Title

Presence and movement of humpback whale (*Megaptera novaeangliae*) mother-calf pairs in the Gold Coast, Australia

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Abstract

Identifying and protecting key habitats for species is crucial as anthropogenic influences increase, particularly in coastal areas. This increasing anthropogenic pressure on the recovering humpback whale (*Megaptera novaeangliae*) population may require adjusting management and conservation strategies. The Gold Coast bay in eastern Australia has long been hypothesised to be an important habitat, primarily for humpback whale mother-calf pairs. Here we investigated distribution, temporal patterns and behavior from 2,305 humpback whales in the Gold Coast bay from 2011-2017. The data was collected from whale-watching vessels using citizen science. We analysed seasonal presence of mother-calf pairs, dive times, direction of movement and location to determine possible habitat use of the bay as a resting area. In average a quarter of all sighted whales were mother-calf pairs with peaks of sightings each October. The recorded average dive time of 3.20 minutes was short compared to that in migratory corridors and there was a difference in dive times between pods with calves and without calves. Mother-calf pairs were sighted more often closer to shore relative to other pods. We compared our results to recognised breeding and resting grounds and found similar results, indicating that the Gold Coast bay may serve as an important stop-over for humpback whale mother-calf pairs.

Keywords: marine conservation, humpback whales, calves, resting, citizen science

Introduction

Marine mammals are key species in the ocean food web and regarded as indicators of environmental and anthropogenic impacts (Mössner and Ballschmiter 1997). Noise, pollution, habitat disturbance, entanglement in fishing gear, and ship collisions are some of the biggest threats to marine mammals worldwide (Lascelles et al. 2014). This is of concern particularly to the more vulnerable new-borns and sub adults from mysticetes, as continuous disruption through noise, boat strikes and entanglements can lead to reduced fitness (Braithwaite et al. 2015) or in worst cases, mortality (Torre-Williams et al. 2019).

As humpback whales primarily utilize the neritic zone of the ocean during their breeding season, they are particular vulnerable to entanglement in fishing gear and impacts from boating through vessel strikes and vessel noise (Aschettino et al 2020; Noad et al. 2019). Impacts from vessel noise are increasingly being reported worldwide (Reeves et al. 2005) and can cause major stress for the animal resulting in excessive cost of energy with potential cascading affects on long term survival (Alava et al. 2005).

The humpback whale (*Megaptera novaeangliae*) population of east Australia was severely depleted by modern whaling, bringing the population down to 3-5 % of its pre-whaling population size and at great risk of local extinction (Noad et al. 2008). Whaling ceased on humpback whales in Australia in 1963 before the end of all commercial whaling in Australia in 1978 (Paterson et al. 1994). Although whaling has ceased, and humpback whales in east Australia are now recovering well, some populations such as the South Pacific stock F is recovering at a slower rate (Constantine et al. 2012). Humpback whales face new challenges from increasing anthropogenic pressure, particularly in highly urbanized coastal regions as well as challenges from the impact of climate change with increasing food variability in the

feeding grounds (Avila et al. 2019), which can result changes in timing of arrival at a breeding ground.

Each year, an estimated 28,000 humpback whales (Noad et al. 2019) migrate alongside the east coast of Australia (breeding stock E1), on their annual migration between the Antarctic feeding grounds by the end of summer (December-May) and the winter (June-October) breeding grounds in the tropical waters of the Coral Sea in northeast Australia, where mating and parturition occurs the following season (Brown and Corkeron 1995). After breeding, the whales return south and are known to have stop-over locations alongside the coast (Corkeron et al. 1994) and some opportunistic feeding areas (Owen et al. 2017). This provides opportunities specifically for mothers and calves to rest, and for the mothers to teach their young the skills needed for surviving the long journey to Antarctica (Franklin et al. 2014).

