Monitoring of humpback whales in the Pender Bay, Kimberley region, Western Australia

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Manuscript received December 2010; accepted April 2011

Abstract

Information and learnings from two years of independent and shore-based humpback whale (*Megaptera novaeangliae*) surveys in the remote Kimberley region are presented. Systematic shore-based surveys were undertaken in 2009 and 2010 from the cliff top on the southern part of Pender Bay, Dampier Peninsula, Kimberley region, WA from the Two Moons Whale and Marine Research Base. The humpback whales use Pender Bay for a variety of purposes including calving, breeding, feeding (inferred), resting and staging. The results show the peak of the whale season to be in August with a relatively sharp increase in whale numbers occurring from mid July through to early August with whale numbers slowly decreasing from the end of August through to mid November. The whale numbers were higher in 2009 than 2010 and a range of environmental and meteorological variables have been compared to elucidate any trends. Mothers and calves predominated in the bay in September and October when the relative proportion of calves increased, indicating that Pender Bay was being used as a resting, feeding, calving and staging area. The ongoing challenge of monitoring humpback whales in this isolated part of the Kimberley is to manage the interplay between the availability of whale observers, an isolated location along the Kimberley coast and the amount of logistic support required to keep a field team in operation for the duration of the season which stretches from early June to mid November. We have therefore developed a pragmatic sampling technique, maximising the observer effort based on an average four person team on the cliff top operating five hours per day.

Keywords: humpback whale, seasonal variability, sea surface temperature, meteorological variables, whale behaviours, observer methodology

Introduction

Humpback whales (*Megaptera novaeangliae*) have long been known to migrate along the WA coast (Hedley *at al.* 2009); however, it has only recently become apparent, the comparatively large size of the population and the importance of the Kimberley region for this west coast Group IV population of humpback whales (Jenner *at al.* 2001). Pender Bay was previously known as a humpback whale staging area for the southerly migration commencing approximately mid-September, however the information recently presented by McKay & Thiele (2008), Double *at al.* (2010) and this study, further suggest that the area is significant as a calving, feeding (inferred by us), breeding and resting area as well as a major staging area for the southern migration which commences in mid-late September.

The challenge of visual fixed point monitoring of marine mega fauna in such a remote location requires a permanent observation point to be manned on an ongoing basis with humpback whales arriving early June and departing mid November from this locality each year. A lack of long term quantitative baseline studies for humpback whales in this region necessitates the need to establish such a monitoring program with some urgency based on the likely impacts of: (1) climate change and in particular rising water temperatures and changed primary productivity effects; (2) increased human usage of this coastline; and (3) the natural recovery of the population post the ban on commercial whaling.

A simple fixed point survey technique has been developed which can be implemented through mainly volunteer observers to ensure a rapid census approach to quantifying the relative numbers of whales in the bay each year. The purpose of this paper is to draw attention to this semi-quantitative study, the methodologies being used and the large numbers of humpback whales utilising this part of the Kimberley coast. It is suggested that this type of study should form the basis, along with other recent surveys of humpback whales in the region using aerial, boat and underwater acoustics of an integrated long-term baseline monitoring of relative whale numbers and behaviours based on inter-annual and major climatic events such as ENSO and the Indian Ocean Dipole.

Aims

a) To monitor the relative abundance of the Group IV population of humpback whales in the Pender Bay region of the Kimberley, WA, as part of the annual south-north-south migration along the coast.

b) To characterise the different whale behaviours and usage of the Bay for activities such as resting, breeding, calving, staging, feeding*etc.*

c) To develop a survey method for isolated regions which, as a result, have a heavy reliance on a largely volunteer observing effort.

Methods

Study Site

Pender Bay is located at 122 deg 38'E 16 deg 45'S on the north western side of the Dampier Peninsula, approximately 170 km north of Broome in WA (Fig. 1). The Bay faces in a NW direction with a gently sloping seafloor with an average depth of 12–15 m. Prominent landmarks include Perpendicular Head, Chimney Rocks, Woodhouse Rocks, Bell Point and Cape Borda. These fixed landmarks were utilised to assist with whale offshore distance predictions. Kelk Creek flows into the Bay with freshwater inflows mainly during the wet season periods. It was noted however that in July 2010 unseasonal dry season rains caused a major discharge event into the Bay bringing in terrestrial detritus into the Bay and clouding the water for a 3–4 weeks.

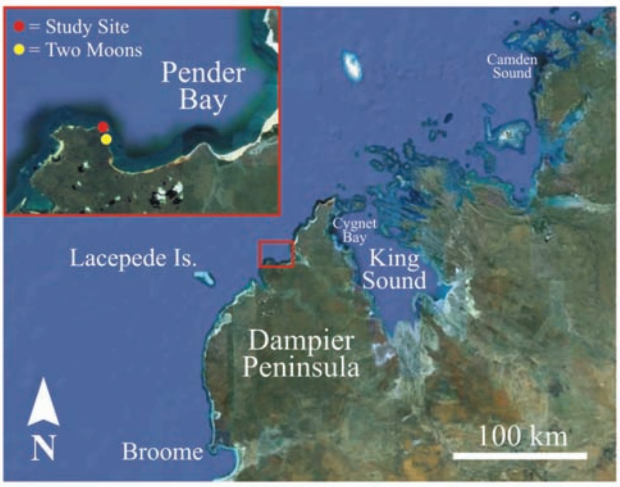

Figure 1. Location of Pender Bay, Dampier Peninsula, WA. Inset. the location of the Study Site [whale observing platform] and the Two Moons Whale & Marine Research Base [Base map courtesy Google Earth].

The whale observing platform (concrete survey pad) is on the cliff top which forms the southern boundary to the Bay located at 122 36.546E 16 45.939S (GPS fix), 30 m above MSL and approximately 1 km west of the *Two Moons Whale & Marine Research Station* (Fig. 1). This region forms the far northern part of the Canning Coastal Bioregion. Tides are semi-diurnal with a maximum range of 9 m during Spring Tide periods. The region can become isolated during wet season monsoonal conditions but is easily accessible from Broome during the dry season periods. Cyclones (normally Category 1 or 2) frequent the area during wet seasons and are mainly associated with major La Nina climatic events. "Whale season" in the Bay typically spans from the second week in June until early November when the last mothers and calves depart the Bay. There has been historically little oceanographic work or marine habitat studies undertaken in Pender Bay, however an automatic Meteorological Station was established by the State Government in 2009 on the Lacepede Islands in a WSW direction from Pender Bay (Fig. 1) and this provided detailed continuous meteorological measurements coincident with the study. Based on its location and the height of the observing platform on the cliff top 30 m above MSL, this geographic location is ideally positioned to capture the inshore S – N – S migration of the humpbacks as part of their annual migration.

Survey technique

The survey was conducted over a two year period, starting on the 2nd of August 2009 and going until the 4th of November 2009, then starting on the 10th of June and running until the 15th of November in 2010. The key to the survey methodology is simplicity and reproducibility, noting that fully quantitative surveys of whales are very challenging (Noad *at al*, in press.). To ensure consistency, a qualified *lead scientist* was nominated to ensure that recording methodologies and timings were strictly adhered to. Four or five other people supported the lead scientist in making and recording the whale observations. Data were immediately entered into a spreadsheet at the conclusion of each counting period by the lead scientist to ensure consistency. Whale counts were made from the cliff top location, with each observed whale behaviour recorded along with offshore distance estimations.

Whale behaviours were further standardised in 2010 based on the experiences from the 2009 survey to ensure that observers distinguished/ recorded the main behavioural types as follows: *breaching, blowing, lobtailing, pectoral slapping, logging* (surface resting), *surface travelling, chin slapping, spy hopping, blow and dive* (blow at the surface followed by a deep dive), *bull run* (a pod of males moving to intercept a female), *other* (any less common behaviour not listed above).

With a 190 degree field of view from the survey location on the cliff top two observers used their "naked eyes" in the left hand (LH) and right hand (RH) quadrants out from the cliff top respectively, with another two observers utilising binoculars in the LH and RH quadrants beyond the naked eye field of view (Fig.

