Australian Marine Mammal Centre

Preliminary Final Report

Project 2013/36

- **Title** - Spatial ecology, migratory paths and critical areas of habitat use of Australia's dwarf minke whales
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- **Organisation -** Minke Whale Project, James Cook University

Activity Period - 02 May 2014 – 31 May 2015

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1. Activity Summary

A clear summary of approximately 500 words outlining the work undertaken and any significant findings (for publication on the Department's web site)
This project conducted studies on the world's only known aggregation of an undescribed subspecies of minke whale (*Balaenoptera acutorostrata* subspecies) which occurs at offshore reefs along the edge of the east Australian continental shelf in the northern Great Barrier Reef. This aggregation was unreported until the 1980s, and lasts for just a few weeks in the austral winter, presumably for socializing and courtship, with 90% of sightings in June-July. A small, highly regulated swim-with industry has developed, based primarily on live-aboard dive-boats from Cairns and Port Douglas and Minke Whale Project researchers have worked collaboratively with them and Reef managers on research to inform the sustainable management of the spectacular wildlife encounters occurring when whales make repeated and prolonged approaches to swimmers. With access to these remote sites provided by tour operators, our annual field work since 1996 has focused on in-water photo-identification exploring the biology and behaviour of these whales, establishing their spatial and temporal distribution and analysing the interactions to minimize potential harm to them. The management of this industry has been acclaimed as world's best practice but many important biological questions remained unanswered. Although many whales were recorded returning in subsequent years (up to eight years in succession), their migratory paths and location for the rest of the year were unknown. A "world-first" satellite tracking of four individuals in 2013 provided proof-of-concept for applying small, minimally-invasive LIMPET tags to their dorsal fins and this AMMC funding enabled us to deploy ten more tags over a two week period in July 2014. All transmitted successfully for periods from 15 to 72 days and their tracks have

reinforced the migration pattern observed during the pilot study, with all except one whale showing generally southward movements through the GBR, and down the east coast of Australia. Two transmitted long enough to leave Tasmania on a similar SSW route as our longest transmitting whale in 2013, which reached the sub-Antarctic.

Funding from this project also enabled us to place trained volunteer research team personnel onto all swim-with permitted live-aboard vessels to maximise the quality and quantity of data collected including especially the underwater digital images of whales donated by passengers and crew. Although not funded by this project, ongoing analysis of over 20,000 pictures and video clips from 2014 has already revealed that one of our whales tagged in 2013 returned to the study site, interacted readily with tourists in at least four encounters over 15 days and very importantly, showed no damage at his dorsal fin tag attachment site.

Analysis of all 14 tracks has provided our first insight into the detailed movements of these whales and their habitat use including identifying several locations where they were probably feeding along their migratory route. It has also provided the first information about the likely extent of their human interactions along Australia's east coast and our results will help to improve the GBRMPA and Australian Government management strategies to mitigate the risks and threats to this undescribed subspecies which supports an economically important tourism industry in the GBRWHA.

2. The Outcomes/Objectives

The degree to which the Activity has achieved the objectives

The main goal of this project was to provide insights into the habitat use of dwarf minke whales (*Balaenoptera acutorostrata* undescribed subspecies) within the Great Barrier Reef World Heritage Area (GBRWHA) and along their migration route down the east Australian coast and into the Southern Ocean. Photo identifications collected over the last 19 years by the Minke Whale Project during "swim-with whales" interactions have previously documented site fidelity over a brief period in winter, with individuals returning to the same northern region of the GBRWHA in many years. Until recently there was no information available on where these individuals went when they left this region (Birtles et al. 2002; Sobtzick 2010; Mangott et al. 2011; Curnock et al. 2013). A pilot study conducted in 2013 with four dwarf minke whales successfully demonstrated the utility of using minimally invasive location-only LIMPET satellite tags to provide insights into the migratory behaviour of dwarf minke whales.

