance from shore that humpback whale calves were recorded was 21 km in 2011, 20.3 km in 2010 and 22.4 km in 2009.	3.2.1.2 3.2.3.2
Comparison JPP and Pender Bay during 2009 and 2010	There was a significant difference in the relative abundance of humpback whale calves sampled from the air off Pender Bay compared to James Price Point in 2010. There were approximately five times more humpback whale calves per kilometre off Pender Bay (0.016 calves/km) than off James Price Point (0.003 calves/km). These results are similar to those obtained in 2009. In 2010, numbers of adult humpback whales per kilometre recorded off Pender Bay were not found to be statistically different than offshore of James Price Point.	Please refer to RPS 2010; RPS 2011
JPP population estimate	In 2010, the estimated number of humpback whales travelling north through the Migration Corridor Survey area was 9,256 (95% CI: 2,088–25,634). The population estimates for animals heading in a northward direction during the northward migration period in 2009 was 11,364 (95% CI: 2,721–31,567). There was no evidence of a significant difference between these two estimates.	Please refer to RPS 2010; RPS 2011
Direction of travel	The majority of humpback whales were observed heading north until late July in 2011. There was a period of mixed directions throughout August and then a majority southward trend in the September. This was similar to the findings in 2009 and 2010.	3.2.2
Migration route	In 2011, 80% of humpback whales were observed between 8.7 and 44.6 km from the coast. In 2010, 80% of whales were recorded between 7.3 and 43.7 km from the shore. In 2009, 80% of humpback whales were observed between 9.8 and 47.5 km from the mainland.	3.2.1.2 3.2.3.2
	Based on the combined data from 2009, 2010 and 2011, 80% of humpback whales were recorded between 8.5 and 45.9 km from the mainland. The confidence intervals around these two values suggest it is 95% likely that 80% of whales can be expected to occur between 7.6 and 49.4 km from land in any one year.	3.2.1.2 3.2.3.2

Category	Key Finding	Section
Annual Variation	There were differences in the timing of the migration peak between the years with the 2011 peak being observed 21 days earlier in the 2009 season.	3.2.3.1
	There was no evidence of significant variation between years in the distance of whales from the shore.	3.2.3.2
	Whales not associated with calves were found further offshore later in the season by around 6 km. Whales with calves do not appear to displace further offshore as the season progresses.	3.2.3.4

GLOSSARY

Baseline Survey
A baseline survey provides information on the condition of an area. A baseline survey may include the collection of data for a number of environmental parameters.

Cetacean
A cetacean refers to species of whale, dolphin or porpoise in the Order Cetacea.

Declination
Vertical angle from the point of observation on the aircraft to a target on the surface of the water. Declination can be measured in degrees or percentage.

Distance Sampling
A method of data acquisition and analyses that estimates an absolute density of objects based on a sample of detected objects from a transect line or point. The analytical process estimates the number of objects that were not detected, either having been missed by observers or not being available. From the estimated density, a population for a region can be estimated.

Double-count
Double-counting refers to the same group of animals having been detected and recorded more than once by the same observer. It is undesirable under most sampling conditions as it over estimates the number of animals in a given area.

Dual Platform (refer also to "Platform")
Dual platform refers to two locations of observers, i.e. front seats versus rear seats of an aircraft (same deck, different seats). A dual platform survey arrangement is a standard method used in distance sampling to estimate observer bias and availability bias.

James Price Point Coastal Area
Refers to the coastal waters between Quondong Point in the south, Coulomb Point in the north and offshore to approximately three nautical miles (NM).

Marine Megafauna
Marine megafauna refers to a group of marine animals which are relatively large (approximately >1 m) in size and may be seen from above the surface of the water.

Mark (refer also to "Recapture")
Mark describes the method of recording a group or individual of a target species for the first time during a flight.

Pipeline Corridor
Pipeline corridor refers to the area in which a pipeline 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 seat of an aircraft.

Recapture

During a dual platform survey flight, a recapture occurs when a marked (refer also to "Mark") group or individual (already recorded by one observer/platform) is recorded by the observer on a separate platform. Generally, recaptured records are identified after the flight has been completed and during the data transcription phase.

Relative Abundance

Sighting abundance (No of sightings) standardised against sampling effort of either hours watched or distance travelled (animals km^{-1}). Relative abundance is calculated to account for differences in sampling effort where comparisons between surveys is desired.

Whale Footprint

A so-called "whale footprint" is a term given to the flat circular patch of water formed by the upwelling of water produced by the turbulence of an ascending whale's tail flukes.

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1.0 INTRODUCTION

1.1 Project Background

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

The approvals process for the Browse LNG Precinct at James Price Point was supported by a Strategic Assessment Report (SAR) (DSD 2010), which in turn was supported by a range of baseline survey reports. These included a series of aerial and vessel surveys for humpback whales (*Megaptera novaeangliae*) and other marine megafauna. The marine megafauna surveys were undertaken by RPS through the 2009 and 2010 (RPS 2010 and 2011) dry seasons (June–October) to investigate the inter-annual variability in humpback whale abundance and distribution off the west coast of the Kimberley.

In 2011, RPS was commissioned by Woodside to acquire a third season of baseline data, to obtain a better estimate of the inter-annual variability in humpback whale spatial distribution and abundance during the peak of the migration season. This extensive set of data will be used to develop management measures that will help reduce any potential risks that the development (construction and operation) of the Browse LNG Precinct may pose on humpback whales.

1.1.1 Survey Findings from 2009 and 2010

In 2009, RPS conducted an extensive series of megafauna surveys that provided detailed information on humpback whale abundance, distribution and behaviour off the west coast of the Kimberley. From July to October 2009, aircraft and vessel-based surveys were conducted to focus on the James Price Point coastal area, but also included two reference sites (Gourdon Bay and Pender Bay) as well as the proposed pipeline corridor to Scott Reef (RPS 2010). The 2010 aerial surveys were undertaken between June and October, with a focus on sampling humpback whales around the James Price Point coastal area and the proposed pipeline corridor to Scott Reef (RPS 2011). The two middle transects of the Migration Corridor Survey were extended out into deep offshore water by a further 90 km to investigate the presence of a significant offshore southward migration corridor, surmised in previous years.

Humpback whales were sampled mainly from a fixed wing aircraft using a dual platform, double-count method with the exception of a selected number of transects during the Scott Reef Surveys, which were flown using a single platform to avoid observer fatigue

(RPS 2010; RPS 2011). Vessel-based surveys were conducted along a series of transects and focal follows. The transect surveys used two dedicated fauna observers, one behavioural observer, one traditional owner (TO) and one data recorder. The transect surveys sampled humpback whale distribution, density and short-term behavioural data within 30 n miles of James Price Point and Pender Bay. The focal follow surveys were conducted off James Price Point and Pender Bay using one behavioural observer and one TO. Behavioural data were acquired by following specific groups of whales recording all behavioural observations. These data were used to assess behaviours at both sites and to estimate dive rates and travel velocities.

These aerial and vessel surveys identified a range of humpback whale activities in the study area, including migration, resting and nursing. In particular, a nearshore migration corridor for humpback whales was identified off the west coast of the Kimberley. The majority (80%) of the whales were observed within 8–42 km from shore, within the 10–50 m isobaths. The median distance from shore for groups was 27.1 km in 2009 and 23.1 km in 2010. Data acquired in 2010 along transects that extended into deep offshore waters provided no evidence of a significant offshore change in the migration pathway as suggested by Jenner and Jenner (2009) and RPS (2010).

In 2009, it was estimated that 11,364 (95% CI: 2,721–31,567) individual humpback whales passed through the Migration Corridor Survey area on the northward migration and in 2010 the estimate was 9,256 (95% CI: 2,088–25,634) individual whales. These two population estimates were not significantly different as indicated by the overlap in confidence intervals.

Abundances of adult humpback whale sightings off James Price Point in 2009 peaked in late July and mid-August in 2010 and early September for calves in both years. Most humpback whales recorded before August in both years were travelling north. Between mid-August and mid-September of both years there was no discernible trend in travel direction. After mid-September, the majority of humpback whales were observed travelling south in both years. Groups of humpback whales without calves travelled faster than groups with calves.

The abundance of humpback whales recorded off Gourdon Bay (2009 only) was relatively low throughout the survey period. There were generally more whales observed in Pender Bay than in the James Price Point Coastal area, but only the abundance of calves was found to be significantly higher when comparing the two sites.

Overall, the 2010 aerial surveys supported the 2009 findings that the coastal waters adjacent to James Price Point represent an important migration corridor for humpback whales.

1.2 Project Objectives

The Migration Corridor Survey was designed to quantify the distribution, both temporal and spatial, of humpback whales off the west coast of the Kimberley region, with a focus on James Price Point. The purpose of the 2011 study was to provide a third year of baseline data for humpback whales along the Dampier Peninsula and investigate the inter-annual variations further. The following objectives were established:

- Quantify the distribution and relative abundance (No. whales per km sampled) of humpback whales across the entire James Price Point survey area.
- Describe the temporal pattern in the abundance of humpback whales present in the survey area over the survey period.
- Identify the travelling direction of humpback whales during each survey trip.
- Record unusual or rare species.
- Record vessel presence in the survey area.
- Compare the spatial and temporal variation in whale distribution and relative abundance in the Migration Corridor survey area between each baseline year.

Investigation of the methods for ongoing monitoring of humpback whales (last bullet point) has been conducted separately to this report and is not included here.

Unusual or rare species include those that have not been recorded previously or are recorded only maybe once or twice a season. Examples include sperm whale (*Physeter macrocephalus*), blue whale (*Balaenoptera musculus*), Bryde's whale (*Balaenoptera brydei*), snubfin dolphin (*Orcaella heinsohni*), Indo-Pacific humpback dolphin (*Sousa chinensis*), killer whale (*Orcinus orca*) and whale shark (*Rhincodon typus*). Records of these species have been reported in the Marine Megafauna Survey Report (RPS 2012).

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2.0 METHODS

2.1 Survey Design

The 2011 survey program for humpback whales included a single survey configuration and the same as that used in 2009 and 2010 during the Migration Corridor Survey. The Reference Site Survey and Scott Reef Offshore Surveys conducted in previous years were not undertaken in 2011. A nearshore survey was undertaken but sampled only dugongs, dolphins and turtles, and infrequently recorded species such as whales sharks. The findings of that survey are presented in RPS (2012a and 2012b).

The area of the Migration Corridor Survey extends approximately 39 km north and south of James Price Point, from the mean high water level out to approximately the 80 m isobath (Figure 1). The total survey area is approximately 6,495 km^2. The survey was designed to sample whales transiting through a migration corridor adjacent to James Price Point, where humpback whales travel north to their breeding grounds and later returning south to their feeding grounds in the Antarctic.

The survey design incorporated a dual platform, double-count set-up to acquire (recapture) data for Mark Recapture Distance Sampling (MRDS) analysis and allow for the estimation of a population size (Buckland et al. 2001; Buckland et al. 2004; Thomas et al. 2010). This method has the advantage that a more thorough set of data are acquired because two observers generally record more animals and more species than an individual observer would. This method has benefits whether or not Distance Sampling analysis is undertaken.

The survey was conducted along six east-west transects, each of approximately 90 km in length and with a combined total of approximately 540 linear kilometres (Figure 1). The parallel transects were spaced 13.48 km apart. In 2009 the area in which whales could be reliably detected (effective strip width – ESW), and therefore reliably modelled, was found through the *Distance* program to be between 5 and 5.5 km from the aerial trackline. Beyond this range, whales became increasingly less likely of being detected and modelling of their density unreliable. Furthermore, the underwing fuel tanks obscured part of the observers view beyond approximately 7–8 km from trackline depending on the pitch of the aircraft. For these reasons, the area in which observers were asked to search for whales in 2010 and 2011 was limited to around 6–7 km from the trackline of the aircraft. This restriction allowed for a high detection probability close to the trackline while helping to reduce overall double-counting between transects.

Surveys were intended to be conducted in good weather conditions of Beaufort Sea State (BSS) 4 or less.

All survey flights were conducted from a CASA 212-400 aircraft flown at 1,000 ft (304.8 m) and at 110 knots (204 km/h). To minimise variation due to sampling artefacts and to optimize comparability between years, the same sampling methods and most surveyors from the 2009 surveys were employed in the 2010 surveys and 2011 surveys.

2.2 Survey Platform Configuration

The survey team comprised one team leader and three platforms of tandem observers on either side of the aircraft (Figure 2). The two front observers (Platform 1) comprised more experienced personnel while the two middle observers (Platform 2) were less experienced. The rear observers (Platform 3) comprised Traditional Owners being trained in marine mammal observation.

The front and middle pairs of observers surveyed for and recorded sightings of marine megafauna in a dual platform method: two observers were on each side of the plane (port and starboard), positioned one behind each other (front and middle).