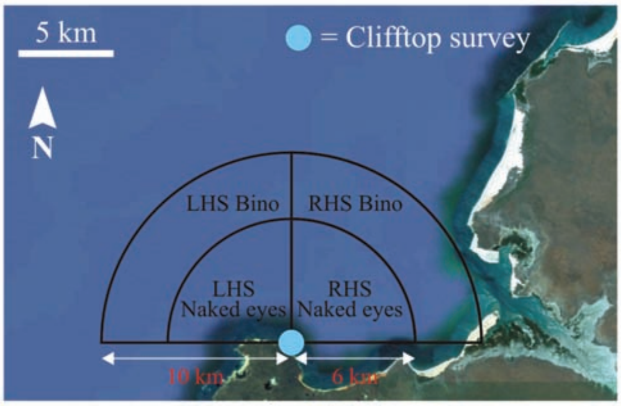

Figure 2. Viewing areas [180 degrees east and west of arc] from the Pender Bay cliff top survey location [Base map courtesy Google Earth].

2), which is normally 6–7 km offshore based on known fixed-points in the Bay and boat-based GPS distance surveys. If a fifth observer was present, they were tasked with following specific pods of whales and recording detailed behaviours and tracks. Counting was undertaken for five minutes commencing at 0700 each day and was then followed by a ten minute break when the field data from the log sheets from the individual observers was entered into the master spreadsheet by the lead scientist. Another five minute counting period was then instigated, followed by another ten minute break and so on. This continued for five hours at a time. This represented 100 minutes of sampling per person per day (actually a total of 400 minutes per day based on the four observer team) with strict timings between observation periods and rest times maintained. The observing team in operation as part of the cliff top survey are shown in Figure 3 based at 16 45.939S 122 36.546E and at 30 m above MSL.

Whilst most counting was undertaken in the morning, from 0700–0920, and Lunch time periods, from 0930–1205, we also undertook afternoon sampling from 1400–1705 on several occasions through the season to enable a time of day sampling comparison. Laminated field log sheets were utilised by all observers and at the end of every five minute period, the data were entered directly into the Excel spreadsheet on a field laptop computer where all related information such as visibility, number of observers, presence or absence of boats and local meteorological conditions were recorded.

Whale sightings and behaviours were recorded separately by each of the naked eye observers on the field sheets. Where individual whales were clearly reappearing, they were only counted once during any five minute recording period. The frequency of the different whale behaviours was also recorded by both of the naked eye observers during the 5 minute scanning periods. The observers scanning the horizon with the binoculars only recorded the number of whale sightings and not the type of whale behaviours. Splashes in the far distance were always counted as separate sightings as we could not distinguish individual whales within a pod in the six to ten kilometre range, as seen by the observers using the binoculars.

Several local landmarks were utilised to train observers to estimate whale distances offshore as well as offshore distance surveys being undertaken by boat and photographed from the cliff top to ensure that the distance estimates were consistent between days/weeks/years/observers.

Volunteers were all trained in the survey technique on the cliff top for three days prior to being allowed to participate in the whale observing team and were carefully monitored by the lead scientist ensuring as high a consistency of approach as possible.

Figure 3. Whale observation team in operation on the cliff top at Pender Bay at 16 45.939S 122 36.546E at 30m above MSL [Photo S. Blake].

Meteorological data were sourced from several locations in the region: Cygnet Bay, Lombadina (commencing February 2010), Lacepede Islands and North Head which included air temperature, mean sea level pressure (MSLP) and wind speed. These data were then compared with the humpback whale sightings and behaviours for that particular day. In addition, sightings of vessels in the Bay were recorded with a standardised key.

Tides

Data from two tide stations, Red Bluff to the south, and Karrakatta (Cape Leveque) to the north of Pender Bay were averaged to ensure a more accurate representation of the timing, height and state of high tide-low tide periods throughout the sampling period. High and low tide periods were defined as 40 minutes either side of the calculated average from the two tidal stations. The incoming and outgoing tides were defined as times falling outside that of the high and low tide categories. The averaging between these two tide stations was validated on several occasions and in all cases were found to be within five minutes of the actual observed tide. This tidal averaging approach was utilised for both 2009 and 2010 data.

Satellite sea surface temperature and Chlorophyll-a

Satellite data from both the Aqua and Terra satellites were analysed with a mean sea surface temperature (SST) and chlorophyll-a value being averaged for each day as long as it was within the tolerances of the validation algorithms for a 10km x 10km region of Pender Bay. These values were then graphed across the two years of humpback whale observations (2009 and 2010) and also for 2008, (a strong La Nina period) the year before our survey commenced to enable comparison.

Statistical analysis

No high end statistical analyses were performed on the data as they did not meet the independence assumption of the most common forms of statistical analysis. In order to account for the dependence in the data, some form of Time Series Analysis or a Repeated Measure Analysis would be required. However, as the data is not currently suitable for high end statistical analysis, we therefore undertook some basic comparative and descriptive statistics. The main purpose of this paper is therefore to highlight any trends observed over the two years of the survey.

As the frequency of occurrence of the different whale behaviours observed was largely influenced by the actual number of whales present in the Bay, all behavioural data has been normalised as a proportion of whales sighted.

Some basic descriptive statistics were undertaken on the 2009 data and the Excel spreadsheet was refined and slightly modified for the 2010 survey period to ensure that statistical analysis were planned prior to undertaking the 2010 sampling. It was found that entering the data directly into the Excel spreadsheet in the field (as per the 2010 survey) was far more streamlined than simply entering the observation data into field log sheets (2009) and then re-entering the information into a spreadsheet. Whilst the completion of the spreadsheet creates more work in the field on site, it prevents the duplication of effort in transposing data in the lab on return and we believe reduces the chance of data entry errors and ensures a more consistent approach to field data completion as questions and queries that the lead scientist may have of the observers can be addressed immediately.

Possible errors identified in the sampling include:

- Double counts of the same whales. There was the possibility that whales could move between the different quadrants during the 5 minute period. This was negated by the observers notifying each other if whales which, had already been counted, were passing into another's quadrant during the 5 minutes.
- Non observation of whales which were present. This occurred when an observer was looking in another direction within the quadrant of interest when a whale appeared; this was mainly manifested during the peak of the season when multiple whales (up to 91) would appear within the five minute period. This error was reduced by having an additional observer present and by having observers inform each other if a whale was spotted by one observer and not the other.
- Inaccurate distance estimates. Without the use of distance estimation devices, distance estimation remains subjective, however all observers were trained in distance estimation through the use of known distances to natural landmarks.
- Variability in observer effort. Surveys were predominantly conducted with four observers however there were times when observers were not available, in which case two or three observers were present. This was accounted for by standardising the data for observer effort by dividing the number of whale sightings by the number of observers present.
- Pseudo-replication of whales. As the sampling periods were close together (10 minutes apart) sometimes we recounted whales between the different five minute sampling periods. Multiple behavioural readings were often taken from the same whales. Unfortunately little could be done to account for this without doing a repeated measure or time series analysis to account for the dependence inherent in most cetacean studies involving behavioural monitoring.

Results and Findings

Numbers of whales and timing

As the 2009 whale survey was not instigated until the 2nd of August we do not know for sure as to when the first whales arrived in Pender Bay, however sightings off Broome indicate that the whales were arriving in early June and the last whale was seen in the bay on the 4th of November. In 2010 the first whale was spotted on the western side of Pender Bay on the 11th of June with the final whale being seen in the bay on the 9th of November, however, we observed that humpback whales were still present further offshore at the Lacepede Islands, as late as mid November.

The mean number of whale sightings per person was higher in 2009 than in 2010 with 3.85 ± 0.12 and 1.52 ± 0.04 whale sightings per person respectively (Table 1), which represents a 60% decrease in the number of whale sightings over the two years. This decrease was still evident even when the years were adjusted for the same August–November time period.