Understanding the spatial ecology of a species is essential for quantifying threats and for developing effective conservation strategies. Thus the identification of critical areas, understanding the seasonality of use, and the vulnerability of these habitats to anthropogenic impacts, will all contribute to the development of appropriate management strategies. If dwarf minke whales are utilising specific habitats within the GBRWHA, along migratory routes on the eastern continental margin, and in Bass Strait, then localized anthropogenic impacts (e.g. ocean trap & line fisheries, shark nets, habitat alteration, shipping traffic, auditory pollution) could have significant consequences for these whales. Describing the spatial ecology of individuals during the 'swim with whales' season will provide critical, industry-independent data on movements and habitat use for informed management of this activity that is likely to grow in popularity in the coming years.

Specific Objectives:

- examine movements and habitat use of dwarf minke whales during the 'swim with whales' season in the GBRWHA
- determine migratory paths and identify critical habitats utilised by dwarf minke whales after departure from the GBRWHA
- determine which physical and biological factors are critical drivers of habitat use
- provide data needed by managers and planners for mitigation of potential threats to dwarf minke whales

Methods

Satellite tracking

In order to provide data on the movements of dwarf minke whales, we deployed satellite-linked transmitters in the Low Impact Minimally-Percutaneous External-electronics Transmitter (LIMPET) configuration (Andrews et al., 2008). The field site was located in the northern Great Barrier Reef (GBR) region (Fig. 1). This area is frequented by the nine vessels permitted by the Great Barrier Reef Marine Park Authority (GBRMPA) to conduct "swim-with-whales" tourism based around the austral winter aggregation of dwarf minke whales. In July 2014 all tagging operations were conducted from the MV Viking (Fig. 2) with additional support and logistical assistance provided by Eye to Eye Marine Encounters, one of the GBRMPA-permitted operations, which chartered two separate vessels, the Elizabeth E II and the Aroona, to support the tagging project (Fig. 3).

Unlike previous LIMPET tag deployments on other cetaceans, where the standard methodology is to project the tag through the air using a crossbow or air-rifle, consistently strong trade winds led us to develop a new method of applying tags underwater while snorkelling with the whales. Transmitters were successfully attached to the dorsal fin at depths between 1 and 5 m (Fig. 4). Tags were deployed while the tagging vessel (MV Viking) was either anchored or drifting. In July 2014, seven whales were tagged with location-only "SPOT" tags while three whales were tagged with dive depth-transmitting "SPLASH" tags (Wildlife Computers, Redmond, WA USA). Both SPOT and SPLASH LIMPET tags were remotely attached to the dorsal fin underwater, with a modified speargun (Fig. 4). On contact with the dorsal fin, the shaft fell away and was retrieved by a tether line, leaving the transmitter attached to the dorsal fin.

Although the AMMC only supported tag deployments in 2014, the data analyses presented here included the movement data from the four tags deployed in 2013 as well as the ten tags deployed in 2014 (Table 1).

The plausibility of each geographic position estimate received via the Argos CLS system was determined using the Distance, Angle and Rate filter (DAR) of the

Douglas Argos Filter (Douglas et al. 2012). This filter uses an algorithm that identifies unlikely positions of the animal based on biologically realistic movement rates and the assumption that an animal is unlikely to move a large distance in one direction and then immediately return to a previous location. For the purposes of this study, the upper limit on movement rate that the animal could sustain for a period of hours (MINRATE) was set at 25 km/h and the maximum distance between consecutive positions (MAXREDUN) considered to be self-confirmatory was set to 3 km. The tolerance level for acute turning angles over longer distances (RATECOEF) was set to 25, a value which is less likely to allow for trios of points that might be indicative of unacceptable Argos error. Positions with an Argos location class of 2 or 3 were exempt from filtering and were retained for data analysis.