The team leader and observers communicated via aviation noise-cancelling headsets that were connected to an eight-channel audio management system, which was also used to record audio entries of sightings and environmental data for subsequent transcription to a database. The audio management system was comprised of a six-track TASCAM recorder and two, four-track Zoom H4N recorders to record each observer and the Survey Team Leader independently and with redundancy. Two Behringer HA4700 headphone amplifiers connected observers with the Team Leader. The pilots were also connected with the team leader through the aircrafts internal audio.

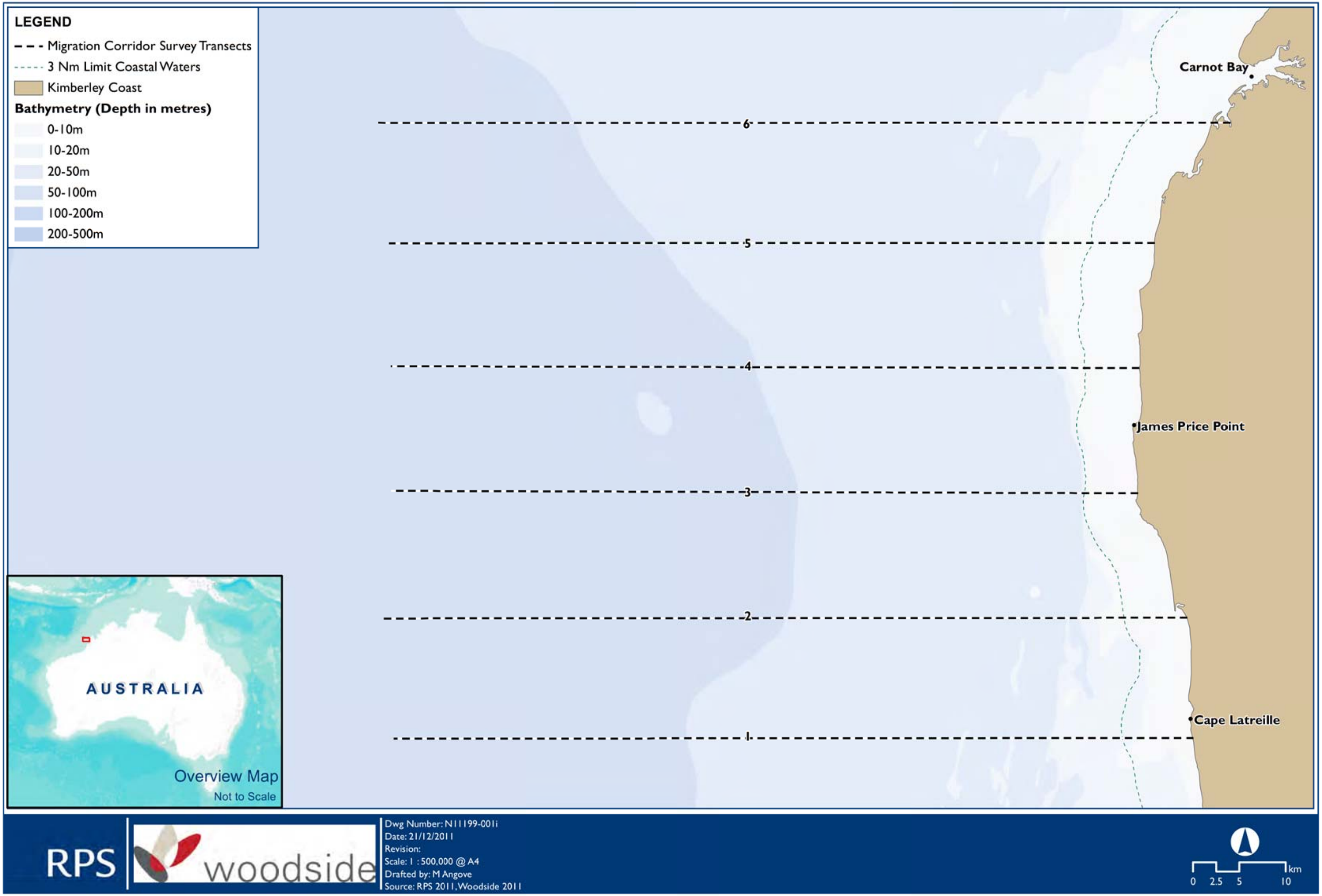


Figure 1: Geographic Extent of the Migration Corridor Survey

Flight track coordinates were acquired every second from a *Garmin GPSMAP 60CSx* with an external antenna located in the cockpit of the aircraft, and downloaded to a laptop. A back-up GPS was also placed in the cockpit, which recorded the aircraft's location every second to the internal memory. Real-time output to the laptop enabled the team leader to monitor survey progress. These positions are reported to be accurate to within 10 to 15 m (GPSCO 2007) of the actual position in general use. Locations of whale groups were fixed using clinometers (*Suunto PM-5*) for declination and angle boards for the horizontal angle to the whales. Geographic positions of the target groups were then established using script written within the database using the method described by Lerczak and Hobbs (1998). Thereafter, perpendicular distances from the track-line to the groups were estimated using *ArcMap 9.3.1*.

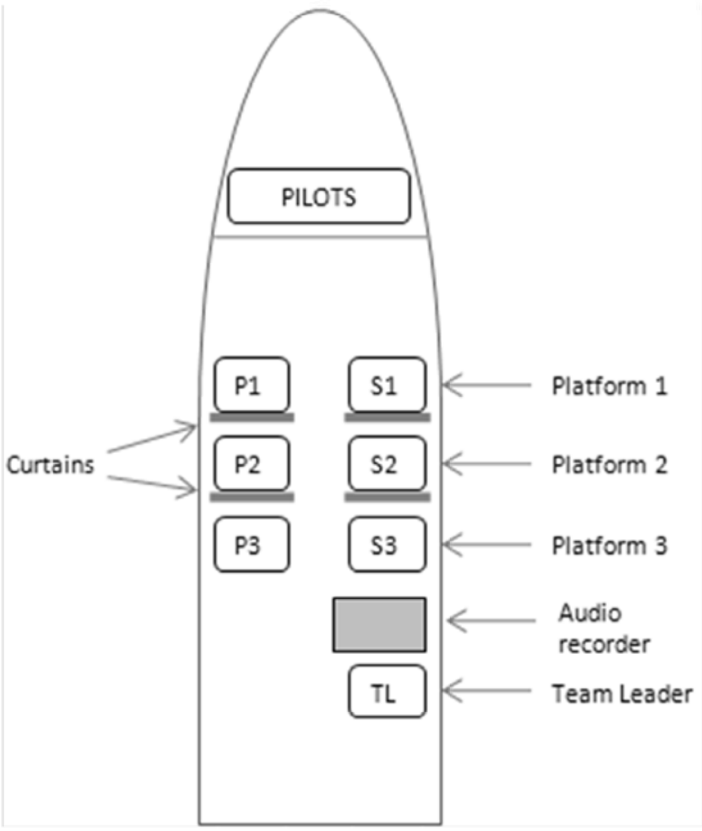


Figure 2: Observer and Pilot Seating Configuration

2.3 Sampling Protocol

The sampling protocol was similar to the 2009 and 2010 surveys (RPS 2010; RPS 2011).

Observers independently recorded parameters of humpback whale sightings using mini-binoculars to improve the detailed description of groups and in particular whether calves are present. Small common megafauna such as sea snakes, birds, fish, dugongs, turtles and dolphins were not searched for or recorded. Sightings of unusual or rare species (such as the snubfin or Indo-Pacific humpback dolphins or whale sharks) and vessels were recorded.

Sighting parameters were recorded in the following order:

- type (humpback adult, humpback calf, unidentified adult, unidentified calf, large unidentified whale, medium unidentified whale, small unidentified whale)
- sighting cue (i.e. blow, body, dive/fluke, jump/splash, breach, slick/footprint (visual pattern on the water surface caused by upsweep of a whale's tails), colour underwater, associated wildlife)
- horizontal angle
- declination angle
- reliability index of the species identification (certain, probable, guess)
- number in group
- number of calves
- direction of travel
- glare
- turbidity.

Records from Platforms 1 and 2 were transcribed into an Access database after each flight. Data collected from the third platform was transcribed into a separate Access database but were not used in the data analyses. The time stamp given to each record during transcription was established from the time that the horizontal angle was recorded. Recaptured data were identified through a combination of:

- proximity in time
- similarity in sighting details
- similarity in declination and horizontal angle when sighting called at same time
- proximity in geographic position after sightings were plotted in GIS.

Where sightings were not confidently identified to species, they were marked as Unidentified Whales (Large, Medium or Small). Signs of large whales such as footprints and white water were also recorded to ensure that all whales were recorded in accordance with the precautionary principle. Each group was only recorded once by each observer. It was therefore necessary to keep track of each group to ensure that double-counting was avoided.

2.4 Survey Schedule

Seven flights were flown between late June and late September 2011, with one approximately every two weeks to cover the 80% peak abundance period for humpback whales, as identified from the data from 2009 and 2010. The flights were scheduled around the neap tides to take advantage of lower turbidity during these times of lowest water flow. All transects were flown on the same day. The order the transects were flown (1-6) or (6-1) was randomised to reduce any biases that could be associated with flying the same transects at the same time of day. The final survey schedule is provided in Table 3.

Survey test flights were conducted over James Price Point from 24–26 June 2011 to ensure that all equipment was functioning and configured, and that observers were competent in making observations of the target species prior to the commencement of the survey.

Table 3: Survey Schedule

Trip Number	Date
1	28 June 2011
2	13 July 2011
3	27 July 2011
4	9 August 2011
5	23 August 2011
6	6 September 2011
7	21 September 2011

2.5 Mapping and Analytical Methods

2.5.1 Mapping

The positions of all recorded whales were estimated using the GPS position of the aircraft and the declination and horizontal angle to the whales. These data were plotted in GIS to provide overall distribution maps. Records of whales that were unidentified to species were presumed to be humpback whales. This precautionary approach is justified from previous results where species other than humpbacks comprised 0.35% in 2009 and 0.8% in 2010 of the total number of sightings that were identified to species.

Recaptured records were excluded from the plots and analyses in order to avoid duplication. Whale headings were characterised into North for those pointing in a north, north-east or north-west direction, and South for those pointing in a south, south-east and south-west direction. Other categories were: East, West and Undetermined.

2.5.2 Percentage Bands

Similar to the 2009 and 2010 Migration Corridor Survey, a map using 2011 survey data was created to show percentages of humpback whale sightings and number of individuals according to their distances from land. Using the estimate of each whale sighting position in GIS, the distance of each position to the nearest land was calculated. These distances were grouped into "bands" and developed for each transect of the Migration Corridor Survey. The corresponding percentage points on adjacent transect lines were joined to form the boundaries of each percentage band.

To identify any potential migration corridors and help investigate changes in the distribution of whales off the west Kimberley coastline in any one year, a fairly simple but robust quantitative descriptor of the migration corridor off the west Kimberley coast is required. To this aim, the distance of each individual whale from land along each transect of the Migration Corridor Survey was analysed to produce cumulative frequency graphs which were used to estimate the 10th and 90th percentiles for 2011 to compare with the previous two years. The 95% confidence intervals around the 10th and 90th percentiles were also estimated. Data from all three years were then processed in the same way and used to define the distances from land within which 80% of whales are 95% likely to be found in any year.

2.5.3 Statistical Analysis

Group and individual data have been reported where considered appropriate as the two can confer relevant information for impact and management purposes. Group structure is likely to be biologically relevant for mating, reproduction and nursing, and should be a consideration in any monitoring program. Individual whales are factored in collision risk assessments and therefore both need to be reported separately.

2.5.3.1 <u>Abundance</u>

Counts of total whales observed along transects were analysed using a two-way Analysis of Variance (ANOVA) with Transect and Year as orthogonal factors. Transect was treated as fixed factor as the location of each transect was chosen and because the counts along each transect was of specific interest. Year was treated as a random factor as the main interest associated with this was whether there was temporal consistency in patterns rather than whether counts differed between specific years. Untransformed counts of the total numbers of whales observed per transect per flight were used as the dependent variable; mothers and calves were both included in the counts and each whale observed was included only once along each transect (i.e. a whale that was observed by both of the dual observers was counted once).

As outlined in earlier reports and in Section 1.1.1, a clear pattern had been observed each year of increasing whale abundance through June to mid July as whales migrate north, leading up to a period of greater abundance until the end of August when whales are moving both north and south, followed by a progressive decrease in abundance as

the final whales are migrating south. Consequently, analyses were done separately for three periods of whale abundance: "Early", "Peak" and "Late" periods. The Early period included the one to three flights each year until July 15, the Peak period included the three flights between July 15 and August 31, and the Late period including any flights after that (two to four flights per year).