After the August peak in 2009, the mean whale sightings decreased markedly in September and then more gradually over the September to November period (Table 1). In 2010, after the arrival of the first whale, whale sightings increased rapidly in late July and peaked in August with a mean of 3.83 ± 0.08; this was then followed by a subsequent decrease in September (2.41 ± 0.09) followed by a gradual decline over October and November (Table 1).

The proportion of mothers with calves increased greatly after the peak in August for both 2009 and 2010 (Fig. 4), with the birth of two calves and several mating attempts (including mothers with calves) being witnessed during the late September to early November period. We can see from Figure 4 that in 2009 the mean percentage of calves increased from 1.07 ± 0.15 in August to 4.17 ± 0.62 in October before dropping off completely by November. That trend was the same for 2010 with the mean number of calves reaching 8.35 ± 0.46 in September and dropping of drastically in November. It was also

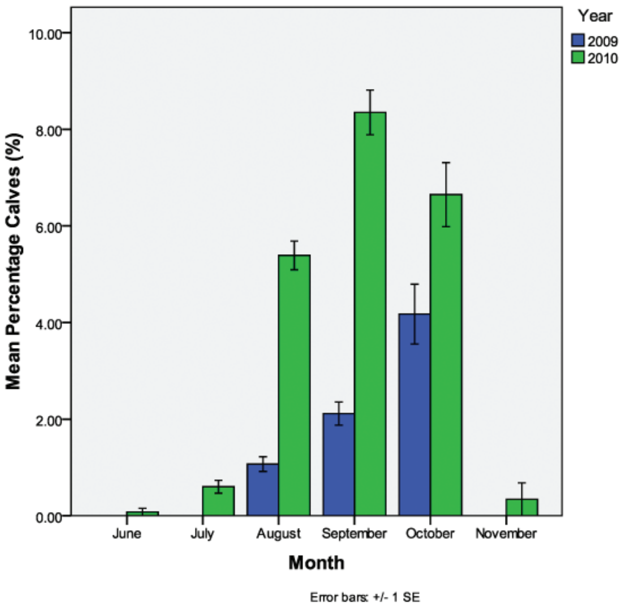

Figure 4. The mean percentage of calves present in each month for the 2009 and 2010 whale seasons.

noted that there were a greater percentage of calves present overall during the 2010 season, almost double that of 2009.

During 2009 we noticed that there was a decrease in the number of whale sightings during the middle of the day, which was referred to as "whale siesta time". This decrease is clearly seen in Table 1 where the mean number of whale sightings drops from 4.21 ± 0.21 in the morning to 3.45 ± 0.14 at lunch before increasing to 4.13 ± 0.28 in the afternoon period. This "whale siesta time" was not as evident during the 2010 season, with little difference present between the different times of day, however behaviours were observed to change.

Table 1

Descriptive statistics of the normalised whale sightings for each of the months of the 2009 and 2010 whale seasons.

Year	Month	N	Min.	Max.	Mean	SE
2009	August	559	0	28.33	6.63	0.22
	September	504	0	8.60	2.35	0.08
	October	275	0	5.75	1.47	0.08
	November	39	0	1.00	0.13	0.05
	Overall	1377	0	28.33	3.85	0.12
	Time of Day					
	Morning	554	0	28.33	4.21	0.21
	Lunch	642	0	26.62	3.45	0.15
	Afternoon	181	0	18.50	4.13	0.28
2010	Month					
	June	437	0	0.60	0.01	0.00
	July	560	0	6.50	0.98	0.06
	August	509	0	10.00	3.83	0.08
	September	469	0	11.50	2.41	0.09
	October	441	0	3.25	0.54	0.04
	November	147	0	1.50	0.07	0.02
	Overall	2563	0	11.50	1.52	0.04
	Time of Day					
	Morning	1165	0	11.50	1.52	0.06
	Lunch	1062	0	9.25	1.53	0.06
	Afternoon	336	0	8.50	1.44	0.10

Sea Surface Temperature and Chlorophyll-a

By plotting the sea surface temperature (SST) with the mean number of whale sightings (Figs. 5 and 6) we can see that there is a negative relationship present, this relationship becomes more apparent with the 2010 data (Fig. 6) with the lowest SST corresponding to the peak in the whale season. From this we can see that the peak in the whale season occurs when the SST is in the range of 26.7–27.9°C.

Chlorophyll-a, used as a proxy of the regions surface waters primary productivity, appeared to have an inverse relationship with SST, with the peaks of primary productivity generally corresponding to the decrease in the regions SST in 2008, 2009 and 2010 (Fig. 7). The chlorophyll-a concentrations also appear to be slightly offset with the peak of productivity occurring just before the start of the whale season, as shown in Figure 8.

A slight elevation in the SST was observed during 2009 and 2010 compared to 2008 with an increase in the variability of both the SST and chlorophyll-a readings in 2009 and 2010 when compared with 2008, a La Nina year (Fig. 7). Winter SSTs were noticeably lower in mid 2008

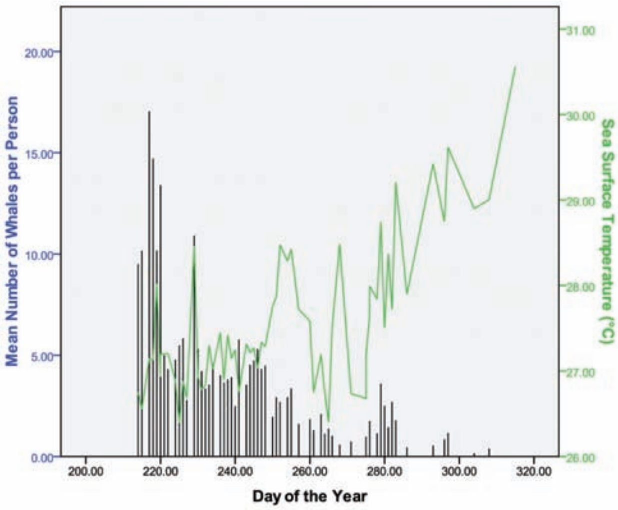

Figure 5. Mean number of whales normalised for viewing effort compared with sea surface temperature over 2009.

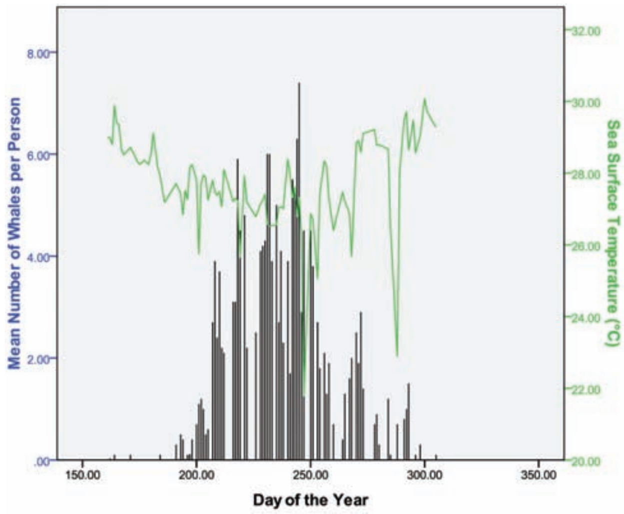

Figure 6. Mean number of whales normalised for viewing effort compared with sea surface temperature over 2010.

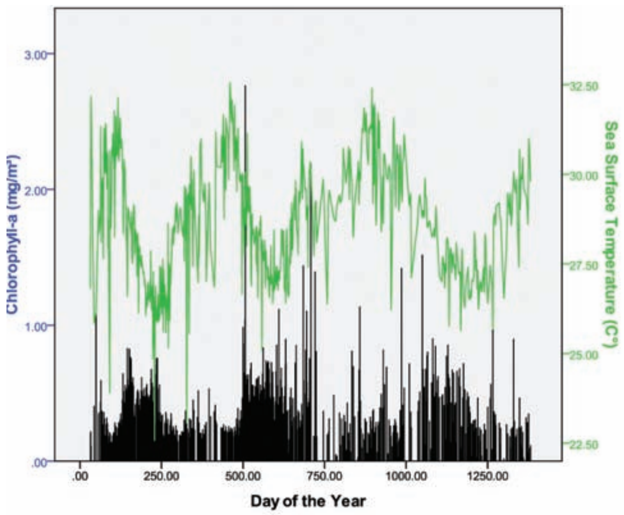

Figure 7. Mean chlorophyll-a concentrations and sea surface temperatures for Pender Bay over 2008, 2009 and 2010.