A continuous-time correlated random walk model (Johnson et al. 2008; Johnson et al. 2011) was applied to the filtered data using the CRAWL package in R (R Development Core Team 2015). Using the model, the position of the whales every 6 hours was estimated. The distance between consecutive positions, and between each position and the tagging location, was determined using the distMeeus function within the geosphere package (Hijmans et al. 2012) in R (R Development Core Team 2015). This function uses the Meeus method (Meeus 1999) to calculate the great-circle-distance between two points assuming the points are on an ellipsoid. Each position was annotated with a distance to the nearest coast obtained from NASA's Distance from Nearest Coastline Dataset and depth from NOAA's ETOPO1 Global Relief Model. For both data sets, a bilinear interpolation method was used through the EnvData System of Movebank (Kranstauber et al. 2011; Dodge et al. 2013). Positions were classified based on latitude as either within the Great Barrier Reef Marine Park (north of 24.5˚ S), or on migration along the east coast of Australia (south of 24.5˚ S and north of 37.5˚ S). The mean (± SE) speed, depth and distance from coast for both regions were calculated.

In order to objectively identify portions of the movement tracks where the behaviour changed from a "transit" state to a more "resident" state potentially indicative of foraging, a Bayesian switching state-space model (SSSM) was applied to the Douglas Argos filtered data using the first difference correlated random walk switching (DCRWS) model described by Jonsen et al. (2005). The model was fit with a 12 hour time-step, using a Markov Chain Monte Carlo (MCMC) simulation method in JAGS 3.2.0 (Plummer 2003) and the bsam package (Jonsen et al. 2013) in R (version 3.1.3) (R Development Core Team 2015). Two chains were run for each model with an adaptation and burn-in phase of 60000 iterations, with an additional 30000 samples generated after convergence was assumed. These samples were then thinned to reduce autocorrelation by retaining one in every 30 samples. The parameter, state, and behaviour mode estimates were based on the remaining 1000 samples. The means of the MCMC samples range from 1 to 2, and were used to infer behavioural state (< 1.5 = transit state, ≥ 1.5 = resident state).

In 2013, two of the tagged whales (MWsat1 and MWsat3) retained their tags long enough to reach the waters around Tasmania, and both of them spent considerable time (> 1.5 weeks) moving around as if potentially foraging in Bass Strait, especially in areas to the east and south of King Island. As detailed below, five of the whales tagged in 2014 also made it to the waters surrounding Tasmania, and four of them also appeared to spend time potentially foraging in this area. Therefore, we focused our initial efforts to determine the environmental factors that influence the distribution of foraging dwarf minke whales on the waters around Tasmania. This analysis was restricted to a rectangle bounded in the north by the 34° S latitude line, to the south by the 45° S latitude, to the west by the 140° E longitude, and to the east by the 152° E longitude. This study area was divided by 10 x10 km grid using the R package 'trip' (Sumner 2011) to determine areas where whales spent a disproportionate amount of time. The 10-km spatial scale was chosen iteratively with 10 km doing a good job of identifying whale residency in an area (Dalla Rosa et al. 2012, Double et al. 2014).

Environmental covariates were extracted for the Tasmania study area using the R package raadtools version 0.2-4 (Sumner, Australian Antarctic Division, 2015). Remotely sensed data for each variable for the entire study period were derived at the finest temporal resolution available and then averaged to create a single raster for each covariate that provided the mean values of the variable over the study period. A single value for all environmental covariates was attributed to each of the time-spent cells. Environmental parameters included near surface chlorophyll-a (chl-a) concentration, sea surface temperature (SST) and the gradient of SST (gSST; calculated as the difference of SST between cells), sea surface height (SSH), sea surface height variance (vSSH), magnitude of water currents (curr) and wind speed (wind). The bathymetry was derived from NOAA's ETOPO1, a 1 arc-minute global relief model of Earth's surface, and was used to calculate the distance from the closest coast (dscst) and from the shelf break (dsshb) considered as the distance from the 300 m depth contour line.

A generalized additive modelling (GAM) framework was used to assess the relationships between whale residency and environmental variables using the mgcv package (version 1.8-6) in R. A single model for each possible predictor was first built to assess the importance of each factor in determining the differences in time spent. Then, by comparing Akaike Information Criteria values (AICs) for the single variable models, the predictors that explained less variance were removed. More complex GAMs were produced including all the variables and removing one variable per time in a backward stepwise selection and assessing which variables had to be retained in the final model comparing the AICs. Predictive GAM plots were used to visualize the relationship between each predictor and the response variable and hypothesize how different environmental variables affect whale habitat use.

