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Monitoring humpback whale (*Megaptera novaeangliae*) behaviour in a highly urbanised coastline: Gold Coast, Australia

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Abstract

The east coast of Australia experiences the world's largest annual humpback whale (*Megaptera novaeangliae*) migration, with an estimated 14,000 individuals in 2010. However, increasing coastal development is accelerating the environmental pressure on migrating marine megafauna. Consequently, solutions to better manage humpback whale presence in urbanised waters are required. We have developed a novel survey method that can be applied to operating whale watch vessels, better integrating the tourism industry into research and ultimately coastal management in urbanised coastal waters. Preliminary results from the first season of observation (May-November 2010) in the Gold Coast bay showed a successful survey return of over 500 individuals that included 14,286 behavioural state observations. The data were analysed in terms of most commonly observed behaviours, movement, pod size and composition. The numbers of mothers with calves were highest in September and October and both resting and feeding behaviours were documented indicating the importance of the bay for these individuals. Our pilot study demonstrated that the benefits of whale watch boat based data collection can outweigh its limitations when strategically deployed and carefully analysed.

Keywords: humpback whales, behaviour, whale watching, Gold Coast, Australia

1. Introduction

Eastern Australian humpback whales migrate annually from their summer feeding grounds (December-March) in Antarctica to their tropical breeding grounds in the Coral Sea in winter (May-October). These large scale migration patterns are well known and well documented (e.g. Dawbin, 1966; Garrigue et al., 2000; Jenner et al., 2001; Noad et al., 2008). However, the movement patterns along this migratory route, the degree of interchange, smaller scale habitat use and the factors that influence the choice of these areas are poorly understood (Castro et al., 2008). It is likely that these are driven by physical and biological factors that can be impacted by high-density coastal development as is experienced on the Gold Coast. The humpback whale is listed as 'vulnerable' under the Australian *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The estimated world wide abundance is believed to be greater than 60,000 individuals (Reilly et al., 2008) and the east Australian population is estimated to be 7,000 ± 660 for 2004 with an annual rate of increase of 10.6 ± 0.5% for the time from 1987 – 2004 (Noad et al., 2008) which would suggest about 14,000 individuals in 2010.

The shape of the Gold Coast inshore area functions similar to a bay in which the current reverses, resulting in calm waters particularly during October each year (Castelle et al., 2007).

This makes the Gold Coast a potential resting spot, as documented by anecdotal reports. In 2009, an estimated 50,000 people partook in the whale watching season on the Gold Coast (Gold Coast, 2010). South-east Queensland is among the most populated areas in Australia with more than 2 million people and a yearly increase of up to 14 % (ABS, 2010), making it one of the fastest growing regions in the world (Baum and O'Connor, 2005). This development consequently increases the pressure upon the adjoining marine environment through habitat loss, constructions, sand mining and pumping, shipping, noise and water pollution. This is increasing the rate of loss of biodiversity and abundance of near-shore marine species (Jackson et al., 2001).

The stretch of coastline within the Gold Coast region is one of the few major developed coastlines in the world where dugongs, whales and dolphins are still present (Chilvers et al., 2005). Despite this, the impacts of such development on marine megafauna, including whales, are poorly understood. As humpback whales frequent the shallow near-shore waters, it is likely that their susceptibility to disturbances from anthropogenic sources is high. Migrating humpback whales rely on stores for energy and thus the whales are particularly vulnerable to the energetic costs of continued disturbance. In order to improve the management of humpback whales in near-shore waters around Australia, information on behavioural activities of humpback whales at aggregation sites is required in combination with collected long-term point observations. Three aggregation areas have been identified: (1) the southern end of the Great Barrier Reef, (2) Hervey Bay and (3) the Gold Coast region (DEH, 2005). The southern end of the Great Barrier Reef in particular around Swine Reef is a suspected calving ground (Chaloupka et al., 1999). Hervey Bay lies approximately 300 km north of the Gold Coast. Over 20 years of studies in Hervey Bay revealed that 30-50% of the humpback whales divert from their southward migration and move into the bay from August to October (Paterson, 1991, Chaloupka et al. 1999). This enclosed bay formed by Fraser Island on the east site is a confirmed resting area in particular for mothers with calves most likely due to calm and shallow waters (Franklin et al., 2010).