2.5.3.2 Patterns of Distance Offshore throughout the Year – All Whales

Variation in the distance offshore was analysed via Analysis of Covariance (ANCOVA) to test for variation in distance offshore among years and to test (and account) for potential increases in the distance offshore of all whales as each year progressed. Given previous suggestions that returning whales travel further offshore when migrating southwards than whales travelling northwards to nursery areas (Jenner et al. 2001), increased proportions of southward heading whales later in the year might be expected to translate into increases in the distance offshore as each year's observations progressed. To test this, an ANCOVA was run using all three years of data; with Year as a factor and the Day of Year (calendar day of year) for observations made as the covariate. The dependent variable was either the average or 10th or 90th percentiles calculated for the (natural log-transformed) distances offshore of all whale individuals along each transect (m), for each flight; thus the six transects surveyed each flight were each treated as independent replicates provided at least some whales were observed (distances obviously could not be summarised for any transects without whales). For each dependent variable, the ANCOVA was first run with the interaction term between Year and Day of Year, if/when this was found to be non-significant the model was then re-run, excluding the interaction term.

2.5.3.3 Patterns of Distance Offshore throughout the Year – Cow-Calf Groups versus Non-Calf associated Whales

ANCOVA was also used to test whether groups of whales which included a calf had a different distribution offshore, or different seasonal change in distribution offshore to other whales not associated with calves. The main factor was the presence or absence of calves in an observation of whales and the covariate was Day of Year. Each observation of a group of whales (or a single whale) was used in calculating the average of the (log-transformed) distance offshore for each transect and flight, calculating separate averages for the two types of observations along each transect/flight. Data were combined across all three years to increase the statistical power of the test because analyses above had found little difference among years in distance offshore.

3.0 RESULTS

3.1 General Results

Flights for the Migration Corridor survey were conducted seven times between 28 June and 21 September 2011, amounting to 16 hours and 14 minutes flying time on transect with a mean of 2 hrs 19 minutes on transect per flight. During this time, approximately 3,533 km of transect were sampled with an average of 505 km per flight. Survey conditions ranged from BSS 1 to 5 but were generally between 2 and 4. Environmental conditions were monitored throughout each flight by the Team Leader to ensure monitoring was taking place during suitable environmental conditions (BSS $\leq$ 4). During the 2011 surveys, conditions were deemed suitable during 3,195 km of transect (90% of transect distance). When seastate was greater than BSS 4, surveying continued at the discretion of the team leader who assessed whether conditions were still appropriate to sample or whether too much of the survey would be affected. The flight schedule and a summary of the environmental conditions experienced during each of the flights can be seen in Table 4.

Table 4: Migration Corridor 2011 Survey Flights Details

Trip Number	Date	Start Time	End Time	Total Time on Transect	Sea State
1	28 June	1346	1639	2 hr 22 min	2–5
2	13 July	1347	1633	2 hr 17 min	1–2
3	27 July	1312	1603	2 hr 23 min	2–5
4	9 August	1305	1552	2 hr 17 min	2–4
5	23 August	1349	1639	2 hr 19 min	2–5
6	6 September	1316	1558	2 hr 14 min	2–5
7	21 September	0715	1008	2 hr 22 min	2–5

Although BSS 5 was encountered during five of the flights, the duration of flight under this condition was very small compared with the overall flight time. In total, 348 groups of humpback and unidentified large whales were recorded whilst on transect (Table 5). These comprised of 467 adult whales and 23 calves. Of these, 341 were confidently identified as humpback whales (318 adults, 23 calves). All records of groups with calves, involved a single calf only. Calves were first recorded on 13 July although some may have occurred in the area before this sample was taken.

A single whale shark (*Rhincodon typus*) was the only other large fauna species recorded.

It is likely that whales recorded as unidentified during the 2011 surveys were humpback whales, given that no other whale species were identified during the surveys and the high prevalence of humpbacks in the survey area.

Table 5: Number of Humpback and Unidentified Whales Recorded during the Migration Corridor 2011 Survey

Trip No.	Date	Transects Order	No. of Whale Groups	Total Adult Whales	Total Whale Calves	No. of HW Adults	No. of HW Calves	No. of Unid. Adults	No. of Unid. Calves
1	28 Jun	1-6	8	10	0	5	0	5	0
2	13 Jul	6-1	24	30	3	20	3	10	0
3	27 Jul	1-6	107	144	2	95	2	49	0
4	9 Aug	1-6	73	100	4	76	4	24	0
5	23 Aug	1-6	53	76	4	53	4	23	0
6	6 Sep	1-6	44	54	2	29	2	25	0
7	21 Sep	6-1	39	53	8	40	8	13	0
Total			**348**	**467**	**23**	**318**	**23**	**149**	**0**

HW = humpback whales, Unid. = unidentified, No. = number

3.2 Results from Mapping and Analyses

3.2.1 Temporal and Spatial Distribution

3.2.1.1 Broad Temporal Distribution

Whale surveys for the 2011 season along the James Price Point Migration Corridor were focussed on the migration peak where 80% of whales were found to have passed through the survey area, based on the data from the 2009 and 2010 seasons.

Humpback whales were present in low numbers (n=10) during late June (Trip 1), but peaked rapidly on the 27 July (Trip 3) when 146 whales (144 adults, two calves) were recorded (Table 5; Figure 3). Their numbers declined more slowly over the subsequent four trips with 61 animals being recorded on 21 September (Trip 7). The median group size across all humpback whale records (including calves) was 1 and the mean was 1.4, with a maximum group size of six individuals observed on Trips 5 and 7.

The first sightings of calves occurred on 13 July (Trip 2). This included one sighting on each of the three northern transects. Calves were also recorded during the following five trips. Calf numbers peaked on 21 September (Trip 7), when eight sightings of calves were recorded, representing 20% of all humpback whale calves recorded.

Sightings of whales were fairly consistent across all six transects over time with no distinct patterns indicating areas of preference along the coast at any time during the migration period (Figure 4).

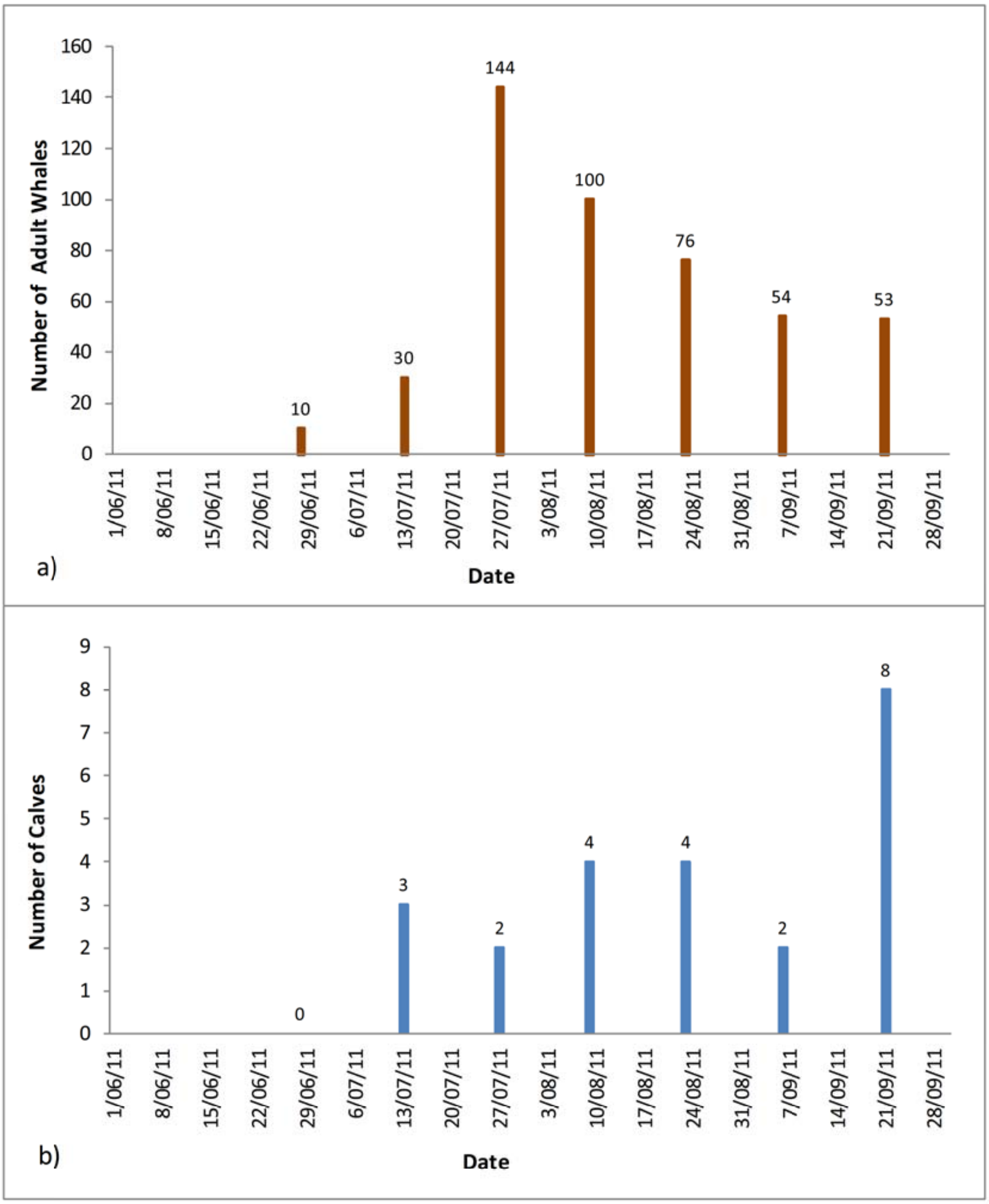


Figure 3: **Total Number of (a) Adult Humpback Whales and (b) Calves recorded during the James Price Point Migration Corridor Surveys 2011. NOTE: These are the raw data (minus recaptures) and do not account for environmental conditions.**

