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A preliminary