A major resting site on this southward migration is Hervey Bay (Franklin et al. 2014) and Jervis bay (Bruce et al. 2014), where the shallow and sheltered waters provide protection for the calves from strong winds and currents as well as harassing bulls and potential predators (Corkeron et al. 1994). In some years, the percentage of calves in Hervey Bay is as high as 40%, towards the end of the season in September and October (Franklin et al. 2011). Mother-calf pairs may stay up to two weeks in the bay (Franklin 2014), demonstrating its use as a resting area and underlining the critical importance of Hervey Bay for humpback whales during their southward migration. Indeed, due to its essential role as a resting site during the humpback whale southward migration, Hervey Bay was declared a Marine Protected Area in 1989 (Corkeron et al. 1994).

South of Hervey Bay, Moreton Bay and Gold Coast bay form areas providing sheltered waters. The Gold Coast bay and in particular the southern part provides calm waters and has been acknowledged as a humpback whale aggregation site (DEH 2005), but the role of the bay and its importance to migrating humpback whales is yet to be fully determined. Previous studies suggested that the bay serves as a resting ground for humpback whales (Meynecke et al. 2013) similar to Hervey Bay. Mother-calf pairs are known to prefer calm and shallow waters (Whitehead and Moore 1982) and have been sighted regularly in the area. In a recent study from the Gold Coast bay, the presence of new-born calves within the bay was demonstrated, suggesting it plays a different and more vital role than previously thought (Torre-Williams et al. 2019). Here we aim to assess the role of the Gold Coast bay for humpback whale mother-calf pairs as a possible resting site by investigating relative spatial distribution of mother-calf pairs in the study area, dive times and frequency of occurrence.

Materials and Methods

Study area

The Gold Coast is the 6th largest city in Australia and the most southern city in the state of Queensland, stretching for 50km along the coastline and bordering the state of New South Wales. It is a fast growing region with a population growth of 3.5 % per year (Hossain et al. 2013) and the highest development rate in Australia. The Gold Coast bay extends about 30 km offshore and runs approximately 80 km in length. The area covered in this study extended from Jumpinpin in the north (27°45'14.2" S; 153°26'15.9" E) located off Stradbroke Island to Tungun in the south (28°14'31.2" S; 153°49'54.7" E).

The Gold Coast bay faces east to the Coral Sea of the South Pacific Ocean and is characterized by its sickle shaped shoreline (Figure 1).

The region experiences a climate with a sub-tropical hot and humid wet season (November-March) and a mild and dry season (April-October). The area around the Gold Coast has an average wave height of one meter (Mirfenderesk & Tomlinson 2008) with an average depth in the central part of the bay of 40m. The inshore coastline of the bay reverses the coastal currents and creates calm waters in particular in the southern part of the bay. Our study was focused within a few nautical miles of the Seaway, covering an area of approximately 500 km² (Figure 1). The Seaway is the main shipping entrance to the Gold Coast bay from an inland water body known as Gold Coast Broadwater. It consists of a long shallow estuary, in which an artificial channel was established by two rock walls leading out to the Pacific Ocean.

Data collection

Data were collected by experienced observers on board of three major commercial whale watching vessels: “Whales in Paradise”, “Spirit of Gold Coast”, and “Gold Coast Whale Adventures” as part of a citizen science monitoring program run by Humpbacks & High-rises Inc. Surveys were undertaken throughout the regional whale season from June to October between 2011-2017. The extend of the survey area was defined by the furthest recorded whale watch trip from the main port. Each survey trip lasted between 2.5-3 hours (between 9:00 to 12:00 h) with three trained observers per survey per day. An average of 72 surveys per year (502 in total) were included in this analysis (Table 2). On each survey, the observes recorded GPS coordinates of the vessels position, depth, date and time of humpback whale observations, as well as presence of calves, pod size and composition, direction of movement, and dive times (Meynecke et al. 2013). Only one survey per day was undertaken, however, it is possible that the same individuals were encountered the following day.