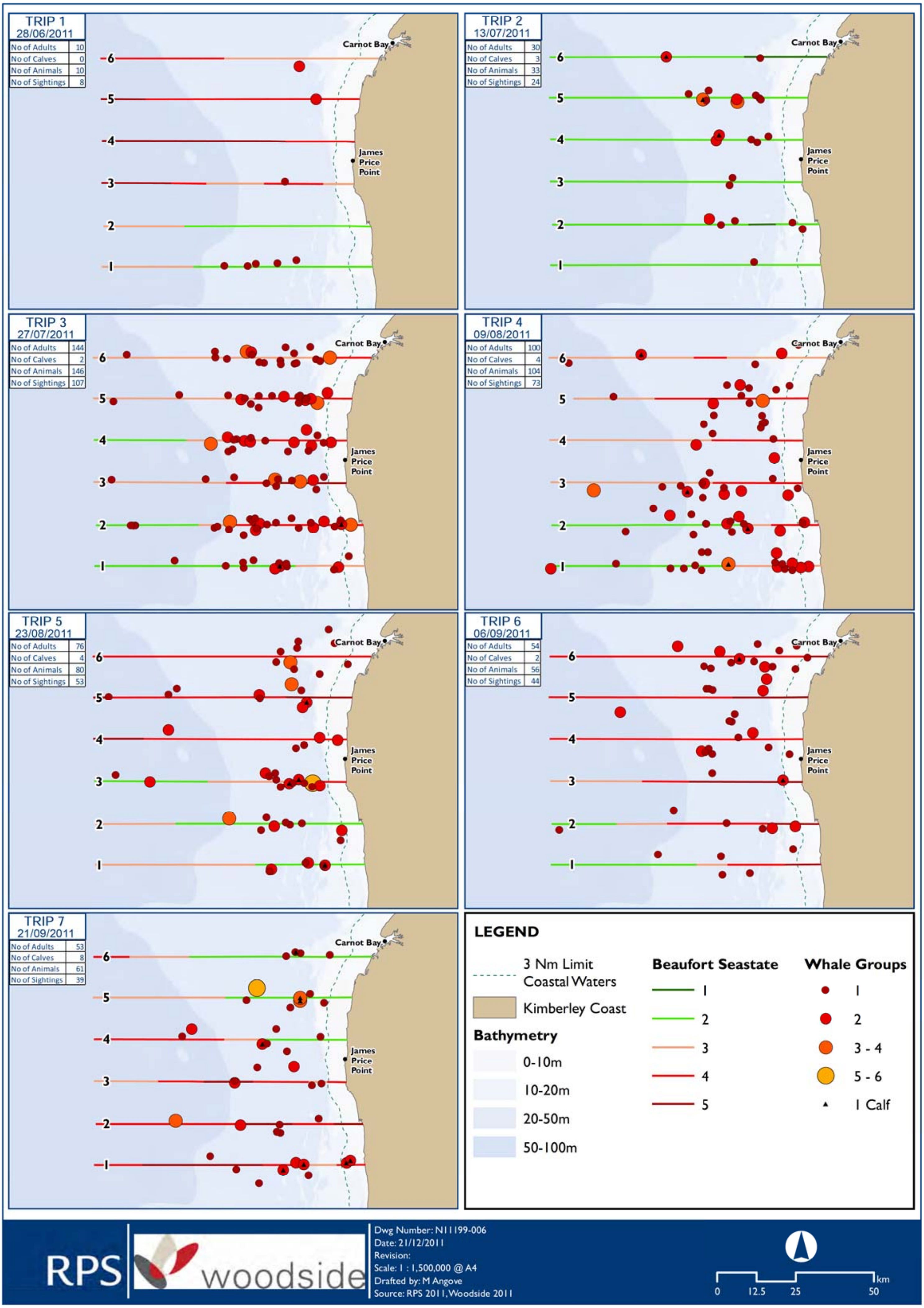


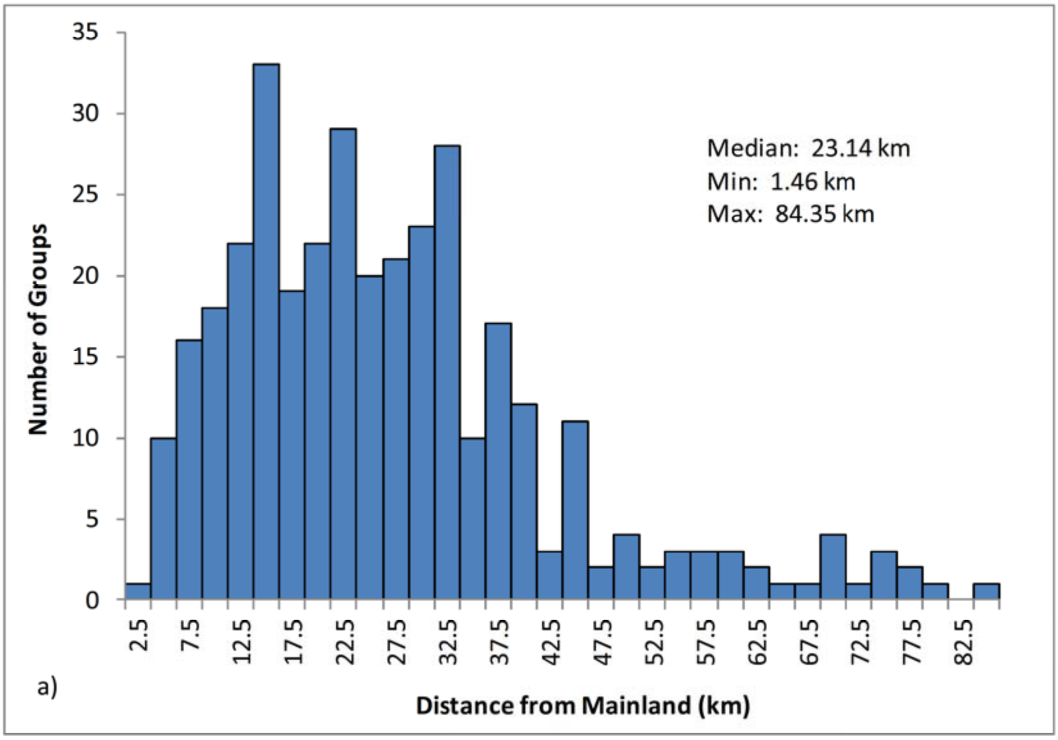
Figure 4: Total Number of Humpback and Unidentified Whales Recorded During the Migration Corridor Survey.

3.2.1.2 Broad Spatial Distribution – Distance from Land

Each group sighting from the Migration Corridor Survey was categorised based on their corresponding horizontal distance to land, with the distance estimates generated in *ArcGIS*. This information was then used to generate a distance from land for each individual whale. These frequency distributions are shown in Figure 5. The greatest concentrations of whales through the season were found between 10 and 32.5 km from shore and peaked at 15.5 km.

Whales were recorded in waters between 1.5 and 84.5 km from shore. In 2011, the number of whales increased out to approximately 18 km and markedly declined thereafter with increased distance from the coast, with only two whales having been recorded more than 80 km from shore. The median distance from land was 23.1 km (mean: 25.7 km) for groups, and 22.3 km (mean: 25.2 km) for individual whales. Eighty percent of individual whales (from 10th to 90th percentiles) were found to occur between 8.7 (95% CI: 6.7–10.5) and 44.6 (95% CI: 39.5–49.7) km from shore.

The distribution of humpback whale calves from the mainland generally followed a similar trend to the adults, where the majority of sightings were in waters closer to shore (Figure 6). The median distance from shore for calves was 21 km (mean: 21.8 km) and was approximately 2.1 km less than the median distance for adults. Only one calf was observed closer than 5 km from shore (4.4 km), and no calves were seen further than 55 km from shore.



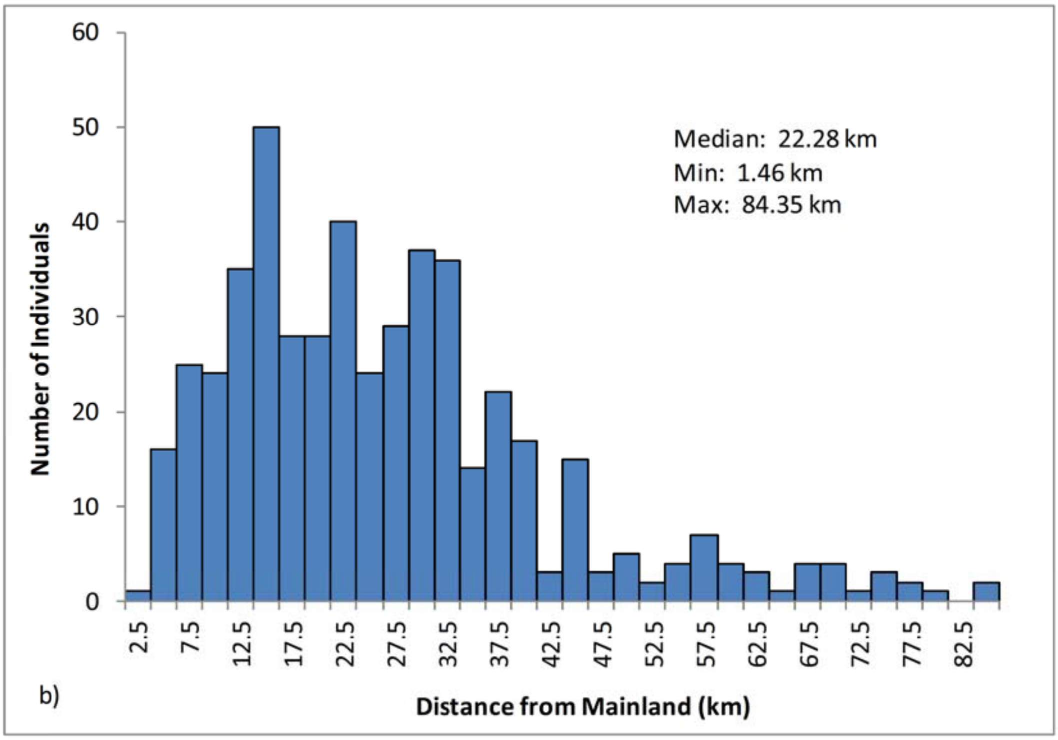


Figure 5: **Distances from Mainland for (a) Humpback Whale Group Sightings (n=348) and (b) Individual Humpback Whales (n=490) Obtained During the 2011 Migration Corridor Surveys**

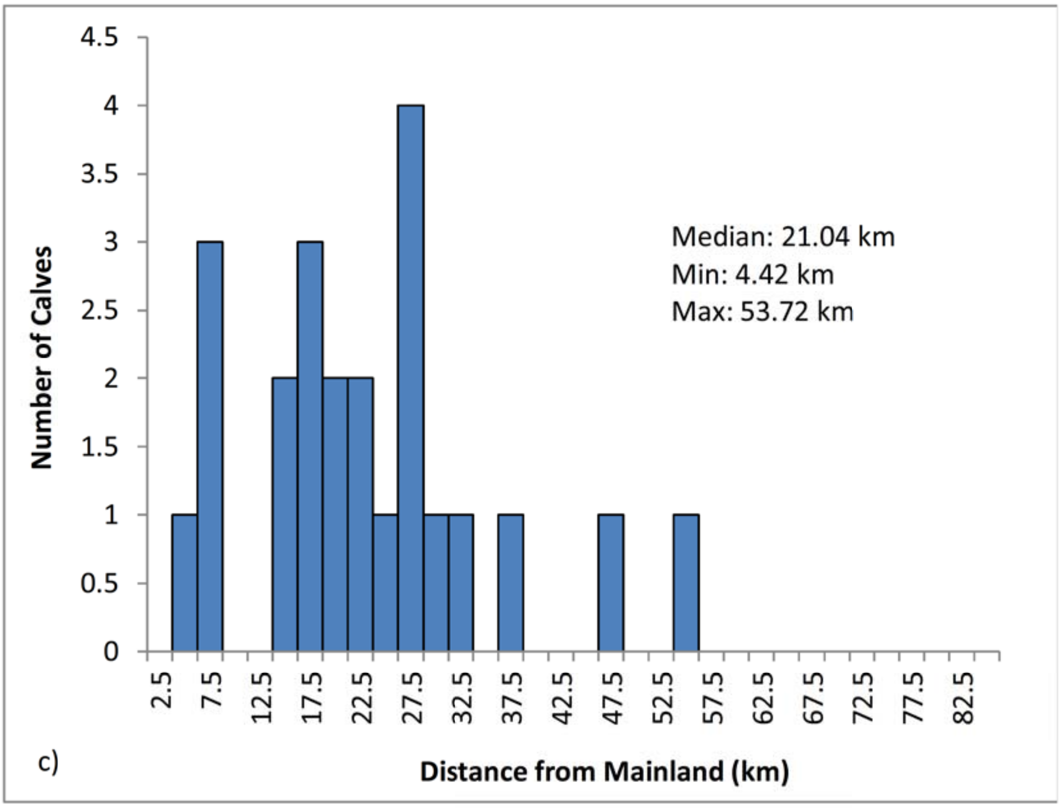


Figure 6: Distances from Mainland to Individual Humpback Calves (n=23) Obtained During the 2011 Migration Corridor Surveys

3.2.1.3 Broad Spatial Distribution – Individual Percentage Intervals

A map of the migration corridor off James Price Point was generated using the distance estimates for each individual whale recorded during the 2011 Migration Corridor Survey, pooled across flights (Figure 7). This figure illustrates the distances offshore for given percentages (5% and 10% bands) of all individual humpback whales.

The majority of individual whales recorded during the 2011 Survey were seen in water depths ranging between 10 and 50 m and 13 to 35 km from shore, indicated by the narrow darker bands in Figure 7. Beyond this range, the density of whales noticeably declined as the 5% distance bands become distinctly wider. Very few whales were observed within the 3 n mile state waters boundary.

Each percentage band was relatively consistent across all six transects. Note that Figure 7 was restricted to the geographical limits of the Migration Corridor Survey area, though the actual humpback whale migration corridor would obviously extend north and south beyond the boundary of this survey.

