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Note on patterns of area use by humpback whales (Megaptera novaeangliae) in 2013 in Hervey Bay, Australia, with an emphasis on mother-calf dyads.

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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

Hervey Bay is an important habitat for humpback whales on their southern migration to their Antarctic feeding grounds. This study examined the distribution of humpback whales within the bay as it relates to oceanographic factors, such as depth and distance from shore, using data from systematic line-transect surveys undertaken from August to September 2013. Patterns of area use of mother-calf dyads were of particular interest given that they are more vulnerable to human-related disturbances than other group types. MC dyads, which are the main group type encountered in September (42.2%), showed a preference for shallow waters and specific areas within the eastern side of the bay compared to non-calf groups. These areas overlap with human activities, such as commercial and recreational whale-watching. Understanding habitat preference and patterns of habitat use of humpback whales in Hervey Bay is therefore a prerequisite for effective management of this critical habitat and whale-watching operations. This is particularly pertinent with the recent trial of the swim-with-whale activities in the region.

Keywords: Humpback whales, *Megaptera novaeangliae*, mother-calf dyads, patterns of area use, habitat preference, Hervey Bay, Australia

INTRODUCTION

Humpback whales (*Megaptera novaeangliae*) Southern Hemisphere Breeding Stock E migrates annually between Antarctic feeding grounds and subtropical breeding and calving grounds (Chittleborough, 1965; Dawbin, 1966; Kaufman *et al.*, 1990; Franklin *et al.*, 2012; Constantine *et al.*, 2014). During their northward migration from June to August, humpbacks in Breeding Stock E-1 travel up the northeast coast of Australia to the area between the Great Barrier Reef and the Australian mainland, bypassing an area known as Hervey Bay (Dawbin, 1966; DEH, 2005). During the southern migration from late-July to November, however, many humpbacks leave the main migration route and travel west into Hervey Bay (Dawbin, 1966; Paterson, 1991; DEH, 2005).

Located on the northeast coast of Australia, Hervey Bay is a shallow, sheltered region of the type typically preferred by female humpback whales when caring for newborn calves in various breeding grounds (Mattila *et al.*, 1994; Smultea, 1994; Craig and Herman, 2000; Ersts and Rosenbaum, 2003; Craig *et al.*, 2014). In Hervey Bay, humpbacks congregate in non-random clusters on the east side of the bay, near Fraser Island (Kaufman *et al.*, 1987; Corkeron, 1993; Forestell *et al.*, 2003), and different age classes utilize Hervey Bay during different times of the season. Sub-adults predominate in the beginning of the season, mature adults are common in the middle of the season, and mother-calf pairs are prevalent from mid-late season (Franklin *et al.*, 2011).

Owing in part to the abundance and proximity to shore of humpback whales, Hervey Bay experienced substantial growth of whale-watching in the late 1980s and early 1990s (Stoeckl *et al.*, 2005; O'Connor *et al.*, 2009), but factors such as competition from more accessible and conveniently-located areas has caused the industry in Hervey Bay to decline (Peake, 2011). In response, in 2014, the Queensland government began allowing trials of swim-with-whales tours in Hervey Bay (Fraser Coast Chronicle, 2014), the first of its kind for humpback whales in Australia.

Understanding how humpback whales, especially mother-calf dyads, utilize Hervey Bay is of particular importance. The introduction of swim-with-whales programs may potentially alter the behavior and fitness of the whales involved. While there has been little research examining the effects of swim-with programs on large whales, there is a growing concern regarding the sustainability of such activities (*e.g*. Samuels *et al*., 2003; Scarpaci and Parsons, 2014; Higham *et al*., 2014), which are discouraged by the International Whaling Commission, IWC (*e.g*. Carlson *et al*., 2013). Recent studies indicate that whale behavior is altered by the close boat approaches required for such programs as well as by the swimmers themselves (Kessler *et al.*, 2013; Lundquist *et al.*, 2013).

A better understanding of how humpback whales utilize Hervey Bay is essential in informing policy and management decisions regarding commercial and recreational use of humpback whale habitat. The current study examines the distribution of humpback whales within Hervey Bay as it relates to depth and distance from shore as well as patterns of area use using data from systematic line-transect surveys undertaken from August to September 2013 in Hervey Bay, Australia.