Here we aim to investigate the behaviour, pod sizes and compositions of 518 humpback whales observed in the Gold Coast bay, Australia during their northern and southern migration in 2010 and compare the findings with the aggregation site in Hervey Bay. Our objective was to provide a first assessment of humpback whale behaviour in a recognised aggregation area along their migration route. It is hypothesised that the bay is used as a resting area for mothers with calves predominantly during the southern migration.

2. Methods

2.1 Study area

The study area comprises the Gold Coast inshore waters from Point Lookout, North Stradbroke Island, in the north to Tweed Heads in the south and 15 nautical miles (nm) east of the foreshore including state and federal coastal waters (Figure 1). The Gold Coast inshore area can be described as a sickle/sense shaped coastal bay facing east to the Coral Sea. This region is wave dominated with an average deep-water significant wave height of approximately 1 m (0.8 to 1.4m) (Mirfenderesk and Tomlinson, 2007; Mirfenderesk and Tomlinson, 2008). The Gold Coast climate is sub-tropical with a hot humid wet season (November-April) and a mild dry season (May-October). The region is influenced by easterly to south-easterly trade winds coming from the Pacific Ocean bringing moist, warm air and constant winds of varying degrees. Generally, windier conditions occur during the summer months and calmer conditions during the winter.

2.2 Data collection

Surveys were conducted on board the commercial whale watch vessel "Spirit of Migloo", operated by Sea World Whale Watch. This catamaran is 24 metres long and 9 metres wide with a 7 m high viewing platform. In accordance with the Australian EPBC Act, the vessel had to keep a distance of 100m from whales and 300m if three or more boats were present at the same whales or if the vessel was moving at a speed higher than 6 knots. When calves were present the vessel had to stay a minimum of 300m from the calf unless the calf moved such that the vessel was within 300m, in which case the vessel had to be disengaged or moved out of the caution zone (300m).

Surveys were undertaken for 5 days a week on two separate trips each day with duration of 2.5 hours each. During these trips, the date, time, coordinates, bearing, pod size, calf presence and displayed behaviour/s were recorded. Maximum distance of the vessel from the shore was 15nm. Locations of the humpback whale pods encountered were recorded by using the vessel's GPS system. The direction in terms of North, South, West and East of pod movement was assessed at the first sighting of a pod. The travel speed of the whales was estimated from the boat speed as an average value while the vessel was positioned alongside the whales as they travelled and changes recorded when the speed changed more than 1 knot. Pod refers to a singleton and two or more humpback whales swimming side-by-side (Clapham, 1993; Corkeron et al., 1994). 'Adults' describes the number of whales in a pod that were not calves however this classification does not imply sexual maturity. Humpback whales under 10m in total length were considered juveniles and whales under 6m in length were considered calves when accompanied by a significantly larger whale with whom they maintained a constant and close relationship (Tyack and Whitehead, 1983) with the adult being the assumed mother (Clapham et al, 1999). The size of the whale was also compared to a known distance alongside the vessel.

Behavioural data were collected using a standardised field data sheet to ensure that the recording of behaviours was consistent between survey trips and observers (Mann et al, 2000). This sheet listed 21 different behavioural states frequently observed in humpback whales (Isaacs and Dalton, 1992; Kaufman and Forestell, 1986; Mann et al, 2000) and also collected information on blow per surfacing, travel speed (knots), dive time and resting time (Table 1).

Utilising a behavioural key, which described each of these, observed behaviours were categorically assigned as one of these behavioural states. Additionally, video footage of all displayed behaviours was recorded which allowed for subjective interpretation between observers. Classifying any given observed behaviour was discussed between observers when necessary. Behaviours were observed and assigned categories by the same two observers who jointly undertook all field surveys throughout the season.