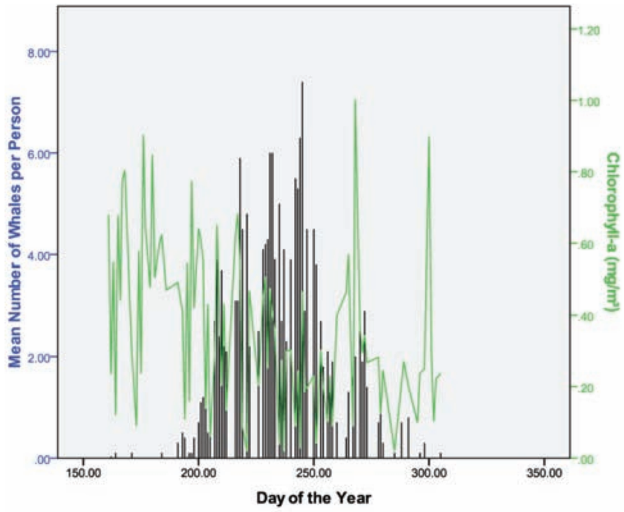

Figure 8. Mean number of whales normalised for viewing effort compared with chlorophyll-a concentrations over 2010.

coincident with the 'whale season' when compared to 2009 and 2010 (Fig. 7). The chlorophyll-a signature was particularly well defined for 2008 (La Nina year) when compared with 2009 and especially 2010. Similar seasonal and inter-annual variability trends in both SST and chlorophyll-a have been observed in the Camden Sound companion dataset where low winter SSTs (26–27.5°C) coincided with high numbers of whales observed in the region in 2008 (Blake, unpublished data).

Meteorological factors

Weak negative trends were observed between the number of whale sightings and North Head air temperature (R=0.345) and wind speed (R=0.152), Lacepede Island air temperature (R=0.519) and wind speed (R=0.155) with weak positive trends observed with both North Head and Lacepede Island MSLP (R=0.443 and 0.400 respectively) for 2009 (Figures 9–14).These trends become less clear during 2010 with little to no trends apparent between the whale sightings and North Head air temperature (R=0.100), MSLP (R=0.063), wind speed (R=0.190) and Lacepede Island air temperature (R=0.095), MSLP (R=0.055) and wind speed (R=0.122) (Figures 15–20).

The sea state, measured by the Beaufort wind scale, appeared to directly correlate with the mean number of whale sightings (Fig. 21). On days where the Beaufort wind scale was zero (very calm and still conditions) the mean number of whale sightings per person was greatest with 2.28 ± 0.09 sightings, this decreased linearly with no whales being sighted when the sea state had reached Beaufort scale 6 (large waves forming white caps with some sea spray), however those rough sea conditions were only represented by 4 sampling periods.

In addition to the sea state, the visibility also directly impacted on the number of whale sightings, with a combination of wind speed, sea state, salt spray and atmospheric haze all impacting on how well the observers could see across the Bay (Fig. 22).

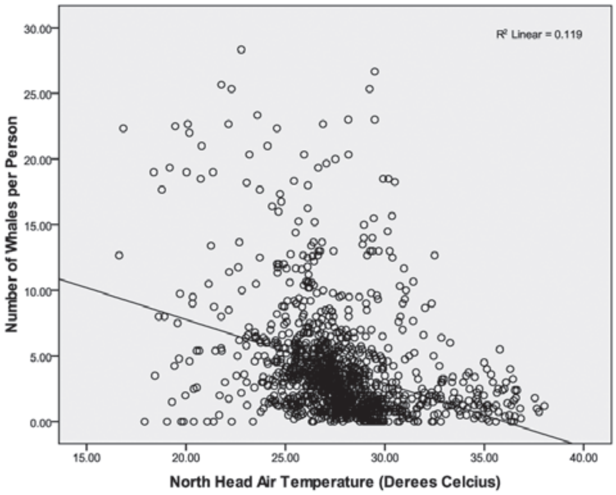

Figure 9. Scatter plot of number of whales normalised for viewing effort against the North Head air temperature with corresponding trend line for 2009.

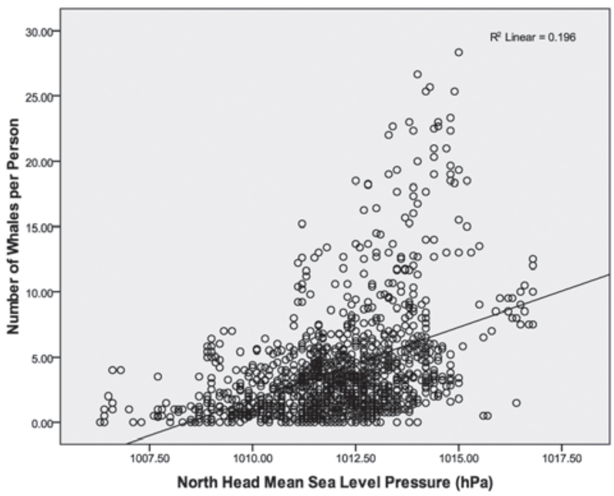

Figure 10. Scatter plot of number of whales normalised for viewing effort against the North Head MSLP with corresponding trend line for 2009.

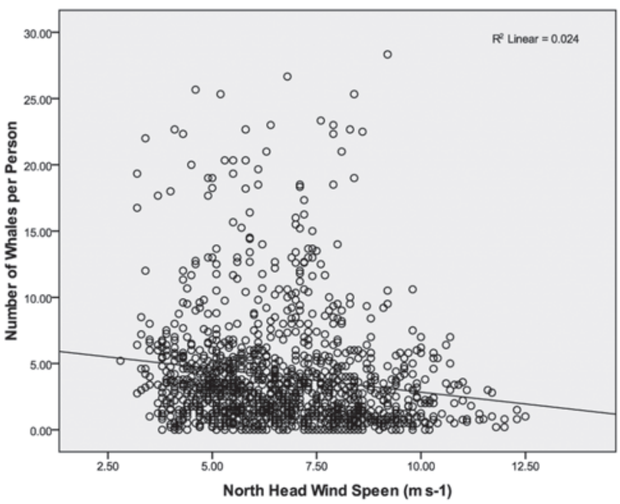

Figure 11. Scatter plot of number of whales normalised for viewing effort against the North Head wind speed with corresponding trend line for 2009.

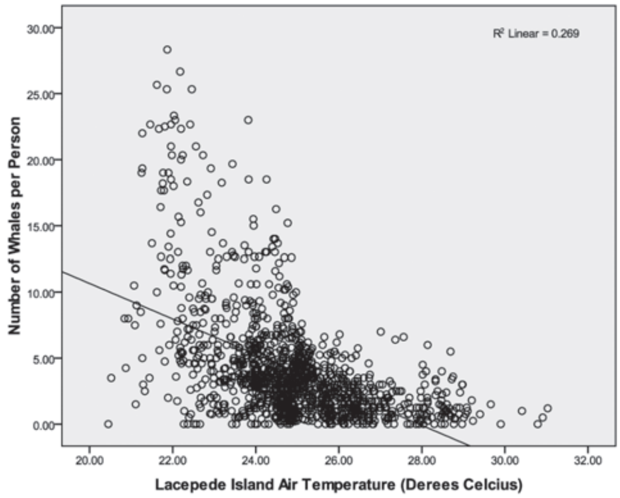

Figure 12. Scatter plot of number of whales normalised for viewing effort against the Lacepede Islands air temperature with corresponding trend line for 2009.