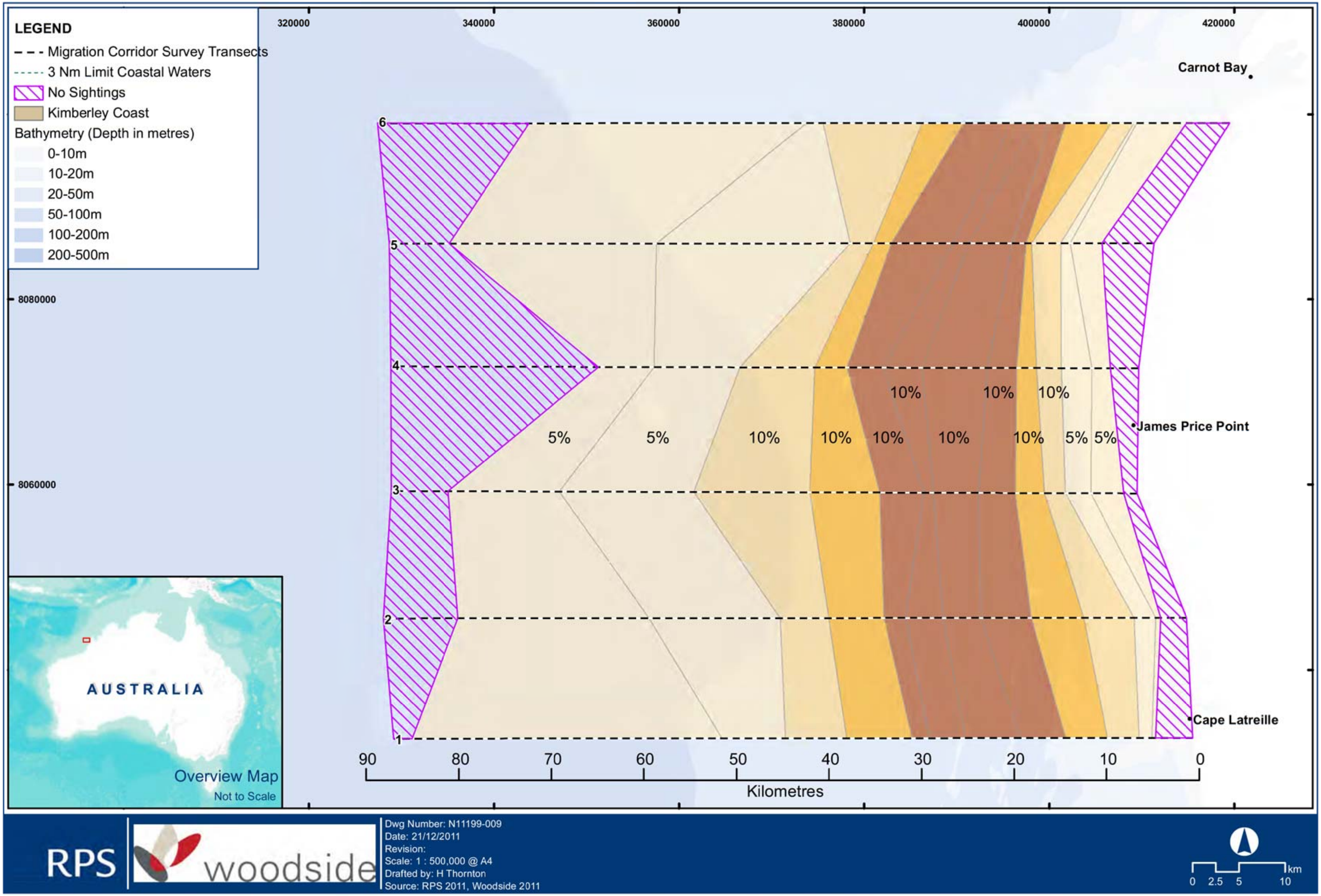


Figure 7: Percentage Group Banding of Individual Humpback Whales across the James Price Point Migration Corridor in 2011

3.2.2 Seasonal Pattern in Direction of Travel

During the Migration Corridor Survey 51% of all whale groups were assigned a direction of travel. The results show the majority of whale groups in the first three trips heading in a northerly direction, followed by a period of mixed directions over the next two trips and then a majority southward trend in the last two trips (Figure 8; Figure 9).

Until late July, most of the humpback whale sightings that were allocated a direction of travel were identified as heading in a northerly direction (north, north-west or north-east). The proportion recorded travelling north (N, NW or NE) in the early part of the survey period (first three trips) was substantially higher (74%) than the proportion of humpback whales that were identified as heading either south (S, SE or SW) (12%) or in other directions (E or W) (14%). This trend in directional pattern then started to reverse after the peak abundance of humpback whales was observed on 27 July, whereby southbound animals increased in proportion (38%) and northbound animal abundance decreased (37%). Over the last two trips, this directional trend continued, with a greater proportion of humpback whales identified as heading south (67%) compared to lower proportions identified as heading north (12%) or in other directions (21%) (Figure 9).

It should be noted that because a high proportion of the humpback whales sightings could not have a travel direction assigned (Figure 8), the specific dates of the peaks in travel direction, as well as the specific numbers involved, may not be precise.

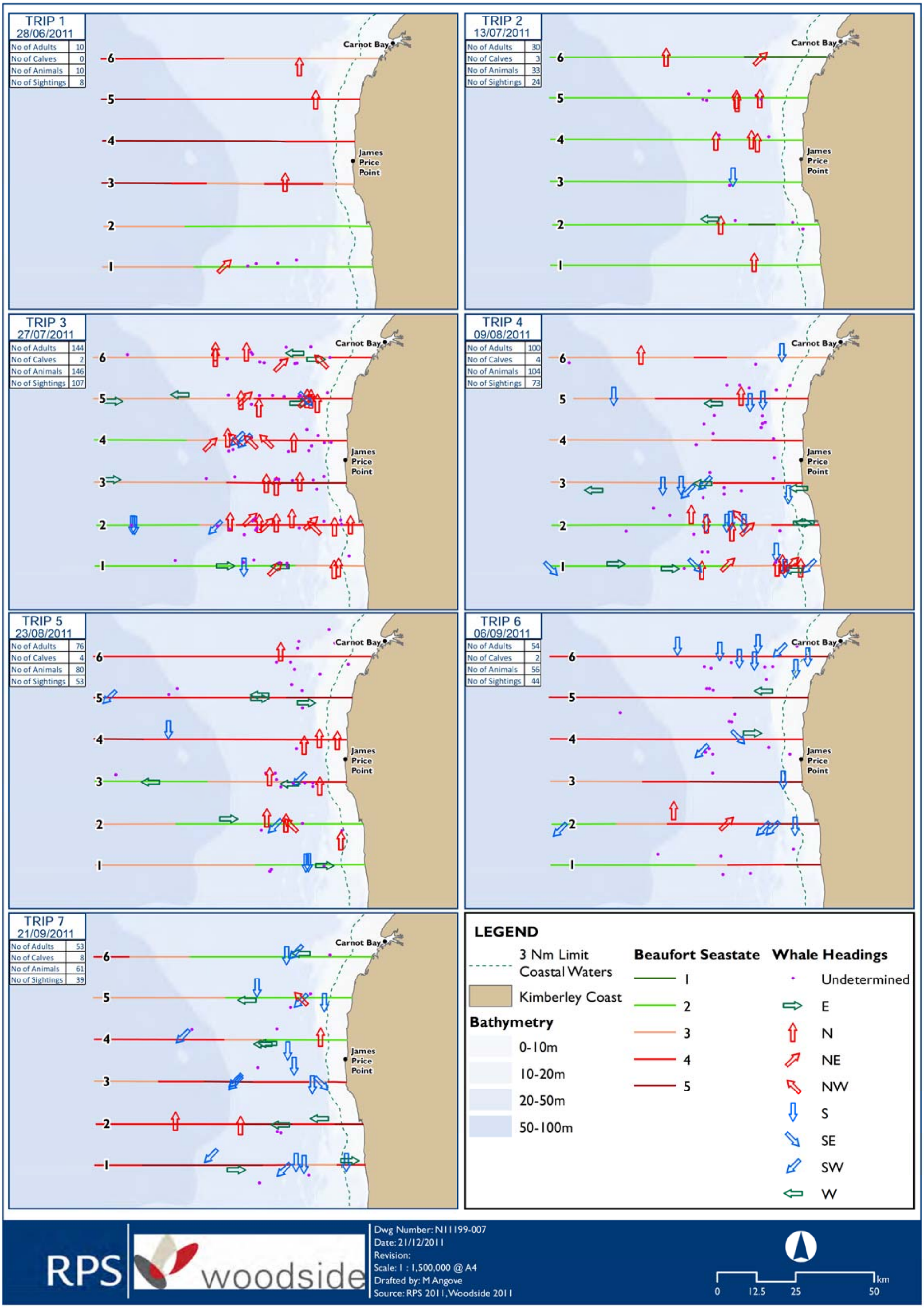


Figure 8: Headings of Humpback and Unidentified Whales Recorded During the Migration Corridor Survey.

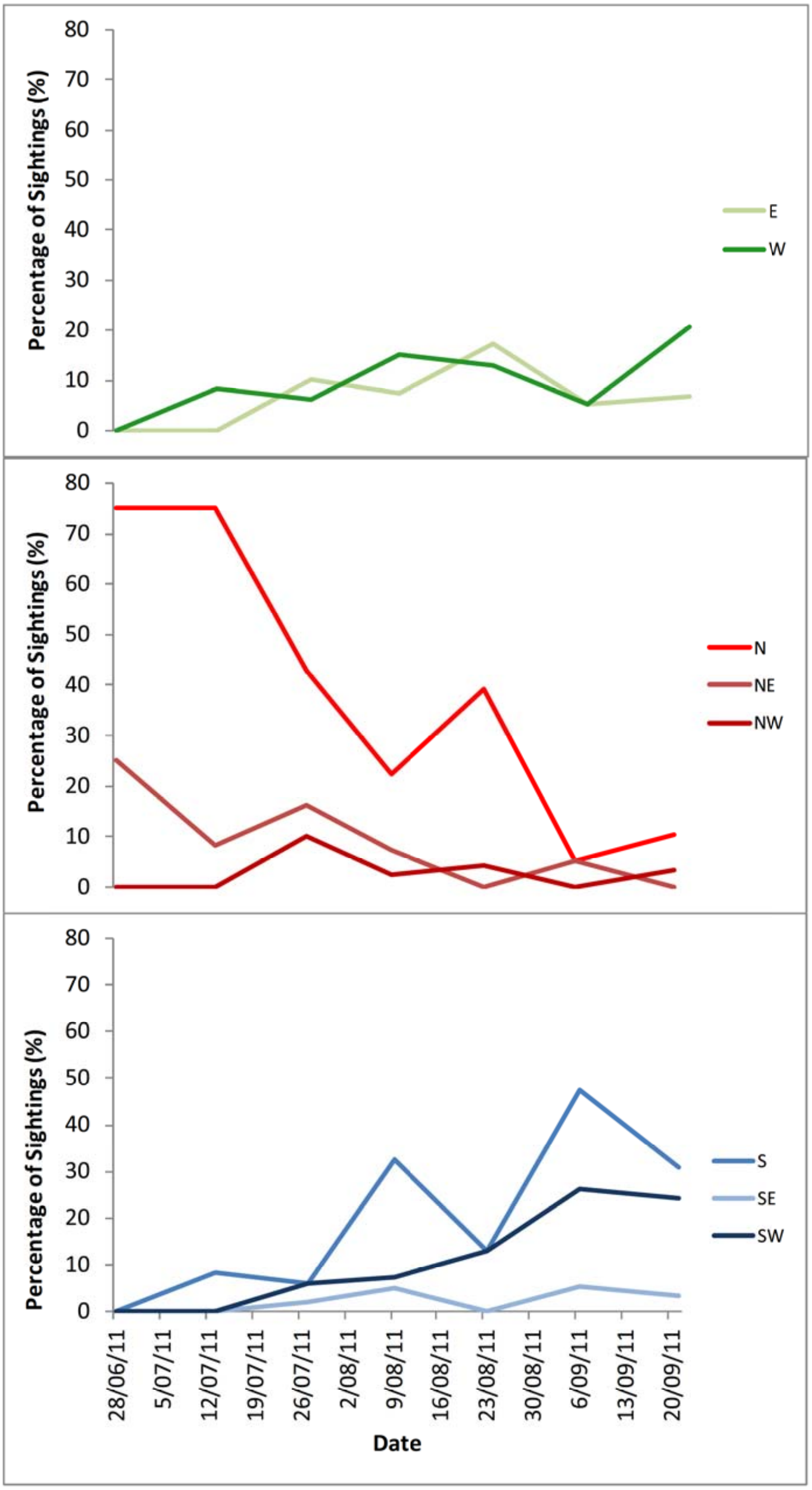


Figure 9: **Percentage of Sightings for each Travel Direction assigned to Humpback Whale Groups during the 2011 Migration Corridor Surveys. Note that the percentages are calculated only on whales that were assigned a direction of travel.**

3.2.3 Comparisons among Baseline Years

3.2.3.1 Abundance Comparisons among Baseline Years

Whale sightings for each year are summarised in Table 6. The average group size is very consistent through the entire period of survey with 1.5 in 2009 and 1.4 in 2010 and 2011.

Table 6: Comparisons between Whale Sightings during the 2009, 2010 and 2011 Migration Corridor Surveys

Year	No. of Trips	No. of Groups	No. of Individuals	No. of Calves	Peak Abundance	Peak Count: Adults (Calves)	Average Group Size
2009	8	372	568	44	18 August	143 (8)	1.5
2010	10	407	530	37	6 August	158 (9)	1.4
2011	7	348	490	23	27 July	144 (4)	1.4

The greatest number of whale groups and individuals recorded during any one flight was obtained during the 2010 survey (Table 6, Figure 10), although the difference was a relatively small 19 more animals recorded during the peak in sampling of 2010 compared to 2011. The timing of the sample with the greatest abundance of whales past James Price Point occurred earliest during the 2011 season, in the 27 July survey. This was 10 days earlier that the largest 2010 sample detected on 6 August and 21 days earlier than the largest 2009 sample on 18 August. It is possible that through sampling every two weeks the actual peak of whale abundance has not been sampled and the timing of the peak sampling abundance for each year should be interpreted cautiously as a reflection of the approximate timing of peak numbers of whales. Figure 10 illustrates the variability around the temporal rise and fall in humpback whale numbers through the season.