2.3 Statistical methods

To examine variation in pod size and composition, the whole sample frequencies and percentages of pod size were reported. In addition, we reported the pod size categories by 'calves present' or 'no calves present'. To further analyse the behavioural data, we reported the frequencies of occurrences of each behaviour and investigated the differences between northern and southern migrations and between pods with and without calves present.

A one-way Analysis of Variance (ANOVA) using SPSS 19.0 was used to determine significant differences between observed behaviours between pods with calves present and pods without calves present.

3. Results

We recorded 518 individual humpback whales, and 14,286 behavioural state observations, between May and November 2010 in the Gold Coast bay. The first and last recorded whale sightings were on the 21st May 2010 and 4th November 2010 respectively. A total of 101 survey days were conducted for 5 days per week. Data were obtained on all survey trips. The total survey time was 400 hours and observations of humpback whales were undertaken for a total of 142 hours. The average rate of survey time (time spend on the water looking for humpback whales) per week was 16 hrs and the average observation time about 6 hrs through out the study period. Survey hours per week ranged from 2.5 to 35 hrs depending on weather and season (Figure 2).

Of the 21 recognised humpback whale behavioural states, “slip under” was the most common accounting for nearly 50% of all observations. The next most commonly observed behavioural state was “round out” which accounted for 10% of all observations. 11 of the 21 behaviours were observed at a frequency of less than 1% of total recorded observations (Figure 3).

About 40% of all movement directions of pods recorded during the main northern migration (May – July) where in northern direction. Movements during the main southern migration (September – November) where less directed with 20 % swimming directly towards the south and the rest in other directions.

3.1 Pod size and composition

A total of 262 pods were observed over the duration of the migration season. Pod size ranged from 1 to 6 individuals, with a mean of 2.42. Approximately one third of the pods were singletons (33%) and nearly half were pairs (45%), one third of which were mother-calf pairs. Nearly a quarter of the pods (22%) consisted of 3 or more individuals (Figure 4, Table 2).

A total of 40 pods had calves (15%) and these pods predominantly occurred as mother-calf pairs. However, on some occasions an assumed escort was present and a single observation documented two mothers and two calves in a single pod.

3.2 Mothers with calves

The first mother-calf pair was observed in late June (26/6/10). This was an early observation for a newborn calf and the sighting suggested that the calf may have been born during the northern migration, possibly only days prior their sighting in the Gold Coast bay. The greatest number of calves was observed in October (38%), followed by August (21%) and September (19%).

The behavioural state "slip under" occurred significantly more frequently in mother-calf pairs than in pods without calves ($F(1,74)=4.42$, $p<0.01$). Breaching occurred significantly more frequently in mother-calf pods than in pods without calves ($F(1,501)=6.52$, $p<0.01$) and occurred significantly more frequently in calves than in mothers ($F(1,74)=5.83$, $p<0.02$).

The mean dive time of mothers and calves was 3.6 mins and the mean travel was 2.35 knots. In contrast, the mean travel speed in pods without calves was 3.5 knots with a similar average dive time. As expected, the mean blow/surfacing was significantly higher in mother-calf pods, at 6.2, than in pods without calves ($F(1,458) = 5.83$, $p<0.02$), where the mean was 4.89. These observations are consistent with a significant decrease in swim speed in post-August (southern migration) observations ($F(1,360) = 27.08$, $p<0.01$) (Figure 5).

4. Discussion

4.1 Summary

The analyses of the first year of continuous observations of humpback whales in the Gold Coast bay showed a large number of sightings (518 in 101 observation days), confirming the region as an aggregation area (DEH, 2005). Mother-calf pairs were mainly sighted from August until November inside the Gold Coast bay indicating that the bay-like environment of the Gold Coast waters may function as a resting spot. Additionally, we determined that calves frequently used the area for activities such as breaching. The observed pods were significantly slower when calves were present (Figure 5) with the general swimming speed being related to the direction of migration – faster during northern migration and slower during southern migration. This was also confirmed by the finding that the whales were moving on more direct paths during northern migration than during the southern migration.