METHODS

Study Area

Hervey Bay is located at 25°00'S, 152°52'E on the east coast of Queensland, Australia (Figure 1). It is a wide, shallow embayment approximately 4,000 square kilometer (km^2), consisting of an area with sand and mud bottom, located approximately 175 nautical miles (n.mi.) north of the Gold Coast. It is generally less than 18 meters (m) deep, with depths increasing northward to more than 40 m, where the bay is connected to the open ocean via an approximately 60 km wide gap (Vang, 2002). The bay is bounded by the Queensland coast to the west and south and by Fraser Island (126 km long) along a northeasterly axis. The bay is open to the South Pacific Ocean in the north, while the Great Sandy Strait enters the bay from the south (Corkeron, 1995). At the northern tip of Fraser Island, the Great Sandy Spit sandspit separates the bay from the open ocean an additional 30 km north. This study was conducted within the Hervey Bay Marine Park boundaries, approximately 1,600 km^2 in area (Figure 1; Chaloupka *et al.*, 1999).

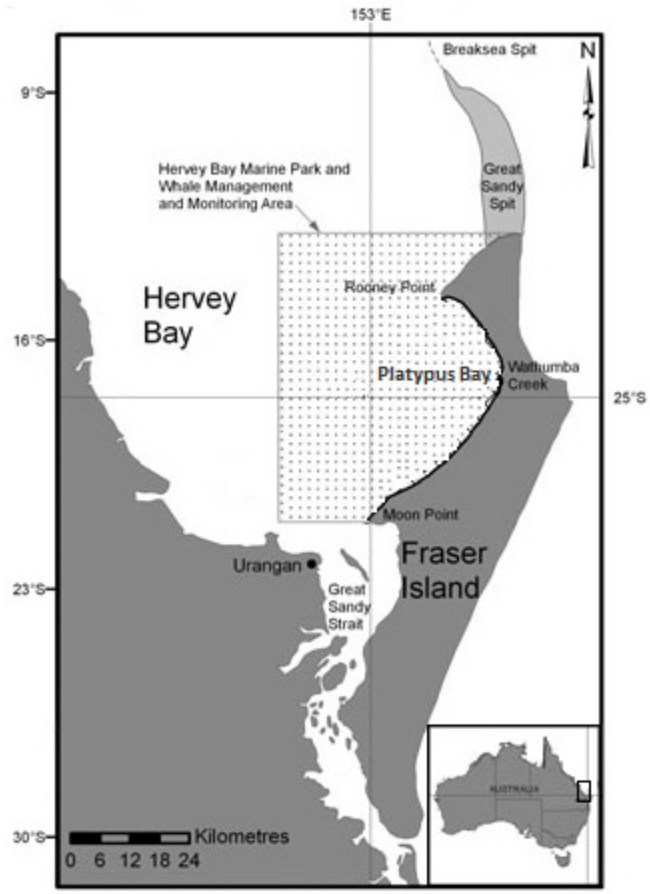

Figure 1: *The location of Hervey Bay on the eastern coast of Australia, including the Hervey Bay Marine Park boundaries.*

Definitions

The following terms have been outlined for clarification:

A *pod* was defined as either a lone (singleton) or a group of humpback whales within 100 m of each other, generally moving in the same direction, and coordinating their behavior as well as speed of travel (Whitehead, 1983; Clapham, 1993; Corkeron *et al.*, 1994). The term "pod" used here does not imply stable groups.

A *calf* was defined as an individual whale visually estimated to be less than 50% of the length of the accompanying whale, less than one body length apart, and maintaining a constant and close relationship (Chittleborough 1965; Tyack and Whitehead 1983). The adult accompanying the calf was assumed to be the mother and were collectively referred to as a *Mother-Calf (MC) dyad*.

Non-calf pods included all pods with no calves present. A proportion of the whales classified here as non-MC dyads include mother, calf and escort(s) pods, which were not identified separately as such in this report, given that the emphasis was on the former.

Vessel Surveys

Surveys were undertaken in August and September to provide a representative sample of the seasonal flow of humpback whales in Hervey Bay. Systematic line transect surveys were conducted from an 8 m motorized research vessel, fitted with a 150 hp four-stroke outboard engine. Sampling was determined by prevailing seas (Douglas Sea State (DSS) and Beaufort Sea State (BSS) ≤ 4). Direction of travel along each line (East-West, West-East or North-South, South-North) was randomly selected using the "sample" function in R (R Core Team, 2013). Speed was maintained between 10-15 knots while on effort. Weather permitting, attempts were made to survey all parts of the study area equally (Figure 2).

Surveys were undertaken primarily between 0800 and 1700. Weather conditions (*e.g.* BSS, DSS, wind direction) were recorded at the start of each transect line and updated as they changed throughout the survey to ensure detailed environmental data on covariates that might affect animal sightability (Buckland *et al.*, 2001). Global Positioning System (GPS) units (Garmin GPSmap 276C and/or Garmin 4000) tracked time and location of the vessel on a one-minute (1-min) basis.

