Increased use levels, effort, and spatial distribution of tourists swimming with dwarf minke whales at the Great Barrier Reef

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Abstract

A permitted tourism industry has developed at the Great Barrier Reef based on swimming with dwarf minke whales (*Balaenoptera acutorostrata* subsp.). Using sightings reported by tourism operators and vessel effort data, this study found a 91% increase in the number of whale encounters over six seasons (2003-2008), and a small number of encounter 'hotspots' accounted for a substantial proportion of these encounters. Analysis of industry effort data revealed that a shift in effort among existing permitted operators was the most likely cause of the increase in whale encounters. Although the number of permitted operators has remained capped since permits were introduced in 2003, this study found substantial latent capacity in these permits. Further research is needed to identify social carrying capacity related issues for high use areas targeted for minke whale encounters, and it is recommended that the number of permits not be increased while the potential for cumulative impacts of tourist interactions on whales remains unknown.

Keywords:

Use levels, dwarf minke whales, encounters, permits, latent capacity

Introduction

Swimming with wild cetaceans is a form of tourism that has increased rapidly in popularity. In the last decade, studies have found a sharp increase in the number of tour operators worldwide advertising tours allowing their customers to swim with larger whales (dolphin swim tours excluded), from 29 operators in 2003 to 51 in 2005 (Rose, Weinrich, & Finkle, 2003; Rose, Weinrich, Iniguez, & Finkle, 2005). The majority of these swim programs are based on humpback whales (*Megaptera novaeangliae*), but a smaller number of operations conducted swims with gray (*Eschrichtius robustus*), southern right (*Eubalaena australis*), bowhead (*Balaena mysticetus*), blue (*Balaenoptera musculus*), sei (*Balaenoptera borealis*), Bryde's (*Balaenoptera edeni*) and dwarf minke whales (*Balaenoptera acutorostrata* subsp.; Rose et al., 2005). There are concerns that this form of whale watching could be 'highly invasive' for the targeted whale populations (IWC, 2000). These concerns led to an outright ban on swimming with cetaceans in some countries (e.g., Spain, Mexico) and strong regulations limiting this activity in other countries (e.g., USA; IWC, 2004).

This article investigates use levels and growth in tourism based on swim interactions with dwarf minke whales at the Great Barrier Reef (GBR), following endorsement by the Great Barrier Reef Marine Park Authority (GBRMPA) in 2003 for operators to conduct swims with these whales. The spatial distribution of these tourist encounters with whales and effort shown by endorsed tourism operators (i.e., to find and interact with whales) have received limited empirical attention. Establishing the scale and distribution of these interactions provides an important basis for monitoring and evaluating potential impacts that may be associated with this activity.

Use Levels and Impacts

As the popularity of swimming with whales increases, so too does the potential for cumulative impacts on targeted cetacean populations. Concerns include energetic costs associated with responses to repeated disturbance, and the impairment of life functions that can potentially impact population viability (Lusseau & Bejder, 2007). Lusseau (2004) investigated linkages between short-term behavioral disruptions and long-term impacts on bottlenose dolphins from tourism vessels in southern New Zealand and found that persistent disturbance and behavioral avoidance of tourism vessels in an area was likely to lead to longer-term area avoidance by dolphins. In Shark Bay, Western Australia, population-level impacts from vessel-based tourism were established in a study of resident bottlenose dolphins (Bejder et al., 2006). Drawing on decades of detailed behavioral observations, this study showed a significant decline in dolphin abundance associated with vessel-based dolphin watching tourism involving only two tour operators. Discovery of this impact triggered government intervention leading to the revocation of one of the marine mammal watching tourism permits (Higham & Bejder, 2008).

Increasing levels of visitor use also have the potential to adversely impact tourist experiences and can result in shifts in visitation patterns. In a study of snorkelers in the Red Sea, for example, Leujak and Ormond (2007) found changes in visitor demographics that were associated with perceptions of crowding, as well as physical impacts on coral reefs from increasing visitation. Breen and Breen (2009) surveyed a range of GBR user groups and found that visitor sensitivity to crowding varied between high use and low use areas, and that levels of use were perceived as too high at several locations within the Cairns Sector of this marine park. Visitor acceptance of encounters with increasing numbers of boats in a marine protected area was the subject of a study by Needham, Szuster, and Bell (2011). Using surveys of people visiting Molokini Shoal Marine Life Conservation District in Hawaii, they found that the number of boats present strongly influenced visitor crowding at this site, with the majority of visitors clearly preferring fewer boats.

Other recent studies focusing on visitor use levels and associated social impacts in marine tourism settings have highlighted the value of appraising indicators of social carrying capacity as part of management frameworks such as Limits of Acceptable Change (LAC; Stankey et al., 1985). For example, Lankford, Inui, and Whittle (2008) used visitor perceptions of crowding to help assess aspects of social carrying capacity at Hanauma Bay, Hawaii. In a review of management issues associated with whale watching at global, regional, and site-specific scales, Higham, Bejder, and Lusseau (2009) identified a need for integrated and adaptive management frameworks to improve sustainability of this activity, and proposed a model based on the LAC framework to assist whale watching communities. The integration of multiple stakeholder perspectives alongside research and monitoring was a core component of Higham et al.'s (2009) model.