4.2 Comparison with observations from Hervey Bay

The findings of this study are coherent with those long-term studies in Hervey Bay (Corkeron et al., 1994; Paterson et al., 1994; Dawbin, 1997; Chaloupka et al., 1999; Franklin et al., 2010). This bay is located at 25°S, 153°E. It is a wide, shallow, often sandy bay (< 18 m deep) (Corkeron et al., 1994) and approximately 175 nm north of the Gold Coast bay. Hervey Bay has been recognised as a resting and in earlier days as a breeding ground for humpback whales (Corkeron et al., 1994). The area is frequently visited by humpback whales during the southern migration for resting and socialising.

The average number of whales per pod sighted in Hervey Bay during an intensive survey period of 13 years was 2.26 (Franklin et al., 2010). This is in line with our first year of observation at the Gold Coast bay returning an average of 2.4 whales per pod. Pods with two whales present (pairs) were the most frequently observed at 45 % (Hervey Bay, 57 %) (Franklin et al., 2010) and one third of all pods observed in the Gold Coast bay had one or more calves present (Hervey Bay, 40%) (Franklin et al., 2010). Proportionately, calves were present less frequently in Gold Coast pods than those in Hervey Bay. This may indicate lower number of mother-calf pairs in the Gold Coast bay. However, mother-calf pairs may particularly use the 3nm zone (shallow <20m and sandy bottom) for resting and this area was not covered by our surveys. It has been suggested that females with calves prefer shallower waters close to shore to minimize predation by sharks and/or to avoid harassment by males (Whitehead and Moore, 1982; Glockner and Venus, 1983; Mattila et al., 1989; Smultea, 1994), or as a function of social organisation (Ersts and Rosenbaum, 2003).

Similar to Hervey Bay, the proportion of pods with calves present increased and the number of singletons decreased towards the end of the year. High numbers of singletons were sighted in July, at which time the whales are finding their partners (Garrigue et al., 2001). The first calves observed in the Gold Coast bay occurred end of June. Therefore, calves accompanied by mothers may be between a few weeks to 3 months of age (Chittleborough, 1953; Chittleborough, 1958), supporting the hypothesis that the Gold Coast bay is not a calving ground, but rather a stopover for mothers with calves during the southern migration.

4.3 Using data from whale watch operators

There are benefits of using whale watch operators as platforms of opportunity for observations. Data from whale watch vessels can provide information on distribution, without expensive survey effort (e.g. Weinrich et al., 2000). The frequency and intensity of survey opportunities for certain areas is often high and enables fine scale analyses (Higham and Lück, 2008). Behavioural observations from land would allow more observes but also limit the time of observation of an individual. The whale watch boats often drift alongside the whales for 30-60 minutes with their engines turned off providing an excellent opportunity to observe individual behaviour. However, the use of whale watch boats for behavioural studies is confounded by some factors. Observations of behaviours may not reflect the entire range of behaviours displayed in an area. When using boats as observation platforms physical factors like changing water properties that may influence whale presence and behaviour as well as the influence of wave height (visibility) on naked eye observation can be confounding factors. A detailed investigation into the effect of physical factors that may influence behaviour was not possible due to limited data points. It is also difficult to collect distribution and abundance information for a larger area (e.g. > 100 sqkm) from whale watch boats. There is a tendency of whale watch boats to continuously go to the same areas and they are restricted to remaining outside the 3nm zone, thereby providing biased information. For more detailed studies it is proposed to use a combination of land and boat surveys and increase the number of observers as well as spatial coverage.

4.4 Conclusions

Information on humpback whale movement patterns and core activities in urbanised coastal waters can be collected with the assistance of the tourism industry. This is useful for estimating trends and to investigate areas of further research and may ultimately help to improve the management of humpback whales in urbanised coastlines. The whale watching industry can make valuable contributions to the understanding of cetacean populations and the number of whale watch operations actively collecting data should increase. Involving whale watch tour operators also allow for raising environmental awareness amongst the passengers (Higham and Carra, 2003). Our data on pod characteristics of humpback whales in the Gold Coast bay indicated that the bay provides an important habitat for whales and is frequently used by mother-calf pairs, as a temporary stopover during their southern migration to Antarctic feeding grounds. Similar behaviours were observed compared to the aggregation site in Hervey Bay confirming the importance of the Gold Coast bay as a habitat for humpback whales. However, site fidelity and total number of individuals using the Gold Coast bay require further investigation. Future studies in the Gold Coast bay should use measures of individual identification to estimate time of residence (Katona et al., 1979; Kniest et al., 2010) and undertake abundance and distribution estimations (Vigness-Raposa et al., 2010).