During the Peak period, between 15 July and 31 August, the mean count per transect per flight was 19.9 whales. There was no interaction of abundance for Year and Transect and no differences in counts were found among the six transects, nor variation among years (Table 7).

Table 7: ANOVA for Whale Abundance during the Peak Periods (2009-2011)

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Year	90.704	2	45.352	0.776	0.468
Transect	219.481	5	43.896	1.473	0.281
Year*Transect	297.963	10	29.796	0.51	0.872
Error	2,102.67	36	58.407		

By definition, counts were substantially lower during the Early and Late periods, with means per transect per flight of 3.6 and 6.4 whales for the Early and Late periods, respectively.

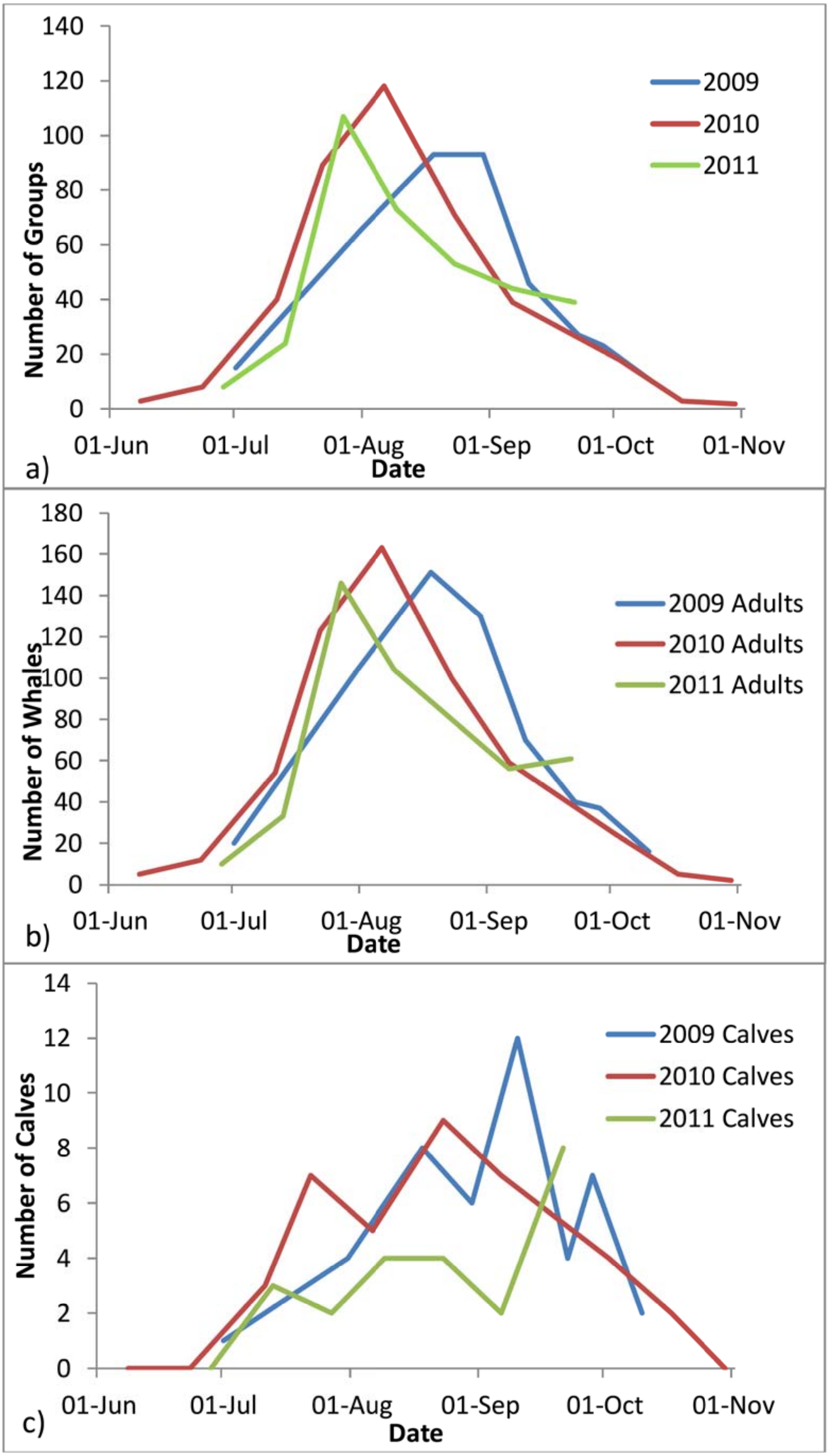


Figure 10: Number of a) Humpback Whale Groups, b) Adults and c) Calves recorded during the 2009, 2010 and 2011 Migration Corridor Surveys

3.2.3.2 Comparison in Heading Direction among Baseline Years

Whale heading data from 2009–2011 are plotted in Figure 11. These three plots demonstrate a trend through each season showing that the whales head predominantly north in the early period, are quite mixed during the middle and mostly head south during the late period. There is a lot of variability in heading through the season but a strong convergence occurs between the proportion of whales heading north and those heading south through August and early September. The convergence between north and south bound animals in 2010 and 2011 occurs at approximately the same time around the middle of August. The later convergence in 2009 around mid-September is likely to be a reflection of the later arrival and departure of whales in this season as indicated in Figure 10. This is a trend that is clearly expected on part of a north-south migration route.

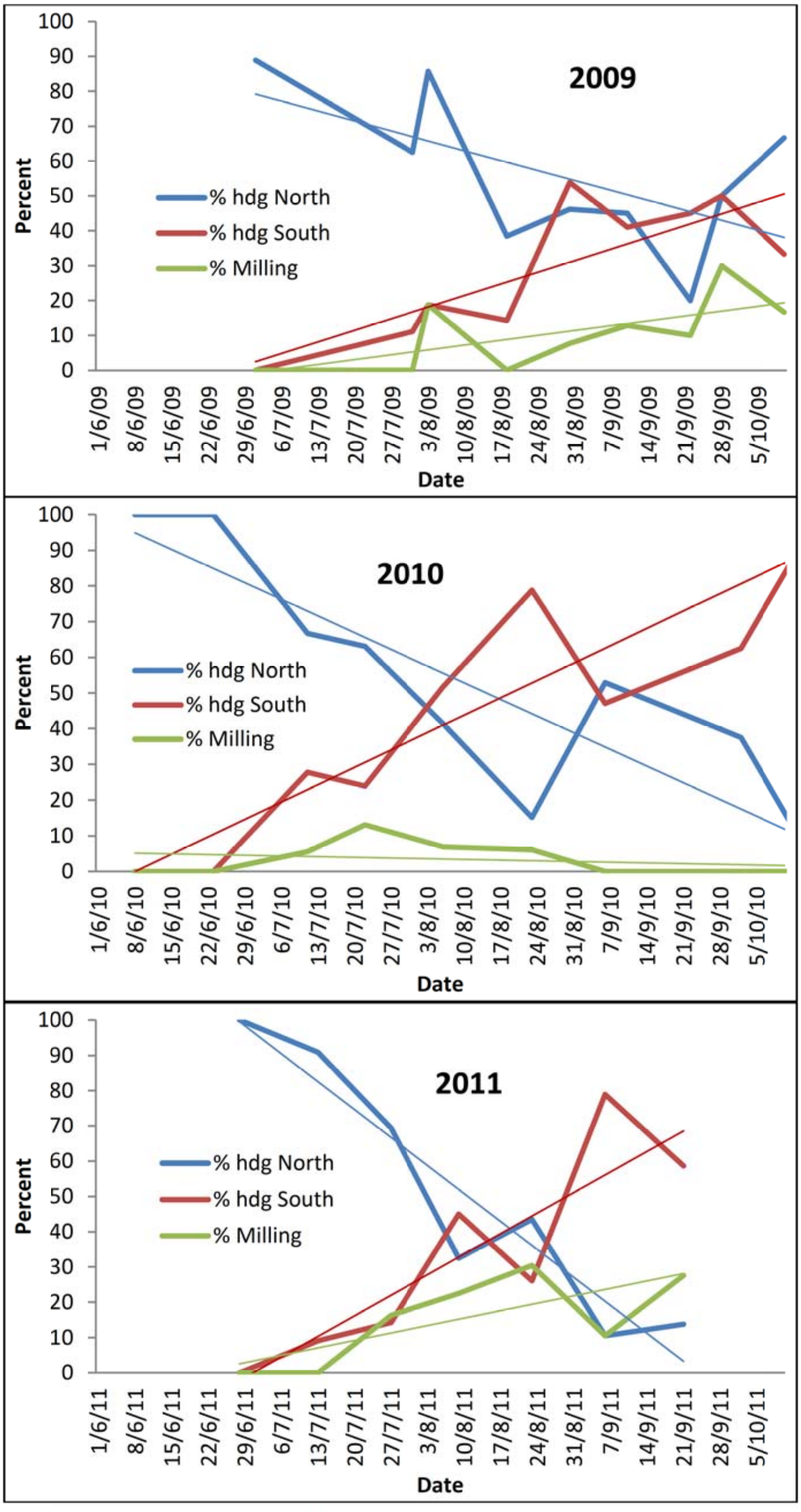


Figure 11: Percentage of Humpback Whale Headings from 2009, 2010 and 2011 Migration Corridor Surveys. Note dates along y-axis have been aligned

3.2.3.3 Comparisons in Distance from Shore among Baseline Years

After pooling flights from each year, the distances from shore between which the whales were observed were consistent among the three baseline years (Figure 12). The spread of data along each transect were similar from north to south and all three years of data showed a skewed distribution with higher densities being located towards the coast. Beyond approximately 45 km the density of whales declined markedly towards the outer limits of the survey area.

In 2011 80% of whales were recorded between 8.7 and 44.6 km from shore. In 2010, 80% of whales were recorded between 7.3 and 43.7 km from shore and in 2009, 80% of whales were recorded between 9.8 and 47.5 km from shore. When all three years of data were combined, the 10th percentile was 8.5 km (95% CI: 7.6–9.4 km) and the 90th percentile was 45.9 km (95% CI: 42.3–49.4 km). Therefore, it can be concluded that in any one year it is 95% likely that 80% of whales can be expected to occur between 7.6 and 49.4 km from land.

In the analysis of the average distance offshore, the initial ANCOVA failed to detect an interaction between Year and Day of Year ($F_{2,124} = 1.699$, $p = 0.187$). This result permitted analysis to be re-run without the interaction of Year and Day. The final results are presented in Table 8 and Figure 13, and these show there is a significant positive relationship between Day of Year and distance from shore ($p = 0.011$). It also shows that there is no difference in this relationship between years ($p = 0.211$), and therefore, the occurrence of whales slightly further offshore as the season progresses appears to be a reliable behavioural trait.