The conceptual approach for non-consumptive wildlife oriented tourism provided by Duffus and Dearden (1990) integrates LAC into Butler's (1980) tourism product life cycle of slow growth followed by rapid growth and eventual equilibrium, which corresponds to a shifting visitor typology from expert specialist to novice generalist. At different stages of the cycle, carrying capacities (e.g., social, environmental, physical) and limits of acceptable change may be exceeded (Duffus & Dearden, 1990). It is, therefore, critical for sustainable management that indicators and standards defining limits of acceptable change are set, that these goals incorporate multiple stakeholder perspectives, and that monitoring being implemented is capable of identifying points where such limits are reached or exceeded.

Considering the difficulties in measuring biophysical impacts from whale watching activities and the potential time lag for any of these impacts to become apparent (Bejder & Samuels, 2003; Bejder, Samuels, Whitehead, Finn, & Allen, 2009), incorporating tourism use levels and potential social impacts into monitoring frameworks such as LAC enhances the ability of managers and stakeholders to respond to undesirable trends when there is uncertainty about indicators of environmental carrying capacity. Higham et al. (2009), however, noted the need to implement management and monitoring at the earliest possible stage in the development of a local whale watching industry. As a result, it is important to gather baseline information about industry use levels, effort, and spatial distribution to inform management and monitoring of activities such as tours offering client swims with whales.

Dwarf Minke Whales in the Great Barrier Reef

Sightings of dwarf minke whales at the GBR were first documented in the 1980s (Arnold, 1997). The majority of these encounters involved live-aboard dive tourism vessels at popular dive sites along the remote Ribbon Reefs between Cairns and Lizard Island (Arnold, 1997; Figure 1). Exhibiting unusually inquisitive behaviour, the whales were reported to approach vessels, scuba divers, and snorkelers, and remain in close proximity for extended periods (Arnold, 1997; Mangott, Birtles, & Marsh, 2011). The majority of encounters occurred during June and July, and they became sufficiently predictable that dive tour operators began advertising swimming with dwarf minke whales as a seasonal attraction for their GBR diving tours from the mid-1990s (Arnold & Birtles, 1999; Birtles, Arnold, & Dunstan, 2002). The purpose of the whales' aggregation at the GBR is presumed to be for breeding purposes, and feeding has not been observed in the area (Birtles et al., 2002).

Figure 1 about here

Valentine, Birtles, Curnock, Arnold, and Dunstan (2004) described tourism operations that were known to conduct swims with dwarf minke whales at the GBR over the period of 1999 to 2000. During this time, there were five live-aboard dive operators conducting regular swims with the whales in the Ribbon Reefs (Valentine et al., 2004). In 2003, the GBRMPA capped the industry and issued special endorsements enabling nine tourism operators to conduct swims with dwarf minke whales under their existing tourism permits. Recipients of these endorsements included four live-aboard dive vessels regularly visiting sites along the

Ribbon Reefs, three day-vessel operations based in Port Douglas that utilize sites around the Agincourt Reef complex (Figure 1), and two charter companies. Two conditions were attached to these endorsements: (a) compliance with a code of practice (originally outlined in Arnold & Birtles, 1999 and subsequently updated in Birtles et al., 2008), and (b) completion of a whale sighting sheet for every minke whale encounter, to be submitted by operators to researchers for reporting results each season to the GBRMPA and other operators (GBRMPA, 2006).

Given the difficulties involved in collecting biological and behavioral data of marine species in the wild, the involvement of commercial whale watching operators as 'platforms of opportunity' can help to fill critical gaps in the collection of monitoring data (Robbins, 2000; Robbins & Mattila, 2000). Reviews of monitoring data collected by whale watching operators have found that although such data are valuable for scientific investigations, inherent sampling biases and the complexity and cost of managing these data can limit their usefulness (Robbins, 2000; Robbins & Mattila, 2000). Scheidat, Castro, Gonzalez, and Williams (2004) noted that whale watching vessels typically do not conduct systematic searches for whales, instead stopping to observe whales whenever sightings are made. Quantifying vessel search effort, therefore, is one of the main problems in analyzing opportunistic data from whale watching vessels to estimate the relative abundance of whales in an area (Leaper et al., 1997). In an attempt to evaluate minke whale abundance and distribution using a whale watching platform around the Isle of Mull in Scotland, Leaper et al. (1997) utilised a real-time computer database recording system ("Logger") linked to a Global Positioning System (GPS) receiver. This systematic collection of vessel search effort data over a three-year period enabled their first estimates of whale densities and relative abundance in the area. A follow-up study by Macleod et al. (2004) incorporated additional environmental variables, enabling predictive modeling of minke whale habitat use in the region.