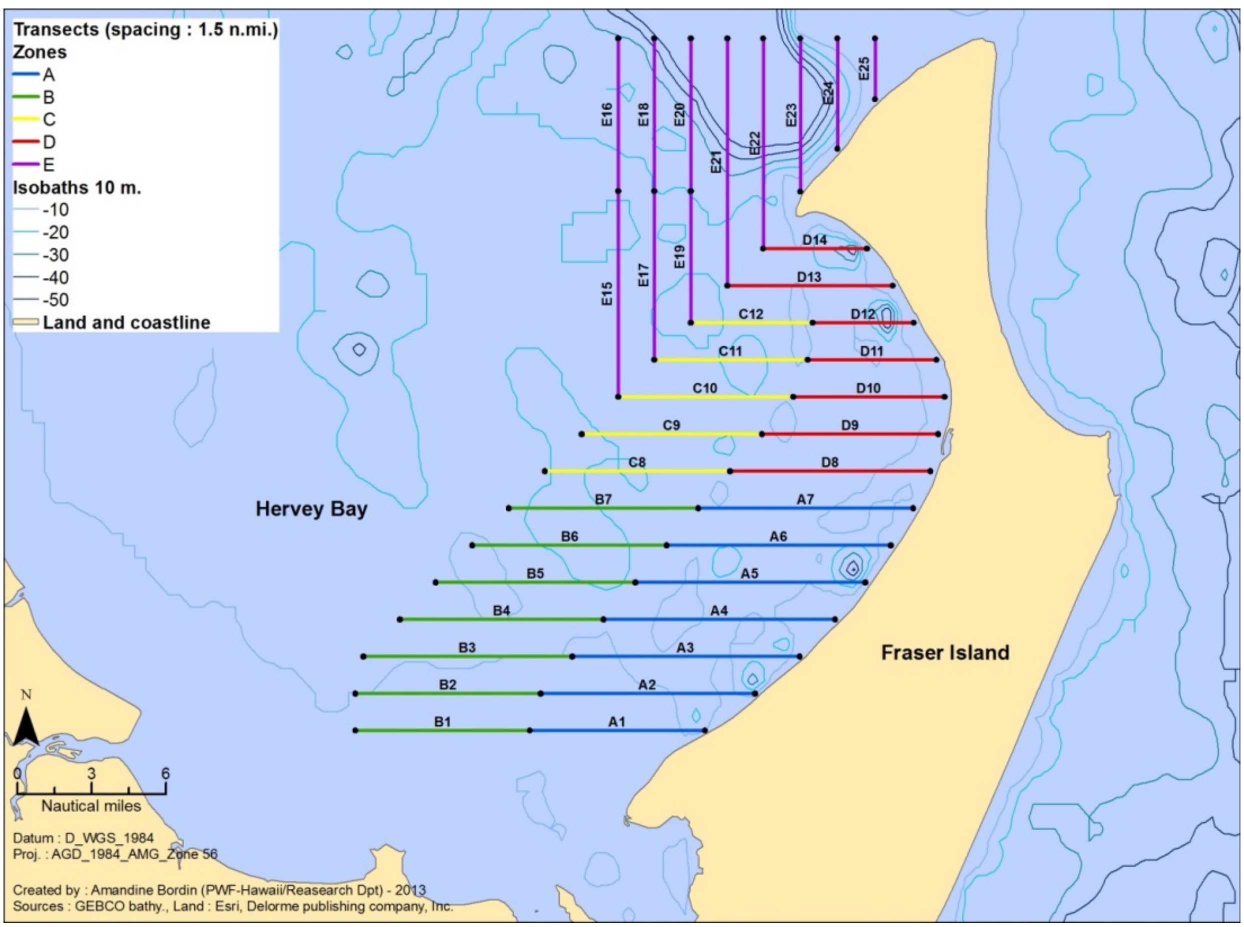

Figure 2: *Transect lines depicting survey area from August to September 2013 in Hervey Bay, Australia.*

Observations were undertaken by experienced observers using a continuous scanning methodology (Mann, 1999), by naked-eye or binoculars (Bushnell 7 x 50). While on- effort, one observer was stationed on the port and the starboard side of the helm scanning equal sections of water, from abeam to forward, at an eye height of approximately 1.8 m. A third person acted as data recorder, with remaining staff, if present, at rest. With the exception of the skipper, observers regularly rotated duties to prevent fatigue.

For each pod encountered, before the group was approached, an initial sighting position (GPS coordinates) was recorded. All pods were then approached following permit conditions as well as state and federal laws. Once within 100 m of the pod a start encounter time and positions was recorded. During the focal follow data on pod size, composition, and initial behavior were recorded on pre-formatted data sheets. Fluke and lateral body photographs (when possible) were taken of each individual whale within a focal pod with a Canon 7D digital camera equipped with a 100-400 millimeter (mm) lens, following established procedures in Forestell *et al.* (2003).