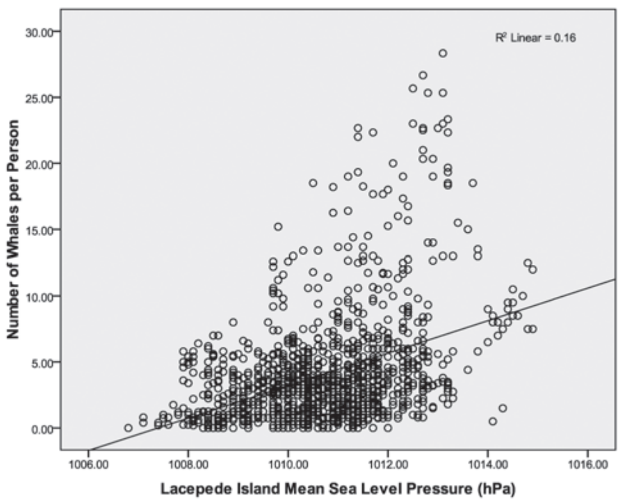

Figure 13. Scatter plot of number of whales normalised for viewing effort against the Lacepede Island MSLP with corresponding trend line for 2009.

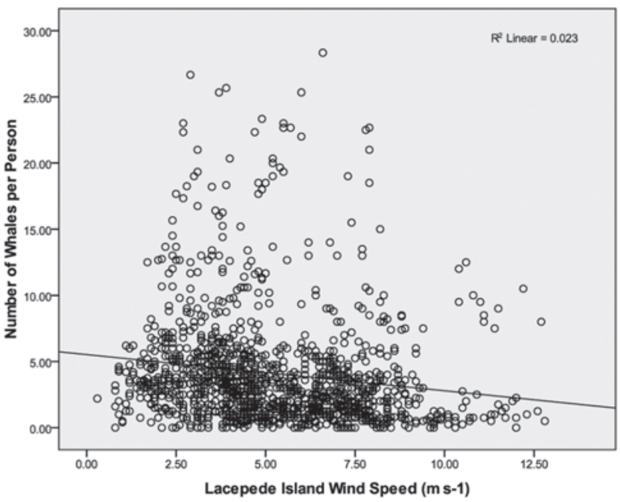

Figure 14. Scatter plot of number of whales normalised for viewing effort against the Lacepede Island wind speed with corresponding trend line for 2009.

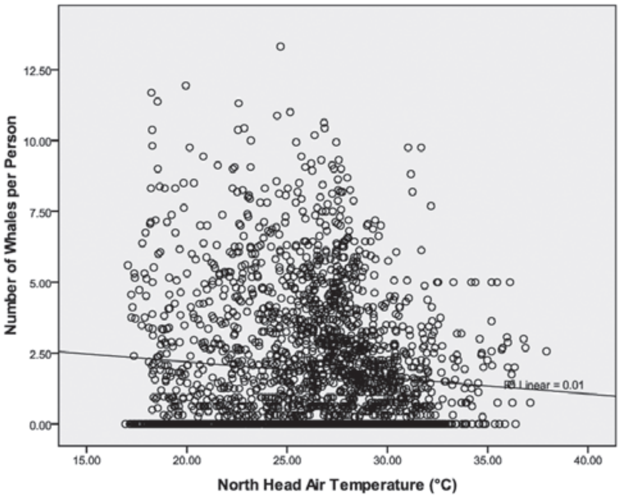

Figure 15. Scatter plot of number of whales normalised for viewing effort against the North Head air temperature with corresponding trend line for 2010.

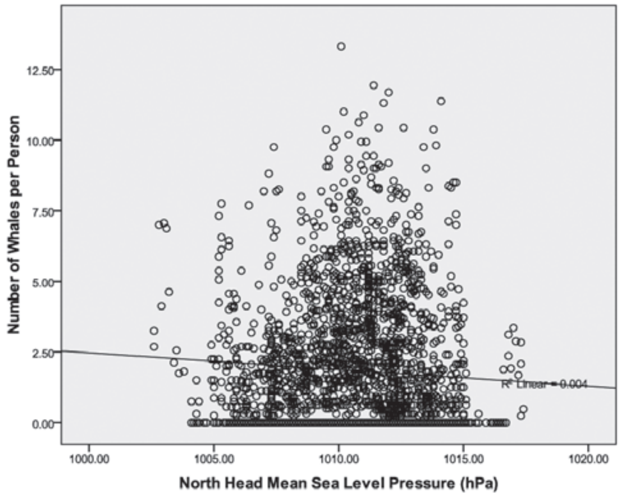

Figure 16. Scatter plot of number of whales normalised for viewing effort against the North Head MSLP with corresponding trend line for 2010.

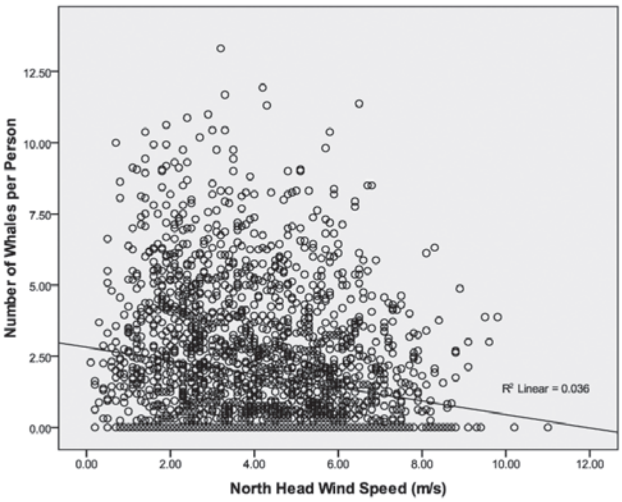

Figure 17. Scatter plot of number of whales normalised for viewing effort against the North Head wind speed with corresponding trend line for 2010.

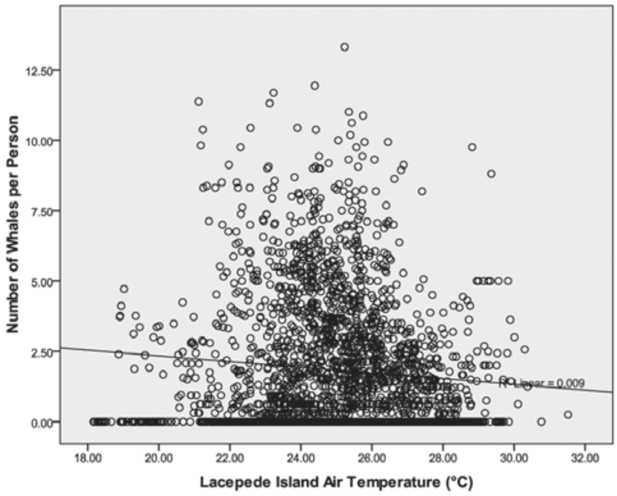

Figure 18. Scatter plot of number of whales normalised for viewing effort against the Lacepede Island air temperature with corresponding trend line for 2010.

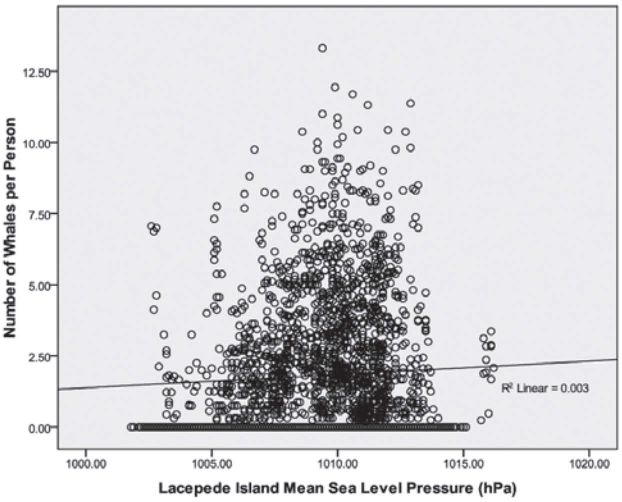

Figure 19. Scatter plot of number of whales normalised for viewing effort against the Lacepede Island MSLP with corresponding trend line for 2010.