Photo-identification studies

There are significant challenges to locating and then collecting data (especially underwater photo-identification data) from small, fast-moving whales that display quite cryptic surface behaviour and that are diffusely distributed across a study area several 1000 sq km in size at remote GBR shelf edge locations in the depths of the austral winter. Successfully overcoming these would have been impossible without the extraordinary researcher access to 'platforms of opportunity' provided by the CHARROA live-aboards with whom we have worked closely for >20 years. The value of this close engagement with the industry and their passengers was first documented by Valentine, Birtles, Curnock, Arnold and Dunstan (2004).

Our field work in 2014 was conducted in close collaboration with the Cairns and Port Douglas-based live-aboard dive-vessel fleet holding swim-with dwarf minke whale endorsements to their tourism permits. The commercial tourism operations of these Cod Hole and Ribbon Reef Operators Association (CHARROA) vessels has been described in detail in Birtles et al. (2014) and Curnock et al. (2013). This project enabled us to place trained Volunteer Researchers onto these vessels to maximise quality and quantity of data, especially the underwater digital images and videos of dwarf minkes donated by passengers and crew. Over the eight weeks of the 2014 field season we received 246 researcher days at sea on 25 trips aboard seven vessels with a total in-kind value of $106,688 (Table 3). Each of these 20-30m long vessels carry 10-30 passengers and most divers now have underwater digital cameras. With encouragement from the vessel crew and our Volunteer Researchers, the passengers donate copies of their digital images and video clips of dwarf minkes encountered during their diving and snorkeling activities.

Dwarf minkes are the most highly patterned of all the baleen whales and the potential for their white blazes and contrasting black and various shades of grey colour patterns being used to identify individuals was first suggested by Arnold & Birtles (1999) and Birtles, Arnold & Dunstan (2002). The details of their colour patterns were described in Arnold et al. (2005), and Sobtzick (2011) unequivocally demonstrated the value of such images by using them to build a catalogue of over 400 individuals and identifying over 200 different individuals in a single year (2008). Between 2006 and 2008 she collected >45,000 photographs and video clips from well over 100 photographers including researchers, passengers and crew and used these to track the minkes in space and time around the study site with individuals being sighted up to eight times in a single season. We have built upon this foundation in subsequent years and this project and the parallel IFAW photo-identification ones have allowed us to extend this work significantly in 2014-15.

Results and Discussion

Satellite tracking

All satellite tags funded by the AMMC were successfully deployed on dwarf minke whales during the austral winter aggregation in the northern Great Barrier Reef Marine Park (GBRMP) (Table 1). Additional funding from the International Fund for Animal Welfare (IFAW) allowed us to purchase a total of 13 satellite tags (including seven SPOT and six SPLASH LIMPET tags). All of the former and three of the latter were attached during the boat time available to us in July 2014. All 10 tags transmitted successfully for between 15 (MWsat7) and 72 days (MWsat9), with a mean and median of 47 and 46 days (Table 1), exceeding the typical mean attachment duration of about 30 days for LIMPET tags on other cetacean species. Transmission durations were similar to those from the pilot study conducted in 2013, which had mean and median transmission durations of 54 and 47 days respectively (range 31-90 days).

The general pattern of movement that we observed after a short period of residency in the northern GBR was a southward migration along the Australian east coast (Fig. 5), although one whale did travel north to the Torres Strait. The tags revealed more extensive use of the shelf habitats around Lizard Island and west of the Ribbon Reefs during the swim-with whales season than was previously known (Fig. 6). Whales spent various amounts of time in the northern GBR after tagging, from as little as 2.3 days to as long as 15.8 days before moving out of that area (Table 1). As can be seen in the plots of distance from tagging site (Figs. 7 – 10), whales typically moved southerly at a consistent speed until exiting the GBR, but there were some deviations, especially towards the southern end of the GBR, around the Swain Reefs (Fig.11 - 12). Interestingly, three whales spent some time (3 – 10 days) meandering about in a relatively small area east of Shoalwater Bay, as close as 16 km from shore at Cape Clinton. This spot seemed unexceptional in terms of bathymetry and oceanographic features, even though it is only 160 km NW of the Capricorn Eddy. Despite this eddy being seen as an important feature for other marine predators (Weeks et al., 2010), it appeared to have little influence on the migrating dwarf minke whales.