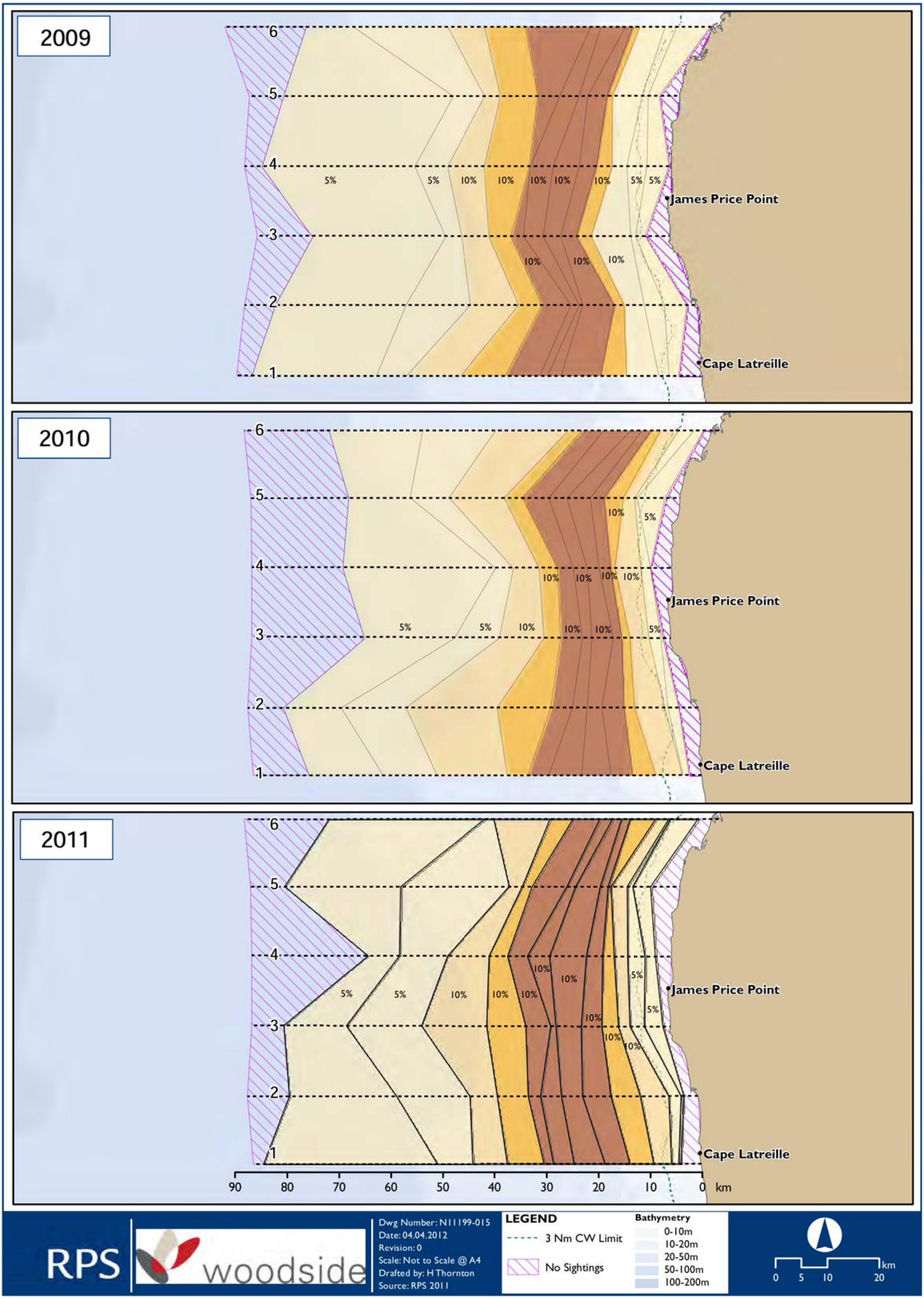


Figure 12: Percentage Group Banding of Individual Humpback Whales across the James Price Point Migration Corridor 2009-2011

Table 8: ANCOVA for Log-transformed Average Distance of Individuals from Shore (m) with Day of Year, across All Flights during 2009–2011

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Year	0.445	2	0.223	1.576	0.211
Day_of_year	0.94	1	0.94	6.652	0.011
Error	17.802	126	0.141		

When the results shown in Figure 13 are back-transformed from the logarithm, the average distance of whales offshore is predicted to be 18.4 km for 1 July increasing to 24.2 km offshore by 1 October.

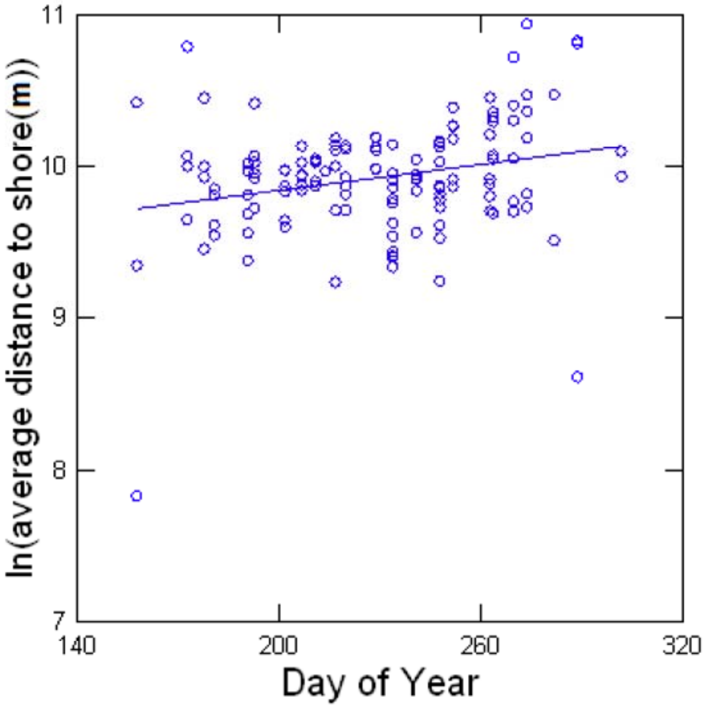


Figure 13: Average Distances of Individual Humpback Whales from Shore per Transect, across all Flights during 2009-2011. The Slope of the Regression Line for the Pooled Years is 0.003 ln(m) per Day (regression constant = 9.27 ln(m))

Similarly, the interactions between Year and Day of Year on distance from shore were not significant when either the 10th or 90th percentiles of distances offshore were used as the dependent variable in the ANCOVA ($F_{2,117} = 2.84$, $p = 0.062$, $F_{2,117} = 0.123$, $p = 0.885$, respectively). Because of this, the ANCOVA could be re-run without the interaction between Year and Day, This test found that the 90th percentile offshore increased significantly as the season progressed (Table 9) but this was not the case for the 10th percentile offshore (Table 10). Years were not significant in either analysis. For the 90th percentile offshore, the relationship between the Day of Year and distance offshore (log transformed) of the 90th Percentile was positive (Figure 14). When the results are back-transformed, the regression equation (see caption for Figure 14) predicts a 90th percentile distance offshore of 30.9 km on 1 July, increasing to 48.8 km by 1 October.

Table 9: ANCOVA for 10th percentile along transects of log-transformed distance of individuals from shore (m) with Day of Year, across all flights during 2009-2011

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Year	0.206	2	0.103	0.317	0.729
Day_of_year	0.276	1	0.276	0.849	0.359
Error	38.685	119	0.325		

Table 10: ANCOVA for 90th percentile along transects of log-transformed distance of individuals from shore (m) with Day of Year, across all flights during 2009–2011

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Year	0.672	2	0.336	1.491	0.229
Day_of_year	2.382	1	2.383	10.568	0.001
Error	26.827	119	0.225		

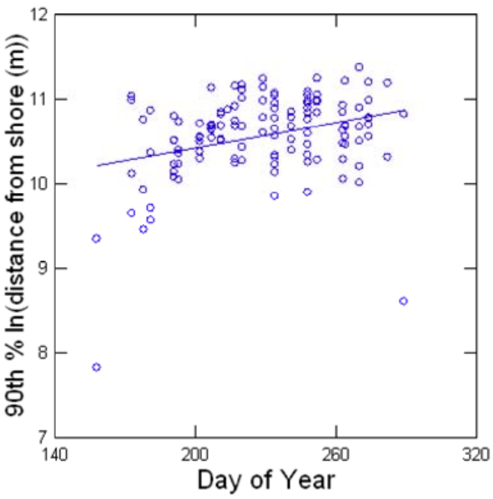


Figure 14: Ninetieth Percentiles of Log-transformed Distance of Individuals from Shore Per Transect (m), across all Flights during 2009–2011. The Regression Equation is 0.005 ln(m) Per Day (regression constant = 9.422 ln(m))

While the ANCOVA did not detect an overall significant effect of Day of Year for the 10th percentile offshore, the initial ANCOVA including the interaction term was nearly significant between Year and Day of Year ($p = 0.067$) and so a decision was made to subsequently test each year separately for co-variation, regardless. Regressions were significant for 2009 ($F_{1,39} = 6.534$, $p = 0.015$) but not 2010 ($F_{1,42} = 0.458$, $p = 0.502$) or 2011($F_{1,36} = 2.763$, $p = 0105$). The slope of the regression line for 2009 was 0.006 ln(m) per day (regression constant = 7.806 ln(m). When back-transformed, a 10th percentile distance of 7.4 km offshore was predicted on 1 July, increasing to 12.8 km offshore by 1 October. When the average 10th percentile distances for 2010 and 2011 were back-transformed predictions of 9.3 km and 9.4 km offshore were given, respectively.

This indicates there is an overall shift in whale distribution further offshore through the season. The differences close to the shore are small but they increase with increasing distance offshore.

3.2.3.4 Comparison of Distance from Shore between Cow–Calf Groups and Non-calf Associated Groups

ANCOVA found a significant interaction between the main factor (Presence of calves in group) and the covariate (Day of Year) (Table 11), suggesting a difference in how average distance offshore varies across the season between groups of whales with and without calves present. When each group was regressed separately against Day of Year, a significant relationship was found for groups of whales not associated with calves ($F_{1,121}$ = 12.060, p = 0.001), with a regression slope of 0.004 ln(m) per day and regression constant = 9.055 ln(m). Back-transformed, this predicts an average distance of 17.8 km offshore on 1 July, increasing to 25.7 km offshore by 1 October. No relationship was detected for groups of whales with calves ($F_{1,66}$ = 0.706, p = 0.404). At least qualitatively, however, the variance in distance offshore appeared much greater across the season for groups of whales with calves than for groups not associated with calves (Figure 15).

Table 11: ANCOVA for log-transformed average distance from shore (m) for groups of humpback whales with and without calves

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
Presence_of_calves	1.270	1	1.270	5.016	0.026
Day_of_year	0.063	1	0.063	0.249	0.618
Presence_of_calves * day_of_year	1.393	1	1.393	5.504	0.020
Error	47.338	187	0.253		

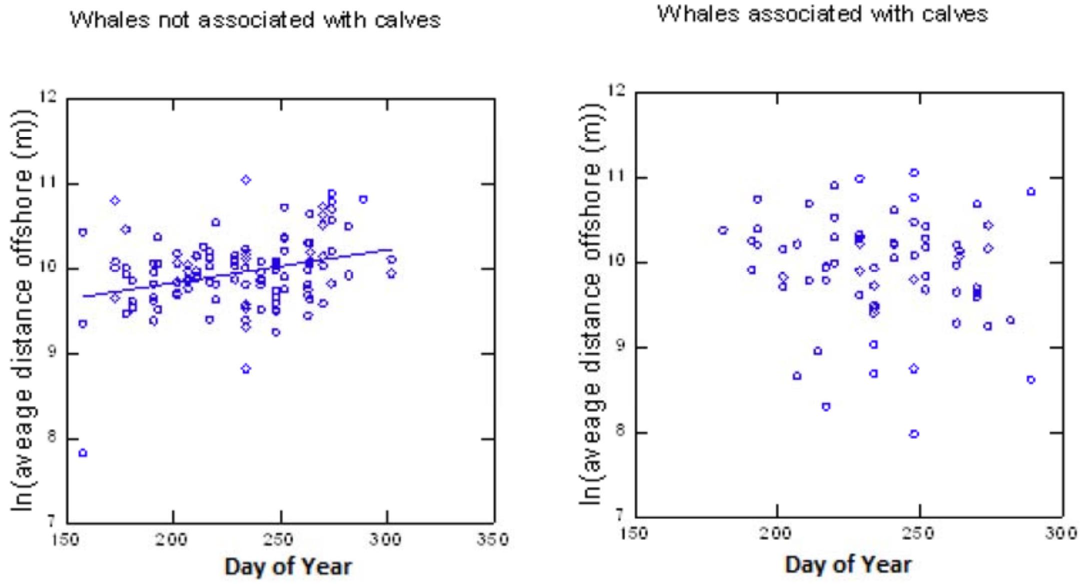


Figure 15: Average Distances of Humpback Whale Groups from Shore Per Transect, across all Flights during 2009-2011 for Groups of Humpback Whales without and with Calves

4.0 DISCUSSION

The 2011 James Price Point Migration Corridor surveys provide the third year of baseline information on humpback whale distribution, abundance and movements past the proposed Browse LNG Precinct.

Weather and sea conditions during the surveys were generally conducive to sampling humpback whales and calves, with mostly BSS ≤ 4. Humpback whales were usually readily distinguished from other large whale species, and sighting identifications were typically confirmed to the species level with a high level of confidence. The surveys for the 2011 season were targeted on the time period when 80% of whales were present in the previous two years. As expected therefore, whales were recorded during each of the seven trips, from 28 June until 21 September.

There were no other large whale species recorded during the 2011 surveys and therefore it was considered reasonable to assume that sightings of large whales recorded as "unidentified species" were humpback whales for analytical purposes based on the prevalence of this species in the recorded sightings. This is additionally supported from the findings of the 2009 and 2010 surveys (RPS 2010 and 2011).

The following discussion presents a summary of the key information and conclusions found for humpback whales through 2009, 2010 and 2011.

4.1 Estimates of Humpback Whale Abundance

During the 2011 survey period, the highest sample abundance of humpback whales occurred on 27 July when 146 whales were recorded. This peak was approximately 10 days earlier than the sampling peak recorded in 2010 (6 August) and 21 days earlier than the 2009 sampling peak (18 August). The differences in timing of the migration peak were consistent with previous research suggesting the peak abundance of the migratory group can vary by up to three weeks from year to year (Chittleborough 1965; Jenner et al. 2001). The timing of the migration peak has been attributed to annual variation in the availability of food in the Antarctic (Chittleborough 1965).