The Study

This article reports on six years of whale sighting sheets submitted by GBR tourism operators (2003-2008) and investigates trends in tourist encounters with dwarf minke whales in the GBR during this period. Industry effort and usage patterns were investigated over the latter three years allowing identification of specific reef sites where whale encounters occurred with a greater frequency per visit. Identification of GBR sites and areas with higher ‘encounter success’ rates can assist with spatial management of encounters and provides a baseline for monitoring potential changes in encounters at these sites over time. Identifying trends or sudden changes in industry effort and use levels can help to provide a basis for determining aspects of social carrying capacity and limits of acceptable change.

Description of Encounters

Based on terminology described by Birtles et al. (2002), an encounter (for tourism and non-tourism vessels alike) with dwarf minke whales is defined as a sighting of and / or interaction with one or more whales, beginning at the time of first sighting by any person on the vessel or in the water nearby, and ending at the time a whale is last sighted, which may occur as the vessel departs the area or when whales leave the area. An in-water interaction occurs when one or more dwarf minke whales are observed by a person in the water (using either snorkel or scuba diving equipment). All in-water interactions are encounters, but not all encounters will result in an in-water interaction because the whales may not approach closely enough.

Encounters with dwarf minke whales often occur at frequently visited reef sites where vessels tie up to a fixed permanent mooring or, on rare occasions, drop an anchor. Many of these sites are visited year-round for scuba diving and snorkeling activities, and divers and / or snorkelers are often already in the water when minke whales approach vessels. At the onset of an in-water interaction, one or two surface ropes are deployed from the vessel. On entering the water, snorkelers position themselves along the rope and remain relatively still while the whale(s) move freely around and underneath them. Scuba divers returning to the vessel often conduct their standard safety stop at 5m directly under the stern and hold onto a submerged chain or metal 'deco-bar' and observe the whales before completing their dive. If whales are sighted while the vessel is moving in open water either between dive sites or conducting a search for whales, the captain may decide to attempt an in-water interaction with the vessel drifting. Alternatively, the anchor may be dropped depending on weather conditions and the vessel's location. Scuba diving is not conducted during drifting encounters in open water. For the comfort and safety of passengers, most vessels typically opt not to conduct drifting encounters in stronger winds (e.g., >20kts).

A six-year monitoring program to evaluate the sustainability of this industry began in 2003 and was funded by the GBRMPA. Tasks of the program included evaluating data in the whale sighting sheets provided by the industry, and conducting biannual stakeholder workshops (pre- and post-minke season) to assess findings, review management issues, and amend the code of practice as necessary (Birtles et al., 2010). Since completion of this monitoring program in 2009, no funding has been available to analyze monitoring data or conduct workshops, but the tourism operators have continued submitting whale sighting sheets to researchers and copies of these are also provided to the GBRMPA.

Whale Sightings Data

Details of each whale encounter were recorded by a vessel crew member (or a researcher when present) on a whale sighting sheet. Information fields provided on this form included time of first and last sighting of a whale, location (site name and GPS coordinates), vessel status (moored, anchored, motoring, drifting), whale species, number of whales, number of swimmers, and the occurrence of any interesting whale behaviors. Analysis of the reliability of these whale sightings data was performed in a separate study by Curnock

(2010), which compared duplicate data recordings for the same whale encounter made by both crew members and researchers. Although the level of data recording precision was greater for researchers (e.g., time recordings on sighting sheets completed by crew tended to be rounded to the nearest five or 10 minutes), the overall reliability of crew member data was shown to be adequate for monitoring purposes (Curnock, 2010).

Vessel Effort Data

Vessel effort data were collected using several instruments and sources over three minke whale seasons (2006-2008), including vessel movement log sheets completed voluntarily by vessel skippers, researcher log sheets, and GPS data loggers (handheld units plus a laptop running the ‘Logger’ software on one vessel). Data fields on the vessel movement logs included site names, times of arrival and departure, latitude and longitude, and the vessel status at the location (i.e., moored, anchored, drifting). Recorders were instructed to complete the logs for all vessel activities during daylight hours. Completion of researcher log sheets was a daily requirement for all researchers when at sea. These sheets contained many similar fields to the vessel movement logs with additional details required to document search time by observers (e.g., number of observers, start and end times), the presence of other vessels at each site and while moving between sites, as well as weather and sea conditions for each site visited.

Although details of observers’ searching effort (e.g., number of observers, direction and duration of watch, weather conditions) were recorded whenever researchers were aboard vessels, such data were not available from trips when researchers were not present. Due to the variation between vessels in their searching effort and the proportion of days when researchers were present (approximately 55%), observer searching effort is excluded in the following calculations of vessel effort versus whale encounters for the range of GBR sites visited by vessels. Instead, results here are based solely on location of vessels and occurrence and duration of minke whale encounters to enable standardized comparisons among sites.