The direction of movement was recorded upon first approaching the whales, and the GPS locations were recorded twice, once upon finding that a stable and positive interaction was established with an individual or a pod within less than 500 m distance and again when the interaction ended. The start of observation location was used for spatial analyses. Mother-calf pairs were defined as two individuals travelling together with one individual being one third (calf) or half (yearling) the length of the accompanying whale with whom they maintained a close range and constant relation with (Acevedo et al. 1995; Valsecchi et al. 2002). A whale observed in close and constant relation with a mother-calf pair was regarded as an escort of the pair. Whales travelling alone were classified as either juveniles (< 10 m) or adults (> 10 m). A regular stop-watch was used to measure the duration of dives. A 'dive time' was recorded for the calf when possible as calves have a limited dive capacity, thus need to surface more frequently. The dive time was recorded when the whale displayed a round out, indicating a deeper dive and ended once the whale reappeared on the surface. If multiple dive times were recorded for the same pod during observation (generally no longer than 30 minutes per pod) the average dive time was used for analyses. To ensure consistency in data collection across years, new volunteers were trained at a workshop and accompanied by experienced observers on the water. An overall bias towards surface active pods may occur due to whale watch operators often seeking active pods for a better customer experience. Mother-calf pods, in particular with new-borns, are less likely to be approached, and so their numbers may be underrepresented in the data.

Data analysis

Adults and calves

Duplicates and incomplete data entries were excluded prior to analysis, removing 248 data entries from 1354 observations. Data was summarised by month and season and compared to known breeding grounds in other areas. The proportion of calves was calculated using the number of total calves for each month and divided by the total amount of whales surveyed each month. Data for each month of the seasons were filtered and the directions “North”, “South”, “Other directions” (pods that were moving mainly east or west) and “Undefined” (pods that were not moving in a clearly defined direction including circling and rapid direction change) were calculated and assigned to each month to determine the general direction of movement during observation. QGIS (QGIS Development Team 2009) was used to create a relative heatmap displaying the density of whales within the area of whale watch trips. A Mann-Whitney U test was used to determine if there was a difference between pods with calves and pods without calves in relation to distance to shore. All assumptions required for a Mann-Whitney U test were met.

The data was based on the GPS location of the whale-watching vessels when whales were within less than five hundred-meter range. The location and number of whales recorded is used as a relative abundance measurement for the area used by whale watch operators. QGIS was further used to calculate each GPS coordinate’s distance to shore, in order to examine a difference between pods with calves and pods without calves’ distance to shore.

Dive times

To compare the dive times between pods with and without calves, all dive times and observations with calves present and absent were filtered and tested for relationships using a z-test for comparing two means. Given the large sample size the central-limit theorem

suggests the data approaches normality (Fischer, 2011). The average of calves sighted per year was calculated and the dive times summarised through the boxplot function in R 3.5.0 (Rcore team 2018).

Results

Adults and calves

A total of 2,305 humpback whales were recorded during 7 years of surveys. Of these, 366 mother-calf pairs were observed, corresponding to approximately 23% of all observed humpback whales. A map showing the relative density of whales observed in the study area with mother-calf pairs and without mother-calf pairs demonstrated that pods with calves were observed significantly closer (average of 2 km) to shore than pods without calves (Figure 2 A-B). All whales were observed in average 5.9 kilometres from shore with mother-calf pairs sighted 4.8 kilometres ($n = 257$) and pods without calves sighted at 6.8 kilometres ($n = 377$; Mann-Whitney U value 28824.5, $p < 0.01$). This corresponds to a mean depth for mother-calf pairs of 33 m and for pods without calves of 40 m.

The travel direction was used to determine which age classes and cohorts were likely associated with the migration, socializing and resting and when the time of transition between northern and southern migration occurs.

Over 60% of adults and 48% of mother-calf pairs were moving in a northern direction in June, July and August. While 58% of adults and 71% of mother-calf pairs were primarily seen to be moving southwards in September and October (Table 1).

The average number of whales sighted within the study area over the 7-year survey was 4.5 humpback whales per square kilometre. The proportion of mother-calf pairs varied annually between 11.5% and 30% (Table 2) and peaked towards the end of the season in October with

nearly 40% of all sighted whales being mother-calf pairs for all 7 years (Figure 3). Of all mother-calf pairs, an escort whale accompanied 28.4%.