For the ten whales whose tags stayed attached long enough for them to reach the southern end of the GBR, total residency time in the GBR area ranged from 21.8 to 49.1 days (Table 1). After departing the GBR, the dwarf minke whales tended to display much less variability in their routes along the Australian east coast. For example, while in the GBR, the mean distance from shore for all whales was 80.6 km but with large variance exemplified by a standard deviation of 25.14 km, whereas while migrating south of the GBR, mean distance from shore was 21.94 km and the SD was only $\pm$ 2.95 km. Along this coast, the shelf break is uniformly close to shore and the whales rarely ventured out past the shelf break after departing the GBR (Fig. 13). There was also a marked increase in travel speeds once a whale departed the GBR, with the mean speed while migrating along the east coast (5.7 $\pm$ 0.97 km h^{-1}) being nearly twice that while moving within the GBR (2.7 $\pm$ 0.50 km h^{-1}; Table 2). Along the east coast, transit behaviour was by far the dominant mode predicted by the switching state space model (Fig. 11).

However, after reaching Bass Strait and the waters around Tasmania, six of the seven whales whose tags were still transmitting spent at least some time in “resident” mode, possibly feeding in the productive waters around Tasmania (Figs. 11 and 14). Defining the exact amount of time spent possibly foraging was complicated because by the time they reached Tasmania, most of the tags had switched to a duty cycle in which they did not transmit every day in order to conserve battery power for attachments that exceeded the number of consecutive transmission days that the battery was capable of. The time-in-area analysis confirmed that there were areas where whales spent a disproportionate amount of time, and the most heavily used “hot-spot” was an area between 30 and 180 km to the east of King Island in Bass Strait. Five of the whales engaged in “resident” mode in this area, and two of them spent further time in resident mode approximately 70 to 150 km to the south of King Island. One of these whales, MWsat12, then migrated along the west coast of Tasmania and after rounding the southern tip moved into an area in the southeast of Tasmania, spending its last 8 days of transmissions in a small area of Storm Bay, east of Bruny Island. Although maps of the environmental variables we examined did not highlight any abundantly obvious feature shared in common by all of the areas of high residency time (Fig. 15), the generalized additive modelling approach did confirm that nine predictors (bathymetry, distance from coast, distance from shelf break, gradient of sea surface temperature, sea surface height (absolute and variance), gradient of current speed, wind speed and chlorophyll-a concentration) were important in the final model which explained 68% of the total variance in time spent in different cells.

Regions of higher time-spent values were characterised by shallow waters, proximity to the coast (but not to the shelf break), high winds and sea surface height but low gradient of sea surface temperature.

Three of the tagged whales retained their tags long enough for us to observe their movements into the sub-Antarctic (Fig. 16). The switching state-space model first predicted MWsat1 (a male) entering "resident" mode once he reached 52.4° S on 15 September 2013, but he continued to move slowly to the southeast, eventually reaching 54.8° S on 10 October 2013, a minimum cumulative distance of 7483 km from where he was tagged 90 days previously. His last position was approximately 700 km to the north of the ice edge as estimated by the maximum sea ice extent in September 2013.

Photo-identification studies

Table 4 summarises the nearly 60,000 underwater digital images and videos of dwarf minke whales received over the 2013-14 seasons during which we satellite-tagged the 14 individuals. These came from 110 different photographers aboard at least 10 different vessels. We had set out in 2014 to encourage these donations and improve their research value by means of various interpretative displays (posters, flyers, industry workshops, Volunteer Research lectures, passenger briefings) that informed the passengers and crew of the live-aboards about our successful tagging of four whales in 2013 and the importance of re-photographing them in 2014 (see Fig. 17 & 18). The results were outstanding and our analysis of this prodigious collection is ongoing as we work slowly through the remarkable resource provided by these numerous citizen scientists.