Data Analysis

To determine if there was a difference in the use of Hervey Bay between different pod types, analysis was first completed using all pods and then on a subset consisting of MC dyads and non-calf pods.

Distribution of sightings

The study area was divided into 52 sectors each with an area of 36 km^2 (6 km x 6 km). Each sector was classified by the mean depth (m) and distance from closest point of land (km). To determine the distribution of sightings, the total number of pods per sector were recorded and compared with depth and distance from shore.

Patterns of area use

Following methods presented in Karczmarski *et al.* (2000), a coefficient of Area Use (AU) was calculated for each sector, which represents the time spent in a particular sector as a proportion of the total daily observation time:

$$AU= DT$$

where D is the time spent by a pod in a particular sector and T is the total daily observation time. In cases where a single observation spanned over two sectors, the sector containing at least 75% of the time spent with the pod was selected. In cases where localization was not distinguishable, the pod was considered to be in both sectors, and the time was split evenly. To compare overall use of the bay by humpback whales, a mean coefficient of AU was calculated for each of the 52 sectors. To ensure accurate mean values, a minimum of five or more observations were required per sector to calculate the mean coefficient of AU. Sectors with less than five sightings (n = 9) were considered to have an AU of 0.

RESULTS

Effort

A total of 39 surveys in Hervey Bay waters were completed from 04 August to 23 September 2013 in Hervey Bay, traveling 4225.17 km (= 2625.4 n.mi.). In total, 274.2 hours were spent on the water and, of these, 94.79 hrs (= 34.6% of field effort) were spent with whales. There were 759 humpback whales observed in 324 pods. Of the 134 pods observed with calves present, 63.4% (n = 85) were MC dyads. Pods ranged in size from one to eight individuals. Mean group size was 2.4 (SE = 0.063, n = 324). Group composition varied between the months of August and September, with the majority of groups being sub-adults (59.5%, n = 97) and MC dyads (42.2%, n = 68), respectively.

Distribution of sightings

All pods

The majority of sightings (61.4%, n = 213) for all pod compositions were observed at depths of 5 m or less, with an overall trend of fewer pods at increased depths (Figure 3 A). A general trend of decreasing sightings with distance from shore was observed up to 20 km, after which a sharp increase in sightings was observed at distances of 20-25 km (Figure 3 B).

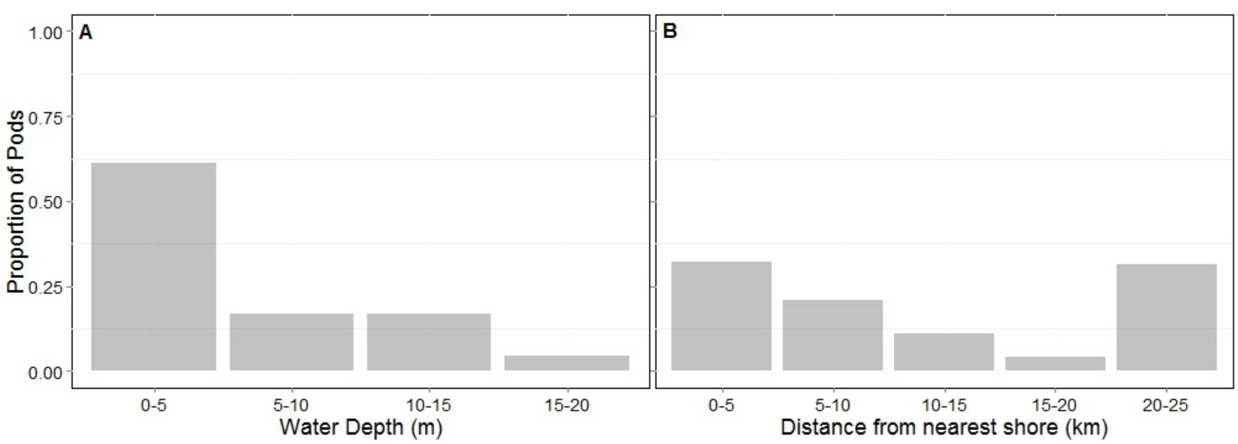

Figure 3: *Distribution of sightings of humpback whales with (A) water depth (m) and (B) distance from nearest shore (km) recorded from August to September 2013 in Hervey Bay, Australia.*

MC dyads

Approximately one third (60.5%, n = 52) of MC dyads occurred in 5 m or less of water (Figure 4 A). MC dyads also displayed a trend of decreased sightings with increased distance from shore up to 20 km (Figure 4 B).