Results

Encounter Characteristics

Over the six-year sampling period (2003-2008), a total of 1477 whale sighting sheets reporting encounters with dwarf minke whales in the GBR were received, of which 98 were completed by researchers. Whale sighting sheets were collected from a total of 23 different vessels over the six-year period, but the vast majority (95%) were submitted by the nine endorsed operators. Among the endorsed operators, the majority of encounters (83%) were reported by live-aboard vessels operating in the Ribbon Reefs. Encounters were distinctly seasonal, with 90% occurring during June and July. In-water interactions resulted from 64% of encounters. The overall mean encounter duration was 84 minutes (± SE = 3.890; range = 1 – 665 minutes). For in-water interactions, the mean duration was 120 minutes (± SE = 2.866; range = 1 – 665 minutes). The overall mean maximum number of whales reported (per encounter) was 2.92 whales (± SE = 0.075; range = 1 – 25 whales), but for in-water interactions, the mean maximum number of whales reported was 3.66 (± SE = 0.106; range = 1 – 25 whales). A comparison among years showed no significant differences in either the duration of each encounter or the maximum number of whales seen per encounter (Kruskal Wallis *H* Tests: $H_{1,1476} = 6.745$, $p > .05$, $\eta^2 = 0.005$ and $H_{1,1476} = 10.632$, $p > .05$, $\eta^2 = 0.007$ respectively).

The number of reported encounters per season, however, increased by 91% over the six-year period, from 171 encounters in 2003 to 327 in 2008 (Figure 2). The total contact time that vessels spent with whales each season also showed a proportionate increase of 90%, from 237.4 contact hours in 2003 to 451.6 contact hours in 2008. The cause of this growth trend was investigated further through analysis of the spatial distribution of whale encounters and industry effort.

Figure 2 about here

Spatial Distribution of Encounters

An analysis was conducted of encounters occurring at specific reef sites where the vessel was either tied to a fixed mooring or was at anchor in close proximity to the site (100m or closer). Fifty-one such reef sites were identified within the Cairns Planning Area of the GBRMP where encounters with dwarf minke whales had been reported, accounting for 72% of all reported encounters. The number of encounters recorded at different sites varied considerably, ranging from a single encounter to 266 encounters at one particular site called "Lighthouse Bommie." This site is a relatively isolated coral pinnacle located near the southern end of Ribbon Reef No.10 (Figure 1), beyond the range of Cairns and Port Douglas based day-boats, and is visited frequently by live-aboard vessels. Lighthouse Bommie accounted for 18% of all encounters in the GBR and 36% of the total time vessels spent interacting with minke whales in the GBR over the six seasons.

A comparison of the top five sites ranked by highest frequency of encounters (Table 1) revealed significant differences in their mean encounter duration and mean number of whales per encounter (Kruskal Wallis Tests: $H_{1,578} = 18.926$, $p < .01$, $\eta^2 = 0.033$ and $H_{1,578} = 42.664$, $p < .01$, $\eta^2 = 0.074$ respectively). Minke whale encounters at Lighthouse Bommie involved significantly more whales and interacting for a significantly longer time than at any other site (Table 1).

Table 1 about here

Industry Effort

Over the three studied minke whale seasons (June and July only, 2006-2008), effort data were recorded for a total of 601 vessel days, representing 51.3% (601/1171) of the total vessel days at sea for all endorsed vessels over the sampling period. Researchers were present on 330 of these 601 vessel days at sea. All of the endorsed vessels assisted with the voluntary collection of effort data, but the representative sample proportions differed between the day-boats (21.9%; 118 / 538 vessel days) and live-aboard vessels (75.5%; 463 / 613 vessel days).

From the combined vessel effort database, a total of 1596 vessel site visits were logged between 2006 and 2008, of which 1247 were by endorsed live-aboard vessels. Although live-aboard vessels have a relatively flexible itinerary where numerous sites are visited over several days (and some sites are dived more than once), the day-boats typically visit three sites per day for a limited time at each site. The mean reef site visit duration by the live-aboard vessels was 180 minutes (± SE = 3.142; range = 2-690 mins), whereas for the day-boats the mean site visit duration was 82 minutes (± SE = 0.991; range = 20-170 mins). The highest mean visit duration for any site was for Lighthouse Bommie (approximately 5 hours, or 302 minutes ± SE = 15.7 minutes). A statistical comparison of the mean duration of visits among the six most frequently visited sites (Challenger Bay, Cod Hole, Lighthouse Bommie, Steve's Bommie, Pixie Pinnacle, Flare Point) showed a significant difference, $F_{1,621} = 20.369$; $p < .001$; $\eta^2 = 0.142$. A one-way ANOVA was used because these data were normally distributed. Tukey's HSD post-hoc tests revealed that visits to Lighthouse Bommie were significantly longer in duration than visits to all other sites examined, $p < .001$.

The mean duration of vessel visits to Lighthouse Bommie increased over the three seasons from 269 minutes in 2006, to 307 minutes in 2007, and 323 minutes in 2008, but these differences were not statistically significant potentially due to low annual sample sizes (Kruskal Wallis Test $H_{1,118} = 1.710$, $p > .05$, $\eta^2 = 0.014$).