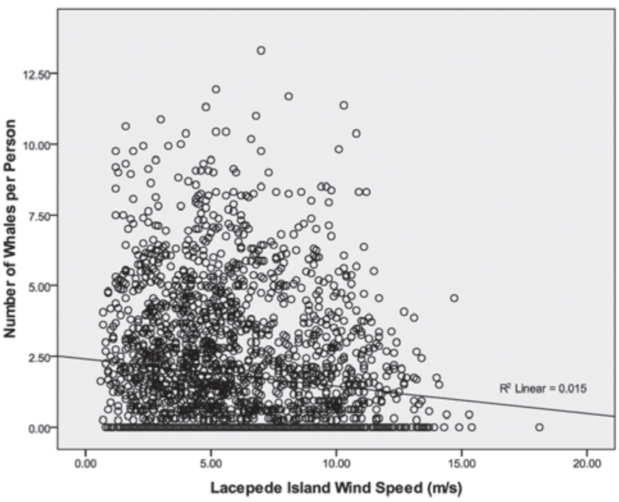

Figure 20. Scatter plot of number of whales normalised for viewing effort against the Lacepede Island wind speed with corresponding trend line for 2010.

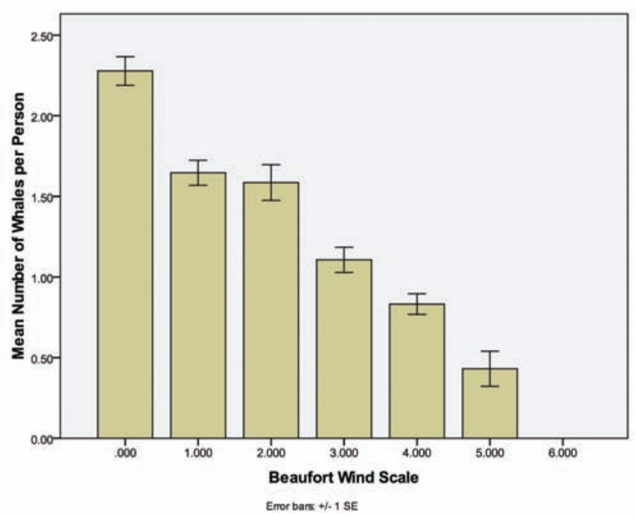

Figure 21. Mean number of whales normalised for viewing effort against the Beaufort wind scale for 2010.

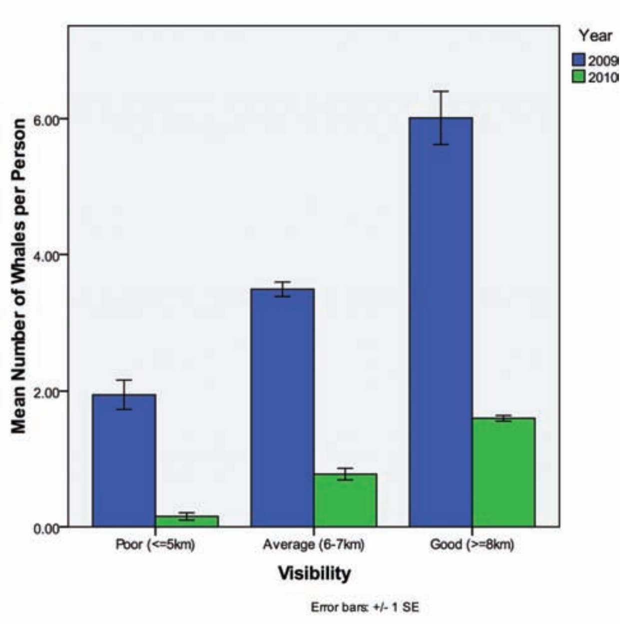

Figure 22. Mean number of whales normalised for viewing effort against visibility in 2009 and 2010.

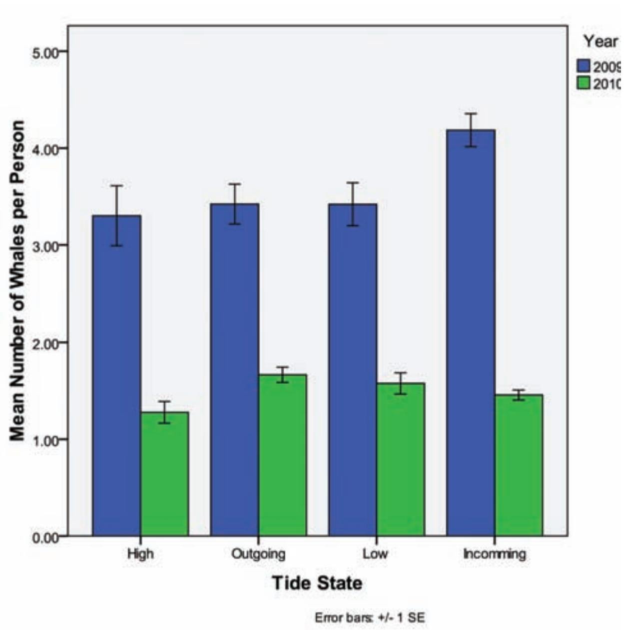

Figure 23. Mean number of whales normalised for viewing effort in different tide states for 2009 and 2010.

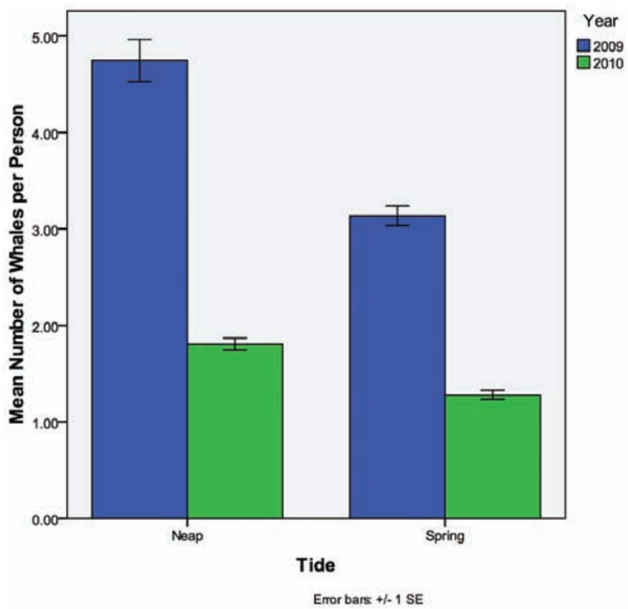

Figure 24. Mean number of whales normalised for viewing effort during neap and spring tides for 2009 and 2010.

Tides

It was observed that mothers and calves would drift in and out of the bay with the changing tides though no clear trend was apparent between the mean number of whale sightings and the state of the tide, apart from an increased number of sightings on an incoming tide in 2009 (Fig. 23). When viewed in the broader context of spring and neap tides there is a consistent trend in both 2009 and 2010 for a relative increase in whale sightings during neap tides and a relative decrease during springs (Fig. 24). This represents a 51% difference between neap and spring tides in 2009 with whale sightings decreasing from 4.75 ± 0.22 during neap tides to 3.14 ± 0.10 during springs, and a 41% difference in 2010 with the whale sightings changing from 1.80 ± 0.06 on neap tides to 1.29 ± 0.05 during springs.

Boats

As many as eight boats were observed utilising the bay during the 5 minute counting period, consisting to a large extent of local fishermen in small boats, however, larger vessels along with a few sailing yachts also frequented the bay. Boat numbers decreased rapidly in the bay in response to an increase in the sea state (measured as the Beaufort wind scale (Fig. 25)) and corresponding wind speeds, with the number of whale sightings following the same trend (Fig. 21). Whale sightings when boats were present, were higher in both 2009 and 2010 with a mean number of sightings per

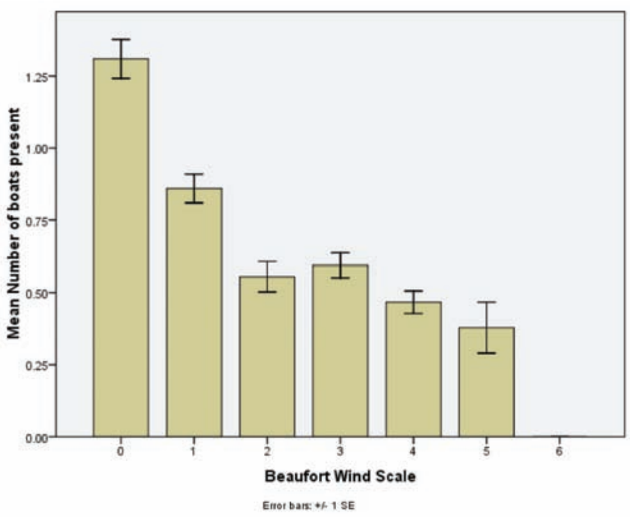

Figure 25. Mean number of boats present against the Beaufort wind scale for 2010.