The research value of this has already been borne out by the discovery in recent months of many photos and video clips of the young male whale "Spot" who returned to exactly the same locations at the back of Ribbon Reef No.10, a year after being satellite-tagged after an epic migration with a known southward journey of at least 7,483km in 90 days (July-October 2013). This whale has now been located in images from four encounters (all with MV. *Spoilsport*) over a 15 day period in June 2014 including 14th June and 21st June at Lighthouse Bommie, 23rd June at Eagle Rock and 28th June again at Lighthouse Bommie. This whale was the first ever dwarf minke to be satellite-tagged (MWsat1) and the first ever known to migrate to the sub-Antarctic and return to its tropical wintering ground. These four encounters were also very reassuring because he again interacted readily with vessels and swimmers. His dorsal fin appeared to be in very good condition with no attachment scars visible and therefore the dart entry (and exit) sites appeared to have healed and the skin re-pigmented.

Our analysis of this wealth of photo-identification material will be ongoing for some time, currently assisted by a number of trained volunteers however, we will need to seek additional funding to be able to fully realise the value of this excellent resource.

Data storage

The Minke Whale Project has accumulated a very significant amount of electronic data over its>20 years of research, including especially our photo-identification material from the last 19 years of field work. These data include:

1. Whale photo-ID database: >150,000 images + >100hrs digital video.
2. Whale Sightings database (Access & Excel): c. 3,000 whale encounters over 16 years (includes >2,301 whale encounters over last 9 years + archival data 1996-2002).
3. Whale watching industry effort database (Access & Excel): >1,300 vessel days at sea records over 6 years.
4. Whale watching tourist survey database (SPSS & Excel): >5,000 passenger questionnaires over 13 years.

In order to ensure the long-term safe storage and retention of these data, we submitted a Minke Whale Project Long-term Data Storage proposal via QCloud- (including RDSI ReDS) earlier this year. In May the Minke Whale Project was informed that we had received a data storage allocation of 18 TB. This storage is funded by the Research Data Storage Infrastructure (RDSI) project, an initiative of the National Collaborative Research Infrastructure Strategy, is funded from the Education Investment Fund under the Super Science (Future Industries) initiative. The storage is housed at James Cook University (one of two regional nodes), and duplicated to Brisbane at the QCIF (Queensland Cyber Infrastructure Foundation) node. The data will be duplicated to Brisbane using the Data Sharing Network (DaShNet). DaShNet is a project funded through the National Research Network (NRN), an initiative of the National Collaborative Research Infrastructure Strategy (NCRIS) and is funded from the Education Investment Fund.

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Our tagging of dwarf minke whales in 2014 would not have been possible without the important contributions of many people.

The research team gratefully acknowledge the long-standing and substantial in-kind field and logistical assistance provided by John and Linda Rumney of Eye to Eye Marine Encounters over the last 19 years and their chartered vessels *Elizabeth EII* and *Aroona* whose outstanding skippers (Shane Steele and Ross Miller, respectively) and highly skilled crews have long played very significant support roles for the Minke Whale Project research. We are also very grateful to Tim North, of Tim North Marine for provision of the research vessel (*MV Viking*) and to him and his crew for truly outstanding support for the tagging team during the 2014 field season. The core research team included Dr Jimmy White, whose unparalleled skills and energy resulted in the successful placement of all 14 tags and the incomparable Dr Dean Miller who filmed every aspect of our research with awesome skill and we thank them both profoundly for their companionship and complete dedication to achieving the outcomes of this ground-breaking research.

The analyses of environmental characteristics around Tasmania were conducted by Elena Fontanesi as part of a graduate thesis project at the University of Tasmania, with guidance from Dr Mary-Anne Lea and Prof Mark Hindell and technical assistance from Michael Sumner and we thank them all for their very significant contribution to the outcomes of this project. This report was prepared with the skilled assistance of Kylie Owen for which we are very grateful.