Population estimates of 11,364 (95% CI: 2,721–31,567) and 9,256 (95% CI: 2,088–25,634) individual whales were estimated to pass along the west coast of the Dampier Peninsula on their way north in 2009 and 2010 respectively (RPS 2010, 2011). In comparison, Hedley et al (2011) estimated that 28,830 (95% CI: 23,710-40,100) individuals passed the North West Cape in 2008 on their way north. Because of the relatively wide confidence intervals around population estimates, little can be surmised about what proportion of the west coast (Group IV) humpback whale population passes along the west coast of the Kimberley. Double et al (2012) identified that many of the Group IV humpback whales seem not to travel the whole length of the migration pathway to the Kimberley but instead stop further south before returning to the

Antarctic. During a separate field trip off Onslow in the Pilbara region in early August, RPS staff reported seeing a humpback mother with a very young calf still showing foetal folds (Leanne Smith pers. comm.). It is considered unlikely that this cow–calf pair would have continued all the way to the Kimberley. These observations provide support for only a portion of the Group IV population reaching the Kimberley, although it is unknown what portion this may be. A population estimate was not calculated in 2011 because the confidence intervals were shown to be so wide and therefore a population estimate of little use as a parameter for future monitoring.

At least within the peak period of whale abundance across all years (i.e. between15 July to 31 August, which in all three years encompassed the three flights with the greatest abundances), no variation in average abundance among years was detected.

Calves were first recorded on 13 July during the 2011 surveys. This was similar timing to the first calf sighting in 2010 on 11 July, but slightly later than the first calf sighting in 2009 on 1 July. However, they may also have occurred in the period between flights and so these dates do not necessarily reflect the actual arrival of calves. The peak in calf sightings during the 2011 season was during the last trip on 21 September. No drop off in calf numbers was seen as per the previous two seasons, most likely due to the 2011 surveys finishing before the previous years. Jenner et al. (2001) reported that peak numbers of cow–calf pairs were observed around mid-September during surveys conducted from 1995 to 1997 in the Kimberley region. It must be remembered that calves are more difficult to spot than adults and can be obscured from sight by the mother or by weather conditions.

Abundance of whales at Scott Reef in 2009 and 2010 was relatively low throughout the season. Although effort around Scott Reef was lower than on the Migration Corridor Survey, with only three flights in 2009 and ten in 2010, the relative abundance (animals per kilometre sampled) was always much lower than near the mainland. Similarly calves were relatively infrequent with only two in each year. Sampling peak abundance broadly coincided with that off the coast of the mainland.

4.2 Distribution of Humpback Whales

In the 2011 surveys 80% of whales whales ranged between 9–45 km from the mainland. Over the three year baseline study, 80% of whales were recorded between 8.5 and 45.9 km from the mainland in the Migration Corridor survey area. Statistical analysis also indicate that whales were not spread across the same area throughout the migration period. Instead, whales were found progressively further offshore as the season progressed. This effect was consistent across the three years of sampling and detectable despite apparent differences in the overall timing of migration among years. While seasonal displacement offshore was not detected in all three years for the 10th percentile offshore, it was detected in at least one year (2009). All this is consistent with observations from Jenner et al (2001) that whales generally migrate further from shore

on the return journey southwards, later in the season, than they do on the northwards migration earlier in the season. Satellite tagging studies by Double et al (2010 and 2012) also show several of the tagged whales moved further offshore during their southward journey on leaving the area around the Lacepede Islands.

The difference, however, does not appear to be great off the west coast of the Kimberley. The difference between the average distance offshore between the start and the end of the migration period was less than 6 km. This information may prove to be relevant in devising management measures and for refining analysis during any monitoring program. Without including this level of detail in monitoring studies, the power to detect change is likely to be reduced.

Patterns for cow-calve pairs, however, appear to be different from the overall seasonal patterns of all whale individuals in that they did not appear to displace further offshore as the season progressed. Groups containing calves were seen in waters relatively closer to shore across the season than groups without calves, with the median distance from shore for calves being 21 km in 2011 (similar to medians in previous years). A small number of whales also travel further offshore, as indicated by data collected along extended transects in the 2010 surveys and previous studies (Jenner et al. 2001; Double et al. 2010), but only those observed in the Migration Corridor Survey area were assessed here. Qualitatively, the variation in the average distance offshore of whales associated with calves also appeared to be greater than for whales without calves; although this may simply reflect a lower precision for estimates of mean distance offshore per transect, as far fewer whales with calves were observed than whales without calves.

The results from the 2011 survey thus suggest that while non-calf associated whales may deviate offshore on their return southward, cow-calve pairs do not. Double et al. (2010) found the that females with young calves tend to stay close to shore between Camden Sound and Exmouth Gulf, possibly in order to reduce the risk of attack by predators. However, the satellite data from this study also showed that there was greater variation in this distance past the James Price Point area than around Camden Sound and Eighty Mile Beach (Figure 9 in Double et al. 2010). Of the eight tracked cow-calf pairs, six travelled west from the Lacepede Islands into deep water before heading south back towards the coast near Eighty Mile Beach. Two of the eight tracked pairs entered the Migration Corridor Survey area and only one travelled within 25 km of the coast. Those findings, which suggest there may be an alternate migration pathway further offshore, were investigated during the RPS 2010 survey by incorporating two extended transects (out to 180 km). However, it was found that only a small number of whales were present along these extended transects and no calves were seen. The highest numbers on the extended transects coincided with the general peak in whales for the region, rather than the second half of the migration season when most humpback whales were presumed to be heading south. Thus, the 2010 surveys found no evidence to support the presence of an alternate migration pathway up to 180 km offshore of James Price Point.

4.3 Migration Timing

The pattern in travel directions observed during the 2011 surveys correspond to the expected trend of the migration path of humpback whale group IV, with the majority of whale groups heading in a northerly direction up until late July, a period of mixed directions throughout August and then a majority southward trend in September. Jenner et al. (2001) also reported the northern migration peak in the Kimberley region was during the last week of July and the peak of the southern migration is in the first half of September. Additionally, based on historical whaling catch records, humpback whales were documented to travel along the Dampier Peninsula to Broome until the end of July (Chittleborough 1965). The timings in the peaks of the northern and southern migrations of humpback whales past James Price Point was also similar for the 2009 and 2010 surveys (RPS 2010; RPS 2011).

As discussed in Section 4.1, the overall peak sampling abundance in whales past James Price Point varied by up to 21 days with it being earliest in 2011, followed by 2010 then 2009. Kellogg (1929) and Dawbin (1997) found that there was some degree of sex and age-class segregation during the migration timing. Generally, cows with yearlings head north before the sexually immature animals and then sexually active male and females followed by pregnant females. On the return journey south the reverse was seen to be the case where females and calves would be the last to leave the northern waters.

In 2011 slightly more than half of all records (51%) were assigned a direction of travel. Vessel-based focal follows in 2009 and the tagging studies conducted by Double et al (2010 and 2012) found direction of travel could be variable indicating that the whales meander extensively. Despite this, the patterns in heading direction change reliably through each year of sampling with the exception of those found heading directly east or directly west. Whales are found to point predominantly north in the early part of the season and south in the latter part of the season. The point at which the change occurs varies between years.

The variability in heading direction (north, south and milling) is too pronounced to be able to clearly identify distinct periods in any given year. This relative confusion in the whale headings is most likely to be a natural artefact of the humpback whale activity in this area; a vessel focal follow survey conducted in 2009 found that many whales meander along the coast rather than travel straight up or down as may be expected elsewhere along the migration route. Tidal currents are also very strong along this coast and probably affect the direction in which whales are travelling as opposed heading. However, there is a distinct pattern in northward and southward percentages of whales as shown by the linear trendlines added to the three categories in Figure 11. The points at which the north and southbound trendlines cross coincide at approximately the same point in time in 2010 and 2011 but occurred more than a month later in 2009. This later crossover of north/south bound whales in 2009 was probably due to the later peak in abundance witnessed in that year compared to the two earlier peaks in 2010 and 2011.

5.0 CONCLUSIONS

An extensive survey program has been conducted in 2009, 2010 and 2011 off the west coast of the Dampier Peninsula to describe the spatial and temporal distribution of humpback whales. In 2009 a wide suite of aerial and vessel surveys were conducted to establish the spatial temporal characteristics and behaviours of humpback whales. Data acquired from vessel surveys were found to be highly variable and of little use in ongoing monitoring. Therefore in 2010 only aerial surveys were conducted to quantify the variability of the spatial temporal characteristics between years. Findings from the first two years of aerial survey campaigns were then used to focus survey effort on the more reliable variables within the humpback whale activities in 2011.

The resultant set of data and supporting analytical findings will be of great value in impact assessment and will help inform any monitoring programs that may be required as part of the environmental approvals for the Browse LNG Precinct development.

Findings from the three years of baseline data collection for humpback whales off the western coast of the Dampier Peninsula are as follows:

- Humpback whales are present from early June to late October–early November.
- Whale abundance rises to a peak between late July and mid-August.
- The population estimate for northbound whales was 11,364 (95% CI: 2,721-31,567) in 2009 and 9,256 (95% CI: 2,088-25,634) in 2010.
- The data from all three years of the MMFS indicate that 80% of whales will occur between 5 July and 16 September in any given year.
- Based on three years of data, 80% of whales will occur between 7.6 and 49.4 km from the shore.
- Distance from shore for groups without calves increases by a significant but small range as the season progresses.
- Groups with calves were recorded slightly closer to shore than groups without calves but not to a significant level.
- Most whales were seen to be heading north until the end of July/early August followed by a period of equal direction and then most were seen heading south during September and October.

Summary and key findings from the 2011 Migration Corridor Survey and from all baseline surveys are presented in Table 12.

Table 12: Summary data from the James Price Point Migration Corridor Surveys from 2009, 2010 and 2011. LCI refers to the Lower Confidence Interval and UCI Upper Confidence Interval

	2009	2010	2011	Pooled
Survey Period	1 Jul–10 Oct	8 Jun–30 Oct	28 Jun–21 Sep	NA
Number of Flights	8	10	7	25
Total survey effort for transects 1-6	19.06 hr	22.28 hr	16.25 hr	47.6 hr
Total length of transects 1-6 (Average length sampled per flight) (km)	4,095	5,067	3,533	12,685
Period of peak sampling	31 Jul–30 Aug	22 Jul–23 Aug	27 Jul–23 Aug	NA
Peak sample number of adults	143	158	144	148
No. of adults from three peak samples	376	365	320	354
Peak sample number of calves	8*	9	4	7
No. of calves from three peak samples	18	21	10	16
Median Group size (mean and range):	1 (Mean: 1.5, Range: 1-6)	1 (Mean: 1.4, Range: 1-7)	1 (Mean: 1.4, range: 1-6)	1 (1.43)
Period in which 80% of individuals sampled occur off the Dampier Peninsula and 95% CI's	16 Jul-17 Sep (LCI: 8 Jul UCI: 22 Sep)	4 Jul-4 Sep (LCI: 29 Jun UCI: 9 Sep)	N/A‡	10 Jul-11 Sep (LCI: 5 Jul, UCI: 16 Sep)
Sampling peak in adults	mid August	early August	late Jul	Early August
Sampling peak in calves	early Sept	late August	mid Sept	Early Sept
Approximate point of north/south crossover in heading direction	Late Sep	Mid Aug	Mid Aug	Late Aug
HW adult median distance offshore (individuals) (km)	23.4	23.1	22.3	22.9
HW calf median distance offshore (km)	22.4	20.3	21	21.5
HW range offshore of 80% individuals sampled (km) and 95% CI's	9.8–47.5 (95% LCI: 8.9-10.7, UCI: 41.2-53.7)	7.3–43.7 (95% LCI:5.7-8.8, UCI: 35.9-51.5)	8.7–44.6 (95% LCI: 6.7–10.5, UCI: 39.5-49.7)	8.5-45.9 (95% LCI: 7.6–9.4, UCI: 42.3–49.4)
Closest distance to shore–adult (km)	0.2	1.15	1.46	0.2
Closest distance to shore–calves (km)	6.7	1.5	4.4	1.5
Estimate of HBW travelling north through Migration Corridor and 95% CI's	11,364 (95% CI: 2,721-31,567)	9,256 (95% CI: 2,088-25,634)	n/a	n/a

*: highest number of calves was recorded outside the period in which three peak whale samples occurred.
‡: Survey in 2011 was conducted in the peak abundance period as calculated from first two year's data.
¥: Last three flights were conducted at 130 knots rather than 110 knots, hence shorter flight time.

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