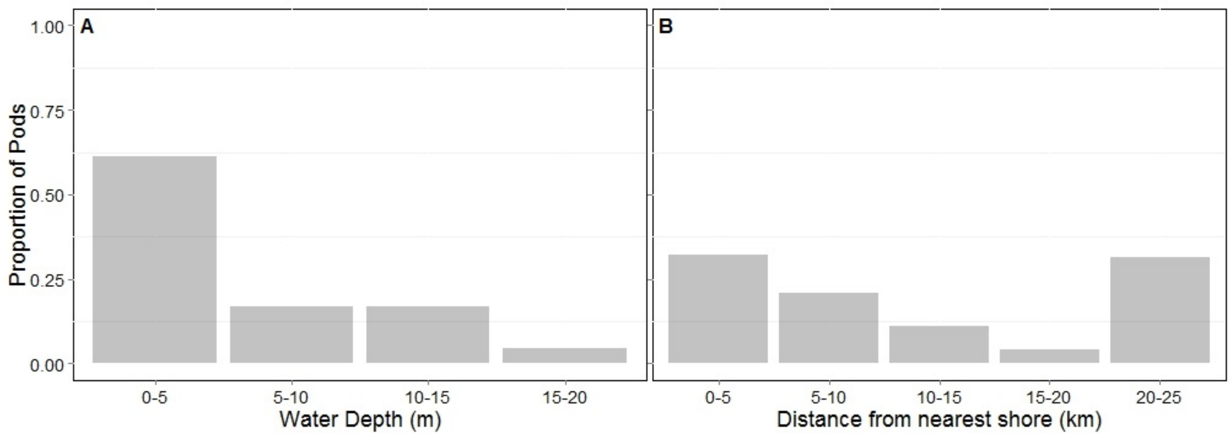

Figure 4: *Distribution of sightings of humpback MC dyads with (A) water depth (m) and (B) distance from nearest shore (km) recorded from August to September 2013 in Hervey Bay, Australia.*

Patterns of area use

All pods

The majority of humpback whale pods remained within the eastern side of Hervey Bay, close to the western coastline of Fraser Island, with higher AU observed within the south-east portion of Hervey Bay (Figure 5).

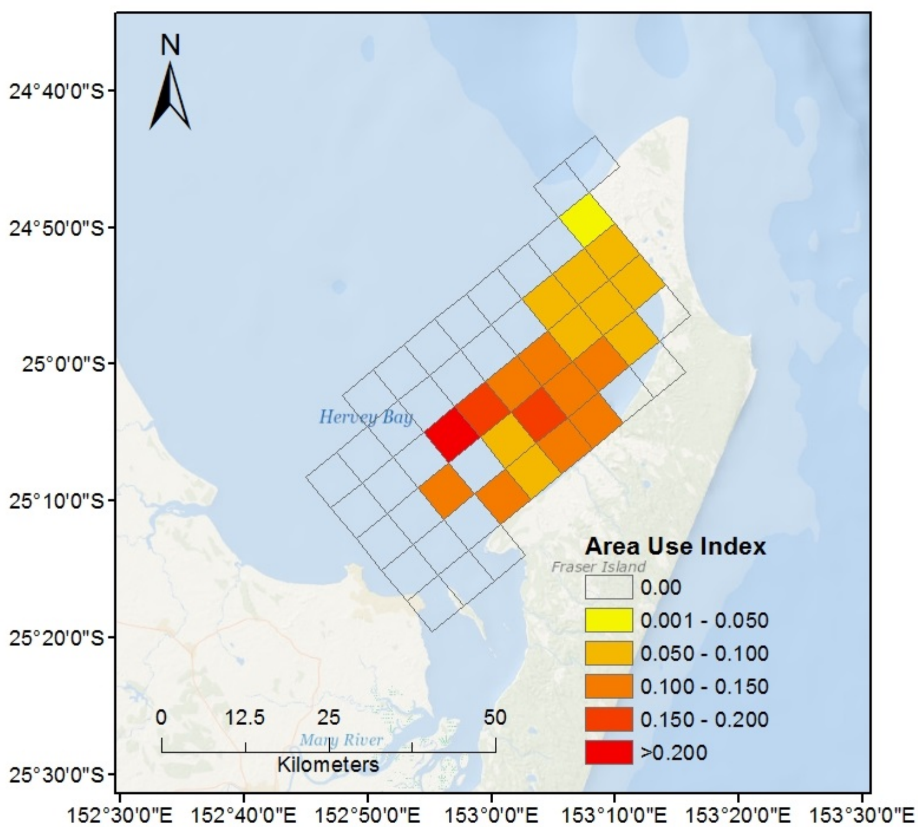

Figure 5: *Mean Area Use displayed by humpback whales from August to September 2013 in Hervey Bay, Australia.*

MC and non-calf pods

There was overlap between AU of MC dyads and non-calf pods within Hervey Bay. MC dyads, however, showed a very strong preference for areas closer to the coastline of Fraser Island, particularly between latitudes 25°10'S and 25°00'S (Figure 6 A and B).