Whale Encounters versus Vessel Effort

To compare whale sightings per unit of vessel effort, minke whale encounters that were reported on days for which no corresponding effort data were available were excluded from the analyses. Encounter rates, expressed as the percentage of vessel visits to a reef site that resulted in an encounter with minke whales, were calculated for 40 reef sites that were visited most frequently by vessels with endorsements to conduct swims with the whales, and where whale sightings had been reported. The proportion of total encounter time at each site was similarly compared with the total vessel effort (combined duration of all vessel visits to the site) as an alternative measure of whale encounter 'success' for each reef site. Results for the top 12 reef sites, all of which were utilized by live-aboard vessels, are presented in Table 2, ranked by their proportion of total encounter time to total effort time (%) from highest to lowest. From these results, it is clear that encounter rates and proportions of total encounter time to total vessel effort vary considerably among sites. Lighthouse Bommie is clearly a 'hotspot' with the highest encounter times and vessel hours logged, as well as the most predictable sightings of dwarf minke whales of any site known in the GBR, with encounters resulting from 77% of visits to the site during June and July.

Table 2 about here

In 2007 and 2008, two 'new' reef sites in close proximity (<1nm) to Lighthouse Bommie appeared in the vessel effort data ('Two Towers' and 'Acropolis') where no vessel visits were logged and no whale encounters were reported in previous years. Researcher observations and anecdotal reports from several vessel crew who had worked in the industry for several years indicate that these sites were rarely used in earlier years. The recent use of Two Towers and nearby Acropolis by the endorsed live-aboard operators as alternatives to Lighthouse Bommie appears to represent a growing awareness of a higher predictability of minke whale encounters in this region near Ribbon Reef #10 (Table 2, Figure 1). Higher occupation of Lighthouse Bommie also likely increased the use of nearby sites as vessels concentrate their time in its vicinity when waiting for their turn or after their time is up.

Trend of Increasing Encounters

These results show that the trend of growth in minke whale encounters in the GBR over the six year study period can be attributed largely to the same small number of endorsed live-aboard operators. These operators have changed much of their effort in recent years and have increasingly targeted 'hotspot' sites such as Lighthouse Bommie during the June to July minke whale season. Vessels spent more time at Lighthouse Bommie than at any other reef site, and the number and duration of visits to this site increased over the three years for which effort data were available. This relatively small site can only be used by one vessel at a time and vessel access to the site is managed by a roster administered by an industry association (Cod Hole and Ribbon Reef Operators Association; CHARROA). The CHARROA mooring roster for Lighthouse Bommie showed that the site was booked at 100% capacity (in ½ day bookings for seven days per week) during the months of June and July continuously from 2003 through 2008. This roster, however, does not completely reflect actual use of the site because some bookings were made and then not utilised (C. Stephen, pers. comm.). It is probable, therefore, that the frequency of vessel visits and the uptake of these bookings increased over the six-year period.

The mooring at Lighthouse Bommie and other CHARROA-administered sites are accessible to all CHARROA members, including some who do not hold endorsements to conduct swims with the whales. A few non-endorsed operators are entitled to use and do visit the Lighthouse Bommie mooring and other sites in the Ribbon Reefs year-round for scuba diving tours, including during the minke whale season. These operators are likely to encounter dwarf minke whales at these sites with the same regularity as endorsed vessels, and this poses a complex management challenge that has not been resolved. Commonwealth and GBRMP Regulations stipulate that vessels without a specific endorsement are not allowed to place swimmers in the water closer than 100m to a whale, but whales may approach swimmers already in the water (Birtles et al., 2008). Non-endorsed vessels also have no obligation to submit whale sighting sheets and thus the full extent of their encounters with dwarf minke whales remains unknown.

Discussion

This article examined operator use levels, growth, and effort associated with a permitted tourism industry at the Great Barrier Reef that promotes swimming with dwarf minke whales. Results showed a 91% increase in the number of encounters with whales over six seasons (2003-2008), and a small number of encounter ‘hotspots’ accounted for a substantial proportion of these encounters. Analysis of industry effort data revealed that a shift in effort among existing permitted operators, especially live-aboard operators, was the most likely cause of the increase in whale encounters. These findings have implications for management and future research.

Endorsements to conduct swims with dwarf minke whales and the GBRMP tourism permits to which they are attached are fully transferable. An operator is also able to move their permit between multiple vessels within a season. The three endorsements held by day-boat operators, therefore, represent a substantial latent capacity in the industry. If any of these day-boat operators sold or transferred their tourism permit or endorsement to a live-aboard vessel, it is possible that this could contribute to more minke whale encounters and an overall increase in the total encounter time in the GBR. The potential for an increase in the number of endorsed operators targeting Lighthouse Bommie and the surrounding area raises concerns not only for the increased potential for cumulative impacts on the whales, but also for impacts on the visitor experience associated with crowding in this area. A visitor study by Curnock (2010) compared tourist satisfaction with the dwarf minke whale experience between 2006 and 2008 to previous findings by Valentine et al. (2004) based on data from 1999 to 2001, but found no decline in satisfaction or negative responses associated with industry use levels.

The changes in industry use of reef sites and resulting increases in whale encounters over the six years studied raises the question about whether this represents a rapid growth phase as conceptualized in Duffus and Dearden's (1990) non-consumptive wildlife tourism product life cycle. Follow up studies examining potential changes in visitor typology can draw on comparisons with Valentine et al. (2004) and may help in evaluating the state of maturity of this tourism industry. This future research may assist with evaluating the potential for additional growth in demand for the activity and planning to minimize social and biophysical impacts before carrying capacities or limits of acceptable change are exceeded.