Dive times

The average dive time for pods without mother-calf pairs was 3.20 minutes (SD: 104 sec) and was consistent over the 7-year period. Moreover, the average dive time for mother-calf pairs was 3.14 minutes (SD: 99 sec). A z-test of comparison between the two means was applied (z value: 1.645) showing shorter dive times for pods with calves at a 90% confidence level but not for 95% (Figure 5).

Discussion

Our study demonstrated the presence of mother-calf pairs close to shore and showed dive times associated with resting behaviour for the 7-year observation period in the Gold Coast bay. The relative abundance of mother-calf pairs varied during the migration season increasing towards the end of the southward migration in October, when an average of 39% of all observed whales were mother-calf pairs. These results are consistent with previous studies such as Guidino et al. (2014) as well as a study from 2010 in the Gold Coast bay that found 38% of all observed whales were mother-calf pairs in October (Meynecke et al. 2013)

The proportion of calves in the humpback whale resting area Hervey Bay has been estimated at around 40% during October (Franklin et al. 2011). In breeding grounds the proportion varies between 16-38 % with 38 % in the breeding grounds of Au 'au, Kalohi, Pailolo channels of Hawaii (Pack et al. 2017), 21 % at the Serra Grande (Goncalves et al. 2018), and 16% at the Albrohos breeding grounds in Brazil (Martins et al. 2018). The proportion of mother-calf pairs observed in the Gold Coast bay falls within the range of previous studies

investigating areas of importance (resting grounds) to mother-calf pairs. The overall average of mother-calf pairs presence (23%, Figure 4) is also substantially higher than the proportion of calves at non-breeding sites and along migration corridors. For instance, the proportion of calves was as low as 0.9 % in a study conducted on North Stradbroke Island, Queensland (Australia) during the northern migration months of June-July (Noad et al. 2008), and the average proportion of calves at humpback feeding grounds in the Northern Pacific was estimated at 7% (Steiger & Calambokidis 2000).

In contrast to resting areas for mother-calf pairs such as Hervey Bay where the majority of mother-calf pairs occur in September-October, our study demonstrated the presence of humpback whales' mother-calf pairs in the Gold Coast bay throughout the entire whale season from June to October. This indicates that the Gold Coast bay is more than an aggregation site for humpback whales but also plays an important role as a resting site for mother-calf pairs of the breeding population E1 of east coast humpback whales during the northern and southern migration. The relatively high number of calves observed in the beginning and middle of the whale season from June to August, might indicate opportunistic calving or an emerging new calving area alongside the coast.

Calves sighted in this study in June and July were likely not born in their known breeding ground in the Great Barrier Reef, which are more than 500 km north of the Gold Coast bay. These sightings further support the finding of Torre-Williams et al. 2019, who demonstrated the presence of new-born calves in the Gold Coast bay.

Diving behaviour

The observed average dive time for mother-calf pairs of 3.14 minutes is comparable to a study in Hawaii reporting average dive times for calves to be 3.15 minutes (Stimpert et al. 2013).

Specific dive times for calves were not available for Hervey Bay, however when comparing our average dive times for all pods (mother-calf pairs included) of 3.20 minutes (192 seconds) our findings are in close range of Hervey Bay's average dive time of 2.48 minutes for all pods (Stamation et al. 2010). Both average dive times between mother-calf pairs and other pods were similar and short in the Gold Coast. The short dive times generally indicate resting or socialising defining the Gold Coast bay as a resting and socialising area similar to Hervey Bay (Franklin et al. 2014). Both speed and dive times are often indications of habitat utilization of a particular area. Dive times are generally shorter at breeding and resting sites, due to various behaviours such as socializing, resting or non-travelling states and mother-calf interactions. Mothers are generally limited in dive duration when accompanied by their calf (Baird et al. 2000) as studies indicated a limited diving capacity of calves, which improves with age (Szabo & Duffus 2008).

Dive times at non-breeding sites were reported to be as high as 14 minutes (Chu 1988) and at feeding grounds, average dive times of approximately 3.50 minutes for all pods were observed as a result of feeding activity (Szabo & Duffus 2008). However, detailed behaviour studies from migratory corridors or feeding grounds are limited due to the inaccessibility of the areas.