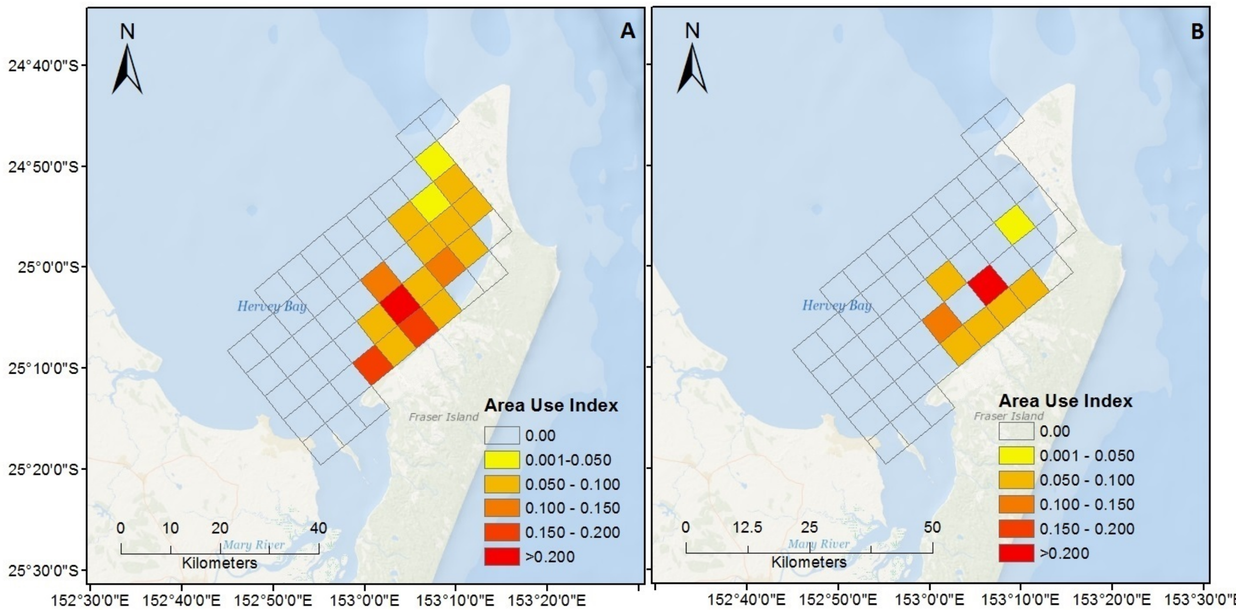

Figure 6: *Mean Area Use displayed by humpback whale (A) non-MC pods and (B) MC dyads from August to September 2013 in Hervey Bay, Australia.*

DISCUSSION

Sightings based on age class

Due to its location along the Queensland coast, humpback whales tend to enter Hervey Bay on their southern migration only (Paterson 1991), from late July to October. Chaloupka *et al.* (1999) suggested that 30-50% of the eastern Australian humpback population frequent Hervey Bay waters, with the most recent winter stopover population in the bay estimated to comprise 6,246 individuals (excluding calves) in 2007 (95% CI 5,011–7,482; Forestell *et al.*, 2011). Humpback whales tend to migrate based on age and sex classes (Chittleborough 1965), with sub-adults being first, then mature adults and MC being the final group to migrate southwards (Dawbin 1966, 1997; Corkeron 1995, Corkeron and Brown 1995; Franklin *et al.*, 2011). As a result, the composition of pods sighted in this study varied by month. Pods consisted of mostly sub-adults in August, while those with calves were more common in September. Furthermore, 42.2% of all pods observed in Hervey Bay in September were MC dyads. This percentage increased to 63.4% when only pods with calves present were considered. This is consistent with previous findings in Hervey Bay (Franklin *et al.*, 2011) and other regions (*e.g.* Ecuador: Félix and Botero-Acosta, 2011). This proportion is, however, higher than those reported in other parts of the world where MC were more likely to be accompanied by an escort, such as Hawaii (*e.g.* Herman and Antinoja

1977; Glockner and Venus, 1983; Mobley and Herman, 1985; Craig *et al.*, 2002) and the West Indies (*e.g.* Mattila and Clapham 1989, Mattila *et al.* 1994).

The first calf observed in Hervey Bay was on August 14, suggesting calves may be between a few weeks to two months old (Chittleborough, 1953, 1958). Consequently, while Hervey Bay may not be considered as a calving ground for this species, it may provide mothers with a suitable and convenient habitat for maternal care during the early stages of the southern migration (Franklin *et al.*, 2011). Care is given, in the form of food and protection to allow for preparation of their calves' first migration to high-latitude feeding areas (Clapham, 2000).