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Figures and Tables

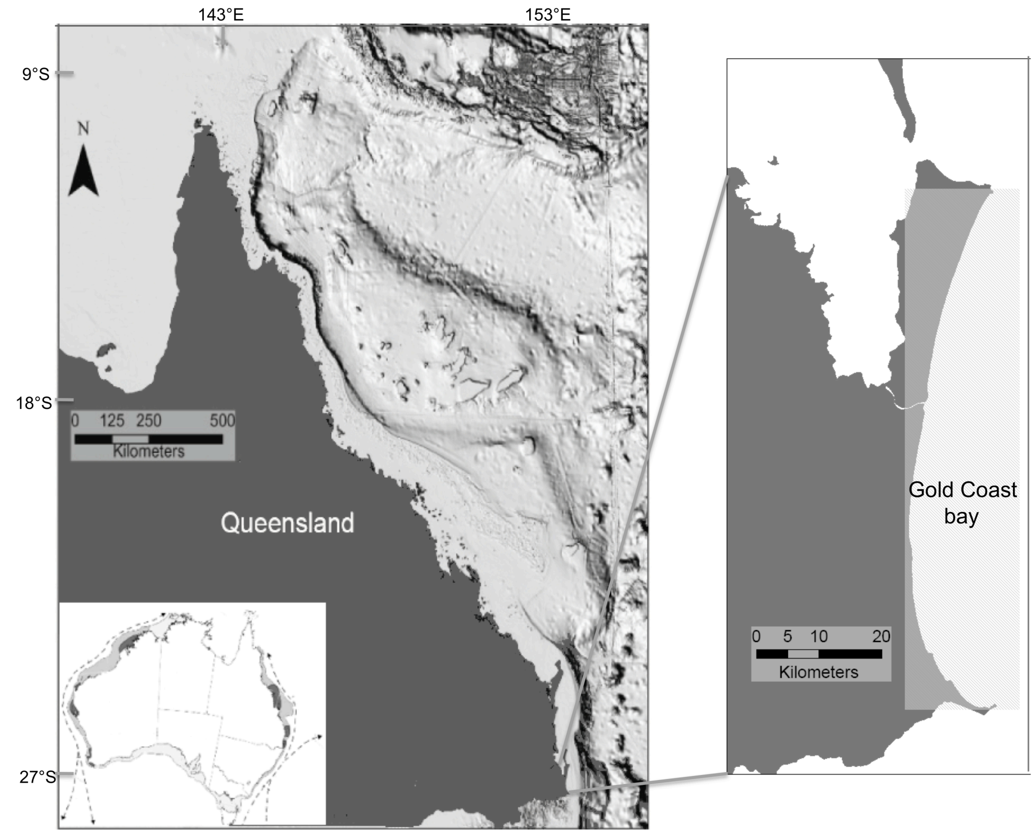
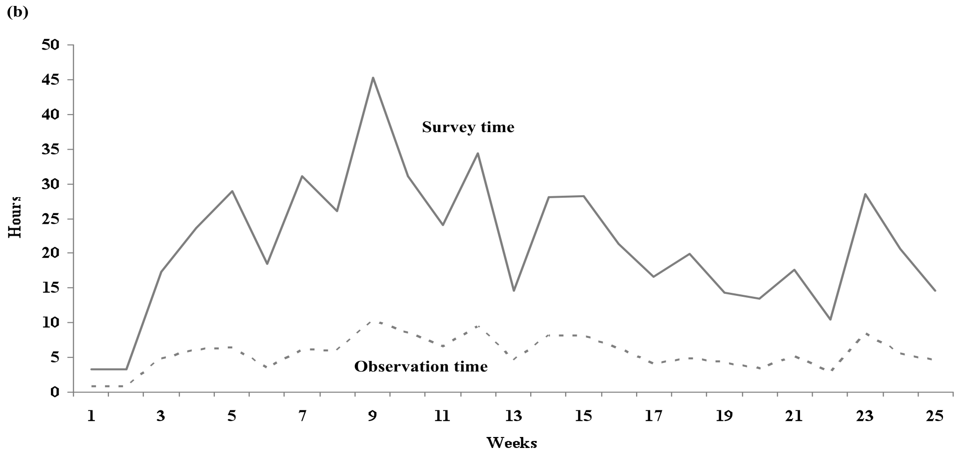