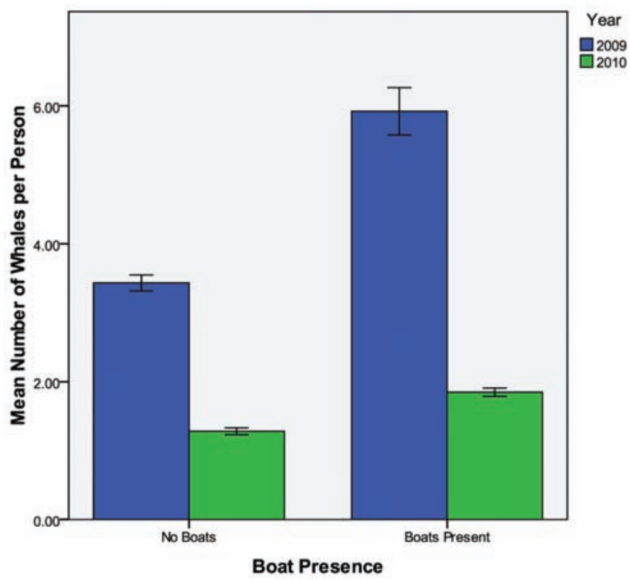

Figure 26. Mean number of whales normalised for viewing effort in the presence and absence of boats for 2009 and 2010.

person of 5.92 ± 0.34 and 1.85 ± 0.06 respectively. When boats were absent, the mean number of sightings per person was lower with 3.34 ± 0.12 in 2009 and 1.28 ± 0.05 in 2010 (Fig. 26).

Whale behaviours

Humpback whale calving, breeding, feeding, resting and associated staging behaviours were all observed in Pender Bay over the two years of monitoring. Overall, the types of whale behaviours remained constant through the season with breaching and blowing behaviours being the most frequently sighted; but also being those most easily seen from the cliff during poor visibility and rough seas.

The time of day appeared to influence the behaviours, in particular breaching, blowing, and surface travelling (Fig. 27). There was a decrease in the proportion of whales blowing around the middle of the day, with the mean proportion of sightings dropping from 0.25 ± 0.01 in the morning, before increasing again in the afternoon to 0.32 ± 0.02. Breaching remained similar during the morning and lunch periods (both 0.09 ± 0.01); it however decreased to 0.04 ± 0.01 in the afternoon. Surface travelling also showed an increase in the mean proportion of sightings during the lunch period, increasing to 0.06 ± 0.01 from 0.05 ± 0.00 in the morning and decreasing to 0.03 ± 0.01.

Changes to the whales' behaviours were also observed coincident with the presence of boats in the Bay, as seen in Figure 28. While boats were present, blowing, pectoral slapping, logging, surface travelling, blow diving and other behaviours all increased while breaching showed a slight decrease.

Discussion

The timing of the whale season was similar across both years of the survey with the whales arriving mid June, their numbers peaking in August before dropping off by early November. Our findings were consistent with those from the underwater noise loggers deployed by Curtin University for the same time period at James Price Point (Gavrilov and McCauley, 2010).

The mean number of whale sightings however was not consistent, with a 60% decrease occurring between 2009 and 2010. Research conducted by McKay & Thiele (2008) in the same area also noted variability in the number of whale sightings between the different years in Pender Bay. We postulate that this variability may partly be in response to the El Nino Southern Oscillation phenomena with associated possible Indian Ocean Dipole effects influencing the broad seasonal patterns of SST and chlorophyll-a concentrations. In order to determine if this is correct however, we would require additional years of monitoring and ideally have thermisters deployed along the edge of the continental shelf and also in a cross shelf pattern out from regions such as Camden Sound, Pender Bay and the southern part of Eighty Mile Beach.

We also experienced uncharacteristic "dry season" heavy rains during July 2010, which resulted in a large injection of red mud and freshwater from Kelk Creek which persisted in the bay for several weeks. We believe that this influx of turbid freshwater may also have impacted the number of whale sightings during that time. A large *Trichodesmium sp*. Bloom was observed in the Bay in early September 2010.

A worldwide study of the effects of SST on the wintering areas of Humpback Whales revealed that in all areas where whales migrate during the winter, the SST ranges between 21.1–28.3°C (Rasmussen *at al.* 2007), consistent with our results, with the peak of the whale season occurring in temperatures from 26.7–27.9°C. These lower water temperatures appear to coincide with peaks in the primary productivity as indicated by our results, however the peaks in the chlorophyll-a appear at the start of the whale season prior to the whale numbers

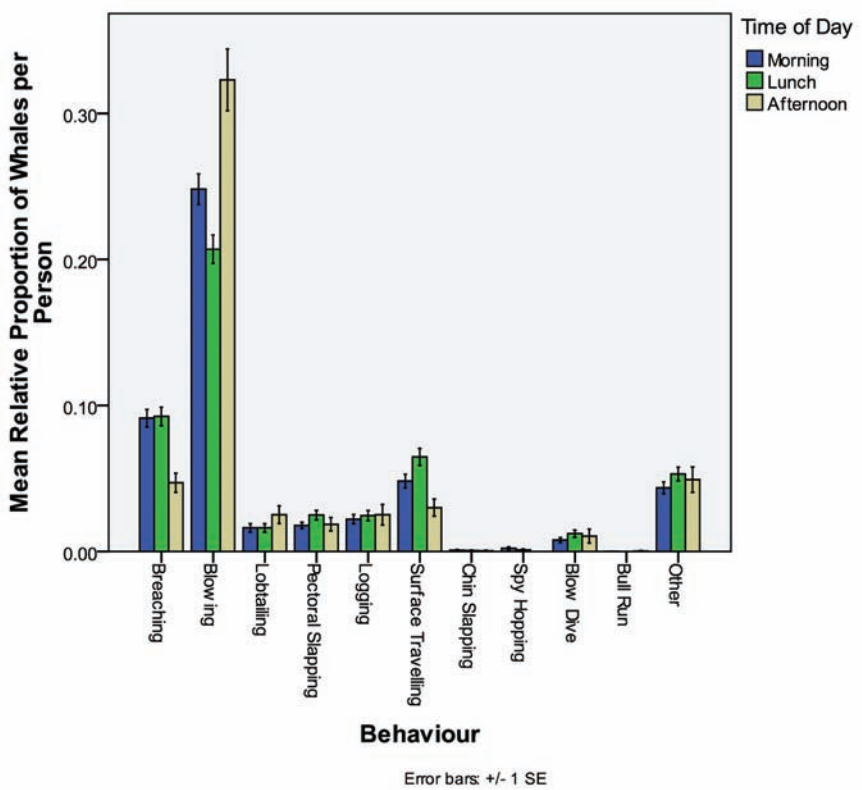

Figure 27. Mean proportion of whales normalised for viewing effort performing different behaviours at each time of day in 2010.