Conservation and management

Humpback whales are exposed to increasing human activities along developed coastlines and/or large fishing industries (Braithwaite et al. 2015). Migrating close to shore, particularly in a highly urbanized area such as the Gold Coast, causes risk to whales and other marine life as they are often exposed to various threats associated with human activity. Threats include entanglements, boat strikes and noise pollution (Aschettino et al. 2020; Alava et al. 2005;

Waerebeek et al. 2007; Wisniewska et al. 2018). Entanglements are one of the leading causes of humpback mortality and can have life-long consequences for surviving individuals (Van der Hoop et al. 2016). Mother-calf pairs utilizing near coastal waters can be particularly vulnerable to entanglements, including to shark nets deployed as part of the Queensland lethal shark control program (Meager et al. 2016).

Furthermore, noise, harassments and collisions with shipping vessels and leisure boats cause stress, habitat displacement, and possibly long-term health impacts for whales. As new-borns are physiologically restricted in lung capacity, body size, swimming and diving endurance as well as in control of buoyancy (Cartwright & Sullivan 2009), effects of multiple disturbance factors make them particularly vulnerable and may impact survival rates. Some studies indicate impacts on animal behaviour from whale watching (García-Cegarra et al. 2019), while others have found little impact (New et al. 2015). However, exposure to various stressors such as boat and noise disturbances can result in a cumulative effect during the humpback whale migration along the coastline of Australia (Stamation et al. 2010). Low frequency vessel noise can cause direct overlap in acoustic signals and hinder humpback whale communication (Rolland et al. 2012).

Theoretical models suggest that increases in humpback whale travel speed in order to avoid disturbances, result in additional energy takeout from their stored blubber layer, effecting reproduction, nursing and calf growth (Braithwaite et al. 2015). Ultimately this could reduce the general health and fitness of individuals and populations, in particular, when impacts of climate change such as increased water temperature and changes in krill abundance are taken into consideration. Given the results of our research and the high vulnerability of mother-calf pairs, improved conservation management is required to reduce the risks such as entanglements (Meager et al. 2016).

Finally, management of the Gold Coast bay should be improved to ensure the health and safety of the recovering population, especially due to the high percentage of vulnerable mother-calf pairs.

As the humpback whale is a highly migratory species covering the largest migration route of any mammal (Clapman 2009), protection beyond static boundaries is critical. While this is challenging across jurisdictional boundaries, dynamic and seasonal MPAs can be a solution, as this protects key habitats for highly mobile species. One new suggestion within the current renegotiations of the United Nations Convention on the Law of the Sea (UNCLOS) from 1982, are the ‘Area-based management tools (ABMTs), which would include MPAs. Area-based management tools are marine areas beyond the limits of national jurisdiction, which contain ecosystems and biodiversity of significant ecological value.

By expanding the protection beyond national waters in the appropriate season, a year-round protection can be assured (Maxwell et al. 2020)

Conclusion

Our research outcomes underline the importance of the Gold Coast bay as a humpback whale resting area. A high proportion of mother-calf pairs were encountered in close proximity to shore (average distance 5 km). Our study suggests that the high numbers of females with their calves within the bay, represent individuals of the population which are known to be particularly vulnerable to anthropogenic threats, as such loss of their energy reserves. Determining the extent of the whale population utilizing the bay as well as a time estimation of residency, is needed to further understand the significance of the bay. This could be done using land or air-based surveys of abundance outside and within the bay. Additional research

should analyse the residence time of whales within the bay using fluke photo identification. Future citizen science surveys may benefit from detailed instructions on how to determine size, or from verification through drone footage.

In recognition of the importance of the Gold Coast bay for mother-calf pairs, improvements of current regulations and stricter monitoring of their violations are required in this area. “Reduced speed” zones could be established in areas of high mother-calf pair density and the 11 gill nets placed along Gold Coast beaches as part of the Queensland shark control program should be replaced with less harmful methods during the whale season such as drone surveillance and personal shark deterrents.

These anthropogenic threats need to be considered as part of a larger conservation management strategy in the region (Reeves et al. 2003). We therefore argue for an elevated protection status of the Gold Coast bay.

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