Figure 1. Location of the Gold Coast bay on the eastern coast of Australia. The extent of the observation area is indicated by the grey box. Map of Australia showing migratory pathways of Australina humpback whale populations. Recognised aggreagtion sites are indicated in dark grey along the Australina coast (DEH, 2005).



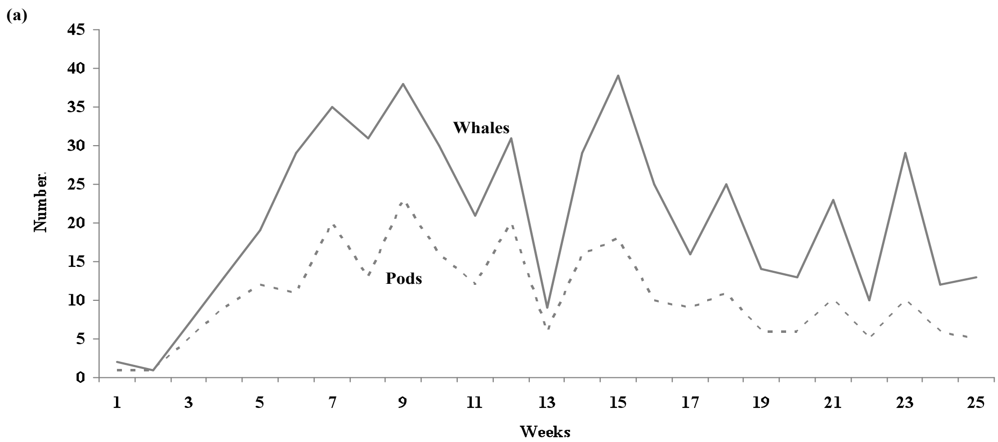


Figure 2. Weekly observations of humpback whale pods, individual whales (a) and observation hours (b) from May to November 2010 at the Gold Coast bay.

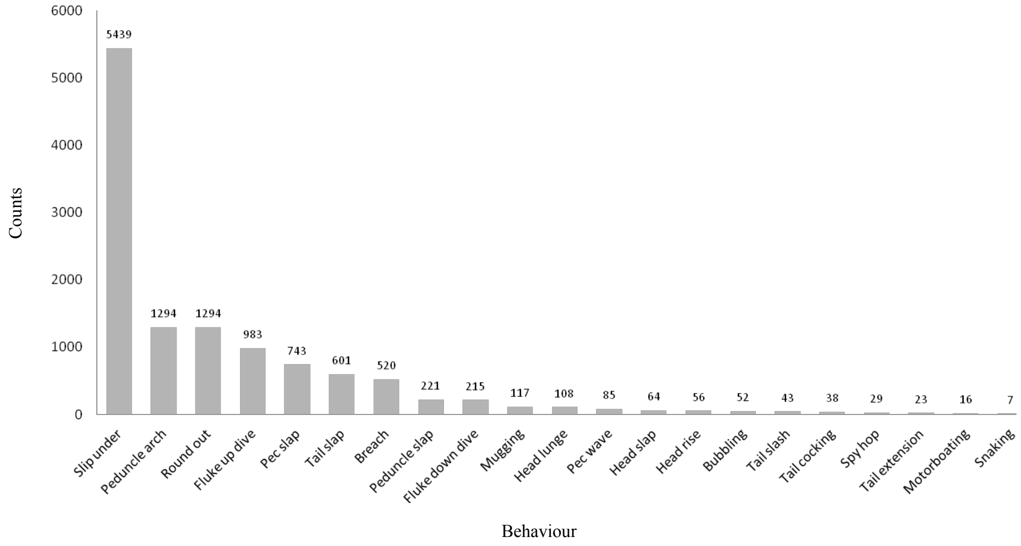


Figure 3. Frequencies of 21 observed behavioural states.