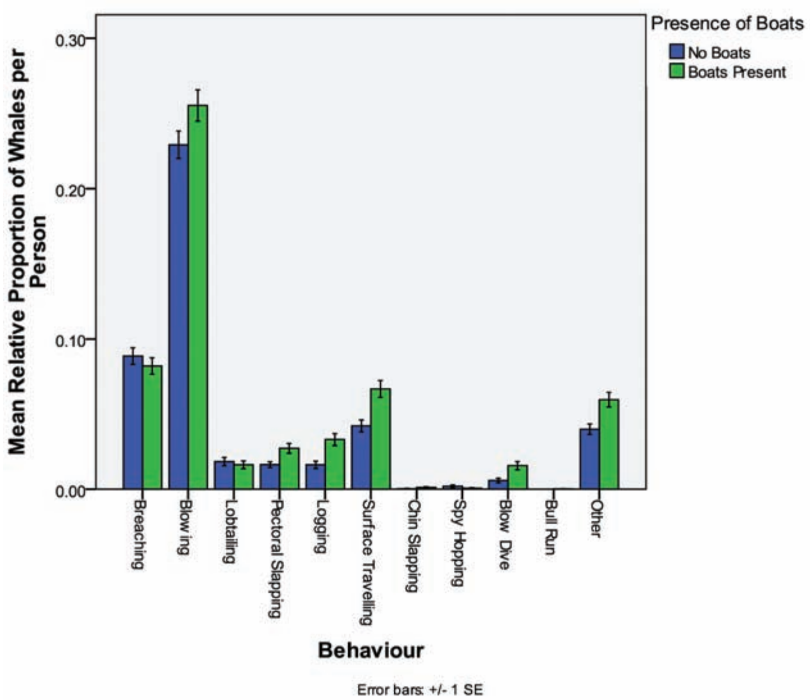

Figure 28. Mean proportion of whales normalised for viewing effort performing different behaviours in the presence and absence of boats in 2010.

reaching their maximum. As chlorophyll-a is used as a proxy of the phytoplankton abundances, and the peak in zooplankton biomass can occur 1–4 months after that of the phytoplankton (Munger *at al*. 2009), this would then put the peak of zooplankton abundance more in line with the peak in the whale season.

As feeding has been observed in other areas of the world during the whale migration and in breeding areas (Canese *at al*. 2006; Stamation *at al*. 2007), we suggest that Pender Bay may also be an important area for opportunistic feeding with feeding having been observed along slicks of breakdown products of *Trichodesmium sp*.

off Cape Leveque. While no whales were observed to be feeding directly in the Bay, we believe that cameras placed in key locations will probably pick these behaviours up in the fullness of time.

The mean percentage of calves peaked later in the season, around September/October, with mothers and calves frequently observed resting close to shore. The occurrence of cows with calves in inshore areas has been well described and it is thought that the calmer conditions inshore aid in conserving the calves' energy which allows for better growth and development of the calf whilst simultaneously providing protection from aggressive adults and Killer Whales (Whitehead & Mann 2000; Ersts & Rosenbaum 2003; Elwen & Best 2004; Double *at al.* 2010).

The relative increase in the percentage of calves is likely the result of two processes. 1. As the adult bulls and cows, both adolescents and mothers without calves begin to leave the Bay, the number of calves present in the remaining population then represents a larger percentage. 2. The mothers and calves travelling south from Camden Sound and the Buccaneer Archipelago stopping off and staging in Pender Bay before migrating south, thereby again increasing the percentage of calves present in the Bay.

These findings further highlight the importance of Pender Bay as a Humpback Whale calving, staging and resting area and are consistent with research conducted by Jenner *at al.* (2001) and McKay & Thiele (2008).

During the course of the study, particularly during 2009, it was observed that the number of whale sightings decreased around midday as well as a shift in the whales' behaviours from more visible displays like blowing to less visible activities such as surface travelling. Research by Karczmarski *at al.* (1998) on the humpback dolphins off Algoa Bay in South Africa also noted a decrease in the dolphins' activities around midday, this was followed by a peak in the activities in the afternoon to levels which were similar to those during morning periods.

Similar trends have also been observed in Beluga whales, where their activity was lower in the morning and midday before increasing in the afternoon (Cornick & Kendall 2008). A study of Humpback whales off Hawaii revealed that the proportion of time spent at the surface was higher in the morning at 0700 hrs and lowest at 0900 hrs before peaking in the afternoon around 1500 hrs (Helweg & Herman 1994), a pattern similar to what we observed. Helweg & Herman (1994) also found that the number of breaches and tail-slaps was greatest at noon, which we also found, and to which they believe serves as visual displays to other whales. While the daily shifts in whale behaviours are still not fully understood, we believe that with continued observation of the whales, the patterns and likely causes of these changes will become more apparent.

Our results indicated that there was little variation in the number of whales sighted with respect to the state of the tides with the exception of the increased number of whales sighted on the incoming tide (Fig. 23). While we are still unsure of the potential effects of the tides on the whales we believe the tidal movements are of more importance to mothers and calves, which are frequently seen drifting in and out of the Bay, which we believe to be a means of conserving energy by passively drifting with the tides. It was also observed that increased whale sightings occurred during neap tides (Fig. 24), however the reason for the increase during neap tides still remain unclear and as such further study would be needed to elucidate the exact effects of the tides on the whales.

The presence of boats appeared to impact on both the number of whale sightings and their behaviours (Figs. 26 and 28). We don't believe that the whales are attracted to the boats in any way, but rather the boats frequent the bay more in calmer sea conditions coincident with better visibility for viewing the whales and hence the larger number of individuals recorded. We believe we are simply witnessing an indirect correlation as both boats and whale counts are favoured by similar environmental conditions such as calmer weather (Figs. 21 and 25). Survey designs clearly need to take into full consideration visibility-related variables.

Common behaviours observed involving whales and other cetaceans in short term responses to boats, are to increase swimming speed, change direction, and spend more time submerged on dives (Corkeron 1995, Scheidat *at al.* 2004; Stamation *at al*. 2010). These responses were evident during this study as indicated by the increase of surface travelling and blow diving behaviours (Fig. 28). We also observed an increase in the number of whales seen logging when boats were present. This suggests that in addition to the above mentioned responses, the whales may also choose to remain stationary while the boats pass through the area.

Research has shown that the prolonged exposure to short term disturbances by boats can result in population declines of cetaceans, with decreased reproductive success and reduced fitness (Bejder *at al* 2006(a),(b); Williams *at al* 2006; Lusseau and Bejder 2007). This could become an issue for Pender Bay in the future, with likely increased access to the adjoining land area and corresponding increases in the number of people wanting to utilise the bay. The appropriate management plan needs to take this into consideration.

We believe the survey technique developed is a pragmatic one with large numbers of volunteers in a highly remote location such as the Kimberley coast. The logistics of implementing a study of this kind relies on access to the permanent marine field location site on the shores of Pender Bay with the Two Moons Whale and Marine Research Base providing basic services. Pender Bay is an ideal location to observe humpback whales in their natural environment, as we believe that ship-based surveys will likely have some effect on humpback whale numbers and behaviours. An unobtrusive cliff top location allows observers to experience humpback whales displaying their natural behaviours including birthing and mating.

Whilst distance estimates of whales offshore remain an ongoing challenge, we believe that as long as the technique is standardised, then it remains a pragmatic way of operating, noting that on very busy observation periods, such as early August 2009 we sighted as many as 91 (unstandardised) whale sightings in a five minute counting period.

In the future, it is important to further elucidate humpback whale distributions within Pender Bay based on habitat types and the morphology of the sea floor and undertake some local primary productivity work based on the fact that we postulate that whales are feeding in this region on an opportunistic basis. In order to make sense of other trends found from this study, we suggest further monitoring of the area as well as collecting additional experimental data that will allow for us to process and analyse more quantitative information using appropriate statistical analyses. Future surveys should ideally attempt to quantify the absolute abundance of Australian west coast humpback whales utilising methods such as those described in Noad *at al.* (in press).

Acknowledgements: We wish to acknowledge the contributions made by the large number of volunteers whilst staying at the Two Moons Whale and Marine Research Base, to Andrew Bowles the owner of Two Moons Whale and Marine Research Base and to all of those sponsors of the research station, noting that this work was largely unfunded and was undertaken around the shared belief to establish an independent baseline for the future. We would also like to acknowledge Ryan Admiraal from Murdoch University for advice on statistical processing techniques. In addition, we would like to thank Mark Gray from Curtin University for undertaking the satellite processing work.

We wish to acknowledge the very constructive comments and suggestions of the independent reviewer on the first draft of the manuscript.

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