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3. Appropriateness

The appropriateness of the approaches used in the development and implementation of the Activity
The main approach that we utilized in order to meet our objectives was the deployment of satellite tracking devices onto dwarf minke whales during their annual aggregation on the northern Great Barrier Reef in the Austral winter. This approach is not without potential controversy because of the economically and socially important nature of the tourism activity that has developed around this aggregation of dwarf minke whales. We were very sensitive to avoid any potential for our research activities to have an adverse impact on any aspect of the encounters between dwarf minke whales and humans. Although our results are somewhat anecdotal due to the subjective nature of observations on "reactions", it is very encouraging that the initial behavioural reactions by the whales in response to the attachment of the tag were very mild. Our objective recording of the immediate behavioural reactions of tagged whales showed that they exhibited relatively minor reactions to the tagging events; some individuals glided very briefly and then swam slowly away on their previous course with four whales showing no increase in swimming speed immediately after tagging. Other individuals accelerated to a moderate pace with several strong beats of their tail after being tagged, but then circled and re-joined the aggregation of other whales around the boat. Four of the 10 whales tagged in 2014 sped up and were not resighted during the remainder of the in-water observation time on the tagging day. In nearly all cases, we did not observe any reaction by non-target whales during the tagging event. In one of the tagging episodes, the tagged whale sped up and two accompanying whales also increased their speed, but this was the only case where we observed a reaction by non-target whales. In 2013, one whale spent an additional five hours swimming around the tagging team after tag attachment and she was then seen engaged in courtship behaviour with another whale. In 2014, one whale remained around the in-water tagging team for approximately 15 minutes before travelling 1.6 km to a tourist vessel moored at an adjacent dive site; after interacting with tourists in the water, this whale then returned the tagging vessel and continued to make close approaches to the in-water tagging team. Furthermore, we believe that our approach of tagging whales when they voluntarily approach humans is very appropriate because it allows us to avoid the typical methodology of having to drive a motorized boat towards a whale in order to apply a tag. Some whales tolerate such disturbance, but it does have the potential for adverse impact and therefore it is extremely fortunate that we can avoid that kind of impact when using our approach of only tagging whales that have voluntarily approached within 1.5 meters of us. An added advantage is that our approach of underwater tagging at very close distances allows us to place the satellite tag very precisely in the most appropriate location on the dorsal fin.

4. Effectiveness

The degree to which the Activity has effectively met its stated objectives
Dwarf minke whales appear on Australia's Great Barrier Reef (GBR) for a few short weeks every Austral winter, presenting spectacular wildlife encounters and enabling a

valuable tourism opportunity. Our research has shown that this is a multi-million dollar industry contributing significantly to the economy of the Cairns and Port Douglas region (Stoeckl, Birtles, Farr, Mangott, Curnock and Valentine 2010; Stoeckl, Birtles, Valentine, Farr, Curnock, Mangott and Sobtzick 2010). Despite their willingness to voluntarily approach human swimmers, little is known about them outside of this time and place. Our main objectives were to determine unknown habitat preferences, migratory paths, and feeding grounds. We effectively achieved these objectives by attaching satellite-linked transmitters to the whales when they were most readily encountered, during their voluntary close approaches to humans on the northern GBR. We used movement models to estimate the positions of the whales as they moved around within the GBR and as they migrated down the east coast of Australia. A switching state-space model was used to objectively identify points in time and space where whales spent disproportionate amounts of time, perhaps for social or for foraging purposes. This identification of areas where whales spent more time in a "resident" mode highlight areas that might deserve extra attention when considering conservation measures to mitigate human activities that might overlap with dwarf minke whale habitat choices. In addition to identifying fixed spatial areas through which dwarf minke whales migrated or potentially foraged in, we adopted a modelling approach to identify key environmental characteristics that appear to influence where dwarf minke whales spend time, especially in the waters around Tasmania, which may be an important foraging area for this small whale on its way from a winter socializing period on the GBR to its final summer foraging areas in the sub-Antarctic. The dwarf minke whale is a relatively small whale that we have demonstrated is capable of an extremely long migration. It is likely that this small whale cannot carry enough reserves to power this migration from stored energy alone, especially after having gone through a likely fasting period during the winter social aggregation. Additional tag deployments will be necessary before we can adequately and completely describe the southern extent of the summer foraging areas for these whales, but this project has made an important and effective first step towards that goal.

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