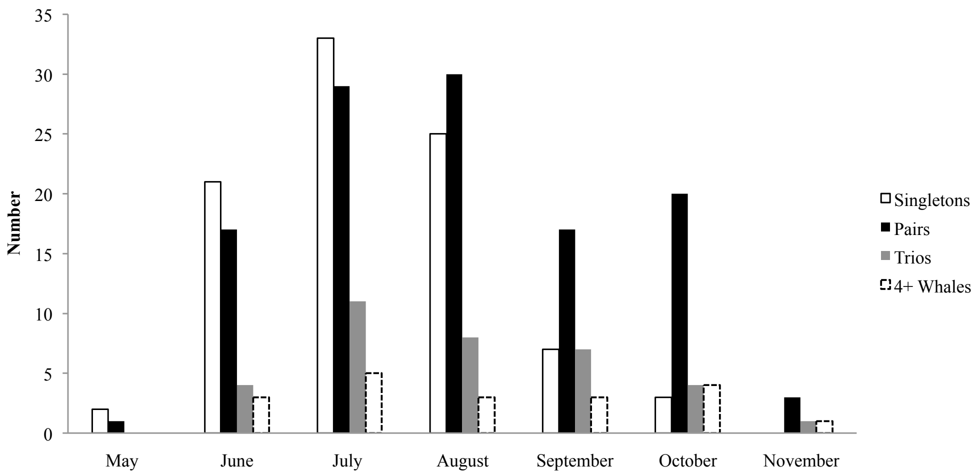


Figure 4. Proportions of pod size over months.