A limitation of this study was the use of only six years of monitoring data, ending at the completion of the 2008 minke whale season, when GBRMPA funding for monitoring ceased. Following the completion of sampling and prior to the 2009 minke season, two of the endorsed live-aboard companies ceased operating. One of these operators attributed their closure to the global financial crisis (Port Douglas and Mossman Gazette, 2009) and this is potentially also the reason for the second operator's closure. The permits and endorsements for these two operations have not been transferred to any other operation and are believed to be for sale. The 2008 minke whale season, therefore, was likely to have experienced the highest level of industry effort since the endorsements were issued. Considering the lingering effects of the global financial crisis on tourism businesses in this region (ABC News, 2012), it may take several more years for industry use levels to approach those reported in 2008.

By drawing on industry generated effort data in an attempt to describe spatial and temporal patterns of dwarf minke whale encounters, it is important to recognize that the use of tourism vessels as 'platforms of opportunity' limits the ability of these data to provide insights into the distribution and abundance of whales in the region (Kiszka, MacLeod, van Canneyt, Walker, & Ridoux, 2007). The distribution of whale encounters instead reflect patterns of industry use of the reef and sites that are favoured for various reasons including accessibility and moorings, prevailing wind and weather conditions, reef faunal communities, topography, and the aesthetic appeal of sites to scuba divers and snorkelers. Encounters with whales by these vessels, therefore, only occur in the limited areas that are visited. To reduce such effort bias, systematic surveys would be required from a vessel dedicated to the task, which would be unlikely to cater to the expectations of tourists. The accumulation of effort data from these tourism operators, however, does provide a useful basis for comparing encounter rates at heavily used dive sites and the transited areas between them, which over the longer term can be monitored for trends.

It is a permit condition that operators endorsed to conduct swims with dwarf minke whales at the GBR complete a sighting sheet for each whale encounter, but the logging of reef sites used and the duration or effort that vessels invest in seeking whale encounters remains voluntary. A recent study by Higby, Stafford, and Bertulli (2012) examined the predictive capability of whale sightings data from tourism vessels in Faxaflói Bay, Iceland. Sightings data typically provided by whale watching vessels is presence-only, and rarely includes absences. Higby et al. (2012) found that the inclusion of absence data, including vessel location and environmental conditions at regular intervals through the cruise, provided significantly greater explanatory power for predicting the distribution of whales. Continued monitoring of dwarf minke whale encounter rates and the proportion of whale encounter time to vessel effort at reef sites can assist in detecting potential changes or trends in the relative abundance of dwarf minke whales at these sites. Determining the cause of any changes or attributing any changes to the tourism industry will, however, be problematic and require careful investigation of a wide range of potential contributing factors, both within and outside the GBR. It is clear that ongoing monitoring of this industry must incorporate vessel effort data to enable such analyses of spatial and temporal variations, and provide a context for any observed changes in the distribution and frequency of minke whale encounters.

The extent and management of non-endorsed dwarf minke whale interactions remains an important management issue that has yet to be addressed. Although anecdotal reports from vessel crews have indicated that non-endorsed tourism operators in the northern GBR area encounter dwarf minke whales each season and photographs from these encounters are often on company websites, few whale sighting sheets documenting these encounters were received over the six-year monitoring period. Some attempts to encourage wider tourism industry participation in reporting were made, but no resources have become available from government or industry to support this task. Given Australian government regulations concerning tourists swimming with whales, there may also be reluctance among non-endorsed operators to report their interactions with whales for fear of prosecution.

The use of permits (or endorsements) is considered to be an effective mechanism for managing the extent of tourist interactions with whales (Birtles et al., 2010). These endorsements represent the only current regulatory tool by which the scale of the activity is limited, and the two permit conditions (i.e., comply with the code of practice, report all minke whale encounters on an approved whale sighting sheet) make it obligatory for operators to contribute to monitoring and adhere to otherwise voluntary management protocols. Management of this industry, including the use and number of endorsements, is currently the subject of a review by the GBRMPA. Anecdotal reports from industry representatives suggest that there is demand from some GBR tourism operators for more endorsements to be issued. Considering the latent capacity found in the existing number of endorsements and the potential market availability of two permits from the tour companies that ceased operating in 2009, any further increase in the industry's capacity without knowing the potential cumulative impacts on whales at the current industry scale would be inconsistent with a precautionary management approach.

Measuring and identifying potential cumulative impacts of tourist interactions on dwarf minke whales is an ongoing challenge requiring dedicated research. Evaluating any potential social impacts that may be associated with crowding at 'hotspot' sites such as Lighthouse Bommie should also be an important consideration when reviewing this industry. Further research into visitor typologies, experiences, and perceptions of crowding will assist with identifying aspects of social carrying capacity at high use areas targeted for dwarf minke whale encounters. The integrated and adaptive management model proposed by Higham et al. (2009) provides a useful framework for engaging stakeholders in identifying limits of acceptable change and providing clear objectives and priorities for continued research and monitoring. Tracking industry use levels will be a necessary component of this monitoring, helping to contextualize any observed changes in the spatial distribution and frequency of whale encounters, and inform social carrying capacities of minke whale encounter 'hotspots'.