Patterns of area use

According to Corkeron *et al.* (1994), humpback whales do not migrate directly through Hervey Bay. Instead, they divert from the main migratory pathway to move into and out of the bay from the north. Once inside the bay, they aggregate in shallow waters in the eastern part of the bay, close to the western shore of Fraser Island (Kaufman *et al.*, 1987; Corkeron *et al.*, 1994; Forestell *et al.*, 2003). Aerial surveys further showed that pods are not randomly distributed but tend to aggregate in clusters (Corkeron, 1993), which might be related to social factors (Corkeron *et al.*, 1994). Results from this study, using AU analysis, support those findings, with a strong aggregation of humpback whales in the eastern part of the bay called Platypus Bay. The spatial distribution of humpback whales in Hervey Bay in 2013 suggests a differential habitat use among different group types. MC dyads preferred near-shore and shallow waters restricted to the western shore of Fraser Island (east of 153°00'E and between 25°00'S and 25°10'S).

A preference for shallower waters by MC groups is also consistent with observations made on other key winter breeding grounds such as the Dominican Republic (Mattila *et al.*, 1994), Madagascar (Ersts and Rosenbaum, 2003), Brazil (Morete *et al.*, 2007), Ecuador (Félix and Haase, 2005; Félix and Botero-Acosta, 2011), Peru (Guidino *et al*., 2014), Central America (Rasmussen *et al.*, 2007), and Hawaii (Herman and Antinoja, 1977; Smultea, 1994; Craig *et al.*, 2014), with the exception of the Au'au Channel in Hawaii (Cartwright *et al.*, 2012). Overall, across those regions, MC groups consistently favor waters less than 50 m deep, and are commonly found in depths of less than 20 m. Furthermore, in areas with steep shoreline gradients, MC dyads are mainly found close to the shore in the shallowest waters available (*e.g.* Madagascar: Ersts and Rosenbaum, 2003; Hawaii: Smultea, 1994). Conversely, where shallow waters extend offshore, females and their dependent calves show a preference for areas up to 10 km from shore (*e.g.* Brazil: Félix and Botero-Acosta, 2011). Unlike water depth, proximity to shore might not be a consistent trait in MC habitat distribution (Cartwright *et al.*, 2012). Segregation by water depth and distance from nearest shore, according to group composition, was not evident in this study and is likely a result of the shallow nature of Hervey Bay, and particularly Platypus Bay, which have maximum depths of 15 m. However, within this shallow water, a distinct area preference was observed between differing group compositions. Further analysis spanning a longer time period might provide insight into preferences of Platypus Bay by different age classes.

It is still unclear what social and environmental factors affect the preference of MC dyads within the shallower waters of their winter grounds. Several hypotheses have been suggested to explain these observations and these are to: 1) decrease predation pressure (Chittleborough 1953; Flórez-González, *et al.*, 1994; Smultea, 1994; Corkeron and Connor, 1999); 2) reduce exposure to rough sea conditions (Whitehead and Moore, 1982; Elwen and Best, 2004; Félix and Botero-Acosta, 2011); 3) conserve energy (Whitehead and Moore, 1982; Elwen and Best, 2004); and/or 4) facilitate social stratification, thereby reducing harassment and risk of injury to calves from sexually active males (Whitehead and Moore, 1982; Glockner and Venus, 1983; Mattila *et al.*, 1989; Smultea, 1994; Ersts and Rosenbaum, 2003; Craig *et al.*, 2002, 2014). The latter hypothesis appear to be the most plausible, applying to breeding grounds across various locations, as females with a dependent calf avoid the costs of male harassment by seeking waters that are sufficiently shallow to deter male escorts (Craig *et al.*, 2014). Segregation of MC dyads from actively breeding adults within wintering grounds can also be a deterministic factor in terms of calf survival as demonstrated in Southern right whales (Elwen and Best, 2004). Cartwright and Sullivan (2009) reported that females with a calf may tolerate a single escort as a "bodyguard" to avoid harassment by other males. This strategy might not, however, be relevant for Hervey Bay. According to Franklin *et al.* (2011), the low proportion of escorts observed in the bay suggests that mothers have the opportunity of spending large amount of time with their calves without having to take into account the presence of male escort(s), or of being harassed by escort(s).