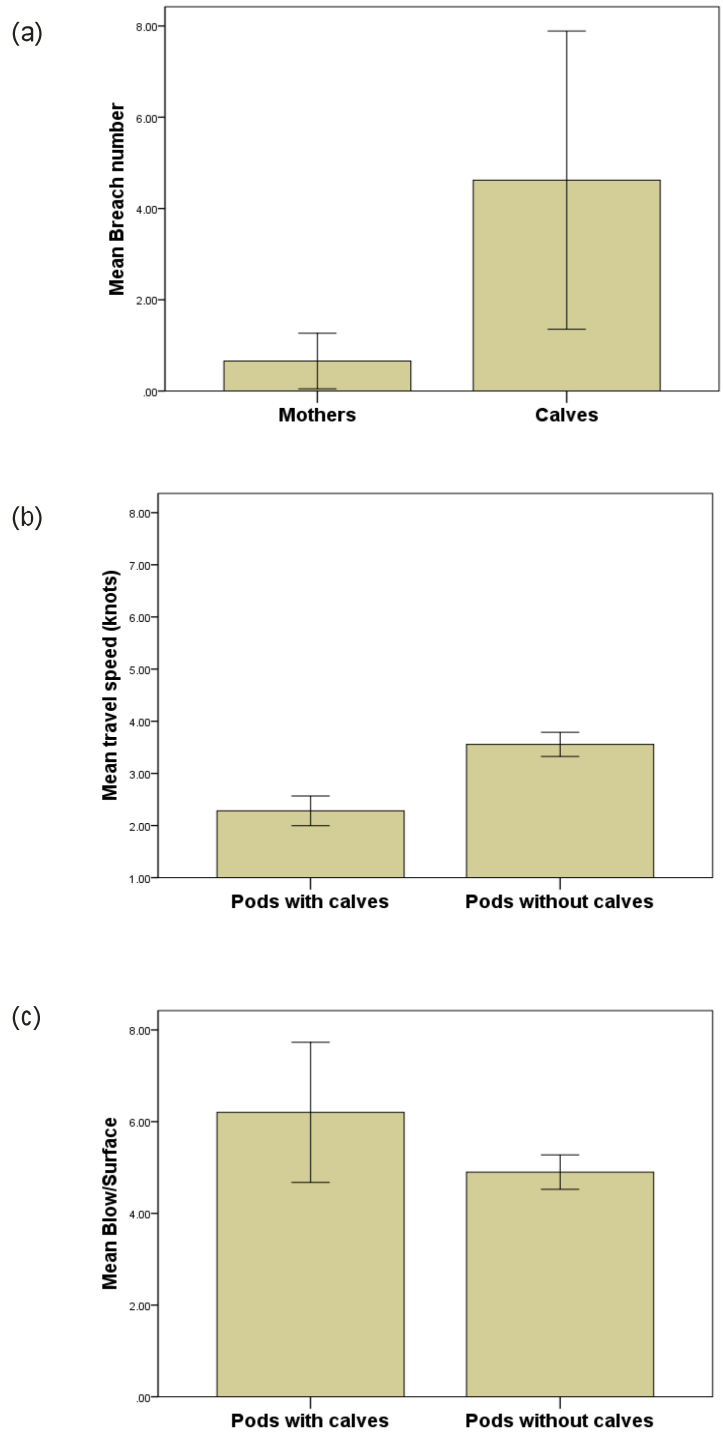


Figure 5a-c. ANOVA results for a comparison of breaching between mother and calves (Fig. 5a) comparison between pods with and without calves in regards to mean travel speed (Fig. 5b) and number of blows per surfacing (Fig. 5c).

Table 1. Description of 21 behavioural stages recorded during humpback whale observations.

Common behaviour (> 100 counts)	Behaviour description	Less common behaviour (< 100 counts)	Behaviour description
Slip under	whale submerges without rounding out and/or arching the peduncle	Mugging	whale or whale pod stay within a few meters of a vessel
Peduncle arch	peduncle arch appears at the surface (e.g. in attempt to dive deeper);	Pec wave	whale extends one pectoral straight up while lying on its side at the surface or both pectoral fins are waved in the air while the whale lies on its back
Round out	diving descent by arching its body (after the last inhalation);	Head slap	whale propels half its body out of the water in a nearly perpendicular direction and hits the water surface with a pound
Fluke up dive	tail flukes brought straight up into the air, exposing the entire ventral surface	Head rise	head is brought up above the surface at a 45-90° angle (eye is generally not exposed)
Pec slap	pectoral fins are slapped at the surface while whale rolls or lies on its side	Bubbling	release of continuous, controlled amounts of air
Tail slap	tail stock and fluke smacked forcefully on water surface	Tail slash	whale strikes its tail in a side to side, slashing movement
Breach	whale propels itself out of the water (clearing the surface with two-thirds of its body or more)	Tail cocking	whale is lying upright in the water, caudal peduncle bent and slightly arched at its posterior extremity (flukes curled down)
Peduncle slap	rear portion of the body, including the caudal peduncle and the flukes thrown up out of the water and then brought down sideways	Spy hop	head is positioned vertically above water with eyes exposed
Fluke down dive	flukes are brought clear of the water (ventral surface not exposed);	Tail extension	flukes and caudal peduncle extended straight into the air
Head lunge	head brought above surface while whale lunges forward fast	Motorboating	whale swims rapidly at the surface with head above body parallel to the surface
		Snaking	S-shaped postural display anterior portion of the head is angled out of the water (dorsal fin above the surface, peduncle arched).

Table 2. Summary of number of whales in pods between May-November 2010 in the Gold Coast bay and number of whales in pods with no calves present and calves present.

Individuals per pods	Pods with no calves present		Pods with calves present	
	n	%	n	%
1	91	40.5	0	0
2	90	40.0	27	73.0
3	28	12.4	7	18.9
4+	16	7.1	3	8.1
Total	225	100.0	37	100.0