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List of figures

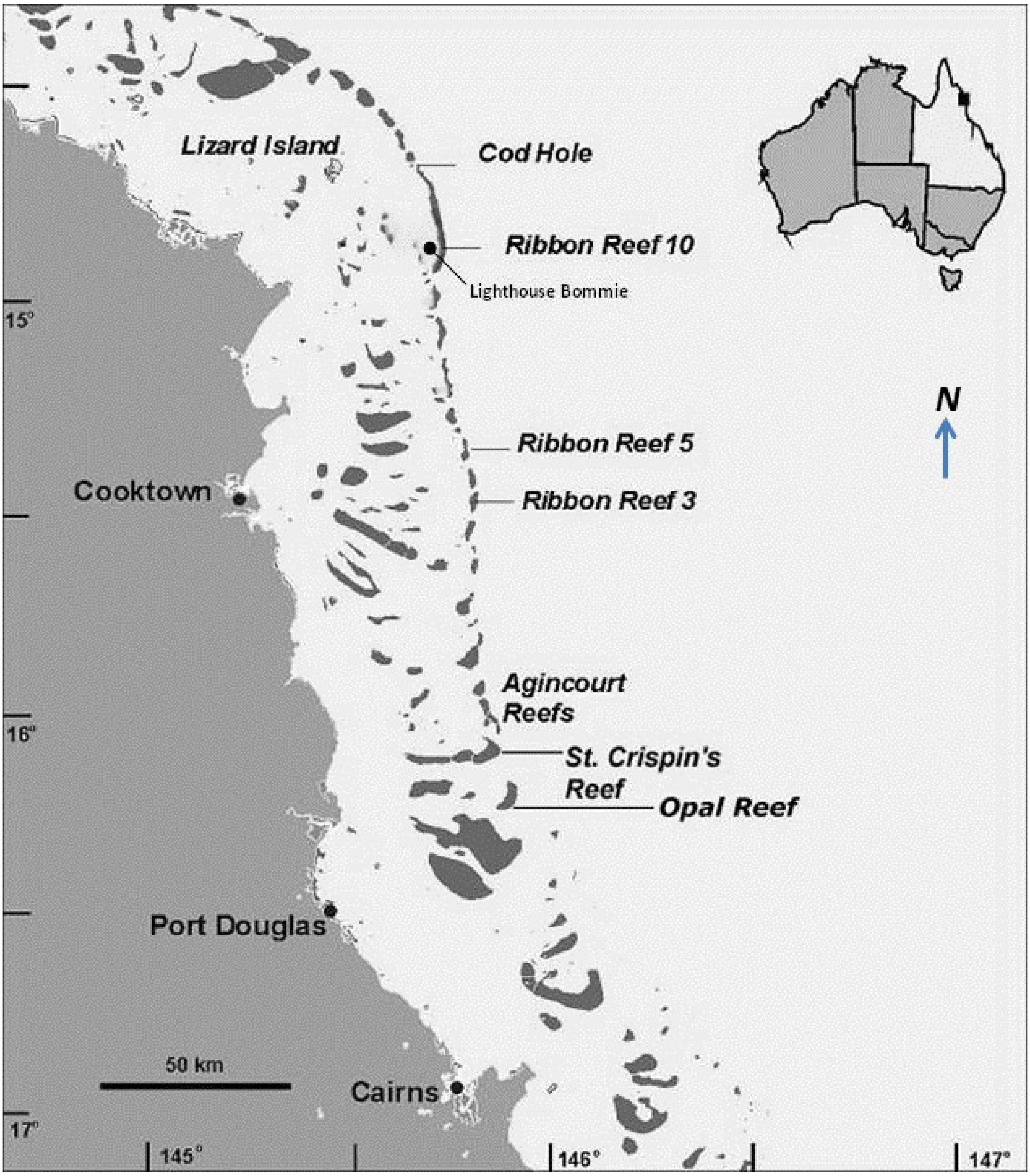

Figure 1: **Location of the Great Barrier Reef swimming-with-dwarf minke whales activity, showing approximate location of Lighthouse Bommie.**