Hervey Bay as an important habitat for humpback whales

Corkeron *et al.* (1994) found no evidence to suggest that Hervey Bay is of importance to any particular age classes. Spatial distribution and pod characteristics of humpback whales in Hervey Bay observed in this study are consistent with previous findings indicating that the shallow, sheltered waters of the Platypus Bay provide an important habitat for mothers and calves in the late season, as well as immature and mature individuals of both genders in early and mid- to late-season, respectively (*e.g.* Franklin *et al.*, 2011). As a result, commercial whale-watching activities in the bay focus mainly on sub-adults and adults early in the season and on groups with calves later in the season.

Due to their preferential use of shallow waters, MC dyads may be more vulnerable to human-related disturbances than other group types. Indeed, part of Platypus Bay preferred by MC dyads overlaps with areas covered by commercial whale-watching and recreation vessels (Kaufman and Martinez, pers. obs., August-September 2013). Given the importance of the bay for humpback whales on their southern migration, understanding habitat preference and patterns of habitat use is a prerequisite for effective management of critical habitat (Smultea, 1994; Ersts & Rosenbaum 2003; Félix and Botero-Acosta, 2011; Cartwright *et al.*, 2012). This is particularly pertinent with the recent trial of the swim-with-whale activities in the region.

Potential implications for the management of swim-with-whale activities in Hervey Bay

The trial of swim-with-whale programs in Hervey Bay (Fraser Coast Chronicle, 2014), in response to a declining whale-watching industry (Peake, 2011), lacks a strong scientific assessment of the sustainability of such activities. This type of activity is considered controversial and non-benign (*e.g*. Samuels *et al*., 2003; Scarpaci and Parsons, 2014; Higham *et al*., 2014), and discouraged by the IWC (Carlson *et al.*, 2013). Close and prolonged encounters have raised concerns for both the well-being of the whales and the swimming participants (Birtles *et al*., 2002; Mangott *et al.*, 2011). Such concerns are also warranted in Hervey Bay, where humpback whales often show inquisitive behavior or "friendly" behavior towards vessels (Kaufman and Martinez, pers. obs., August-September 2013), as documented in gray whales, *Eschrichtius robustus*, by Jones and Swartz (1984). This behavior is known colloquially as mugging (The Daily Telegraph, 2012). Swimming activities are known, in some cases, to affect the behaviour of targeted cetacean species (*e.g*. Samuels *et al.*, 2003; Kessler *et al*., 2013; Lundquist *et al*., 2013) and could have adverse effects on the animals, particularly MC dyads (*e.g.* Lunquist *et al.*, 2013), increasing the potential for disturbance and displacement (Carlson *et al*., 2013). As a result, in-water encounters with cetaceans, especially whales, are banned in many countries, including Australia. The current Australian National Guidelines do prohibit deliberately swimming or diving with whales and dolphins unless authorized under the relevant government agency (DEH, 2006).

This study indicates that MC dyads have a preference for shallow waters and specific areas within Platypus Bay. Pending further analysis expanding over a large time period, this report strongly recommends, as a precautionary measure, research to be undertaken to assess and monitor interactions between humpback whales, vessels, and/or swimmers. Particular emphasis should be focused on MC dyads should this group type be targeted by commercial swim-with-whale operations. The Scientific Committee of the IWC recommended that tourism activities should be evaluated on their own merits given that the effects of such activities may vary by species and/or location (IWC, 2000). Should adverse effects (*e.g.* behavioral changes) be detected, management tools such as spatial exclusion or "no swim" zones (Lusseau and Higham, 2004; Tyne *et al.*, 2014), based on empirical data or limits on interaction time, may be implemented to ensure the sustainability of such operations.

Future research

Platypus Bay, the eastern part of Hervey Bay, is part of the Hervey Bay Marine Park and the Whale Management and Monitoring Area (in effect from August to December). Since 2006, the Hervey Bay Marine Park has been extended into the Great Sandy Marine Park. Planning effective marine protected areas that encompass humpback whale critical habitats require empirical data to determine which environmental and oceanographic features (*e.g*. water depth, distance to nearest shore, etc.) influence this species distribution within a specific area.

The aim of this preliminary study using systematic transect surveys from 2013 was to determine if a relationship exists between the oceanographic variables and humpback whale distribution within Hervey Bay, focusing specifically on MC dyads. Further analyses spanning over a longer time period, including additional variables (*e.g.* slope of seafloor and substrate type) will provide vital information to ensure that human activities in the area, particularly commercial whale-watching and -swimming operations, are managed effectively. This will ensure long-term viability of Hervey Bay as an important habitat for the East Australian humpback whale population.

ACKNOWLEDGMENTS

We wish to thank Pacific Whale Foundation's members and supporters for providing the funding necessary to conduct this study. Our gratitude goes to Andrew Ellis, Alyssa Firkus, Kelly Mackarous, and Alison McGrath for their help in the field. This research was conducted under the following permits: QS2011/GS040, WISP07811910, and CA 2011/04/502.

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