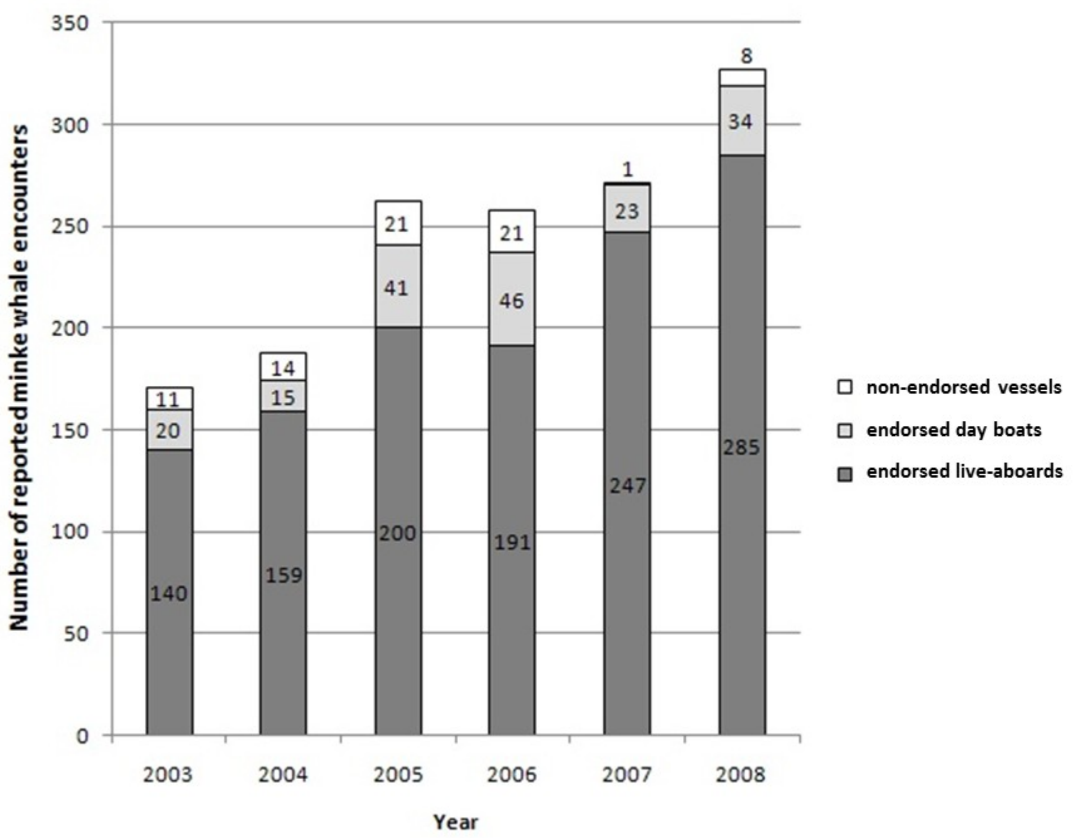

Figure 2: **Number of dwarf minke whale encounters reported per year by vessels in the Great Barrier Reef Marine Park, 2003-2008.**

Table 1: Comparison of summary encounter statistics for the five sites with the highest number of encounters, 2003-2008.

Reef site	Number of encounters	Mean encounter duration (minutes)	Mean number of whales per encounter
Lighthouse Bommie	266	170 (±SE= 9.696)	4.74 (±SE= 0.221)
Steve's Bommie	122	103 (±SE= 9.633)	2.28 (±SE= 0.167)
Challenger Bay	69	77 (±SE= 11.362)	2.59 (±SE= 0.288)
Pixie Pinnacle	65	69 (±SE= 9.401)	2.22 (±SE= 0.213)
Flare Point	57	53 (±SE= 9.994)	2.14 (±SE= 0.268)

Table 2: Comparison of minke whale encounter time and vessel effort by swim-with-whales operators at 12 reef sites visited during three minke whale seasons (June-July, 2006-2008)

Site name (Latitude & Longitude) *Nearest Major Reef*	(a) Total whale encounter time at site (corresponding to effort logs; hrs)	(b) Total vessel hours logged at site (site effort; hrs)	Encounter time/effort time (a/b; expressed as percentage %)	(c) Site visits with whale encounters / (d) total site visits	Encounter rate (c/d; expressed as percentage %)
Lighthouse Bommie (14°52.50'S; 145°41.30'E) *Ribbon Reef #10*	371	606	61	94/122	77
Two Towers (14°52.30'S; 145°40.45'E) *Ribbon Reef #10*	40	73	56	18/22	82
Acropolis (14°53.68'S; 145°40.05'E) *Ribbon Reef #10*	7	21	33	5/9	56
Andy's Postcard (15°20.50'S; 145°44.70'E) *Ribbon Reef #5*	12	38	31	7/14	50
Snake Pit (14°40.10'S; 145°34.10'E) *Ribbon Reef #10*	8	30	28	6/15	40
Steve's Bommie (15°30.10'S; 145°47.25'E) *Ribbon Reef #3*	102	438	23	50/116	43
Fantasia (15°00.10'S; 145°40.80'E) *Ribbon Reef #9*	8	39	19	5/16	31
Blue Lagoon (15°30.47'S; 145°47.83'E) *Ribbon Reef #3*	4	31	14	4/7	57
Joanie's Joy (15°31.66'S; 145°46.67'E) *Ribbon Reef #2*	2	17	12	1/5	20
Dynamite Pass (14°39.80'S; 145°38.60'E) *No Name Reef*	2	22	10	3/13	23
Challenger Bay (14°54.90'S; 145°41.40'E) *Ribbon Reef #10*	34	366	9	28/154	18
Pixie Gardens (14°55.70'S; 145°40.60'E) *Ribbon Reef #10*	10	113	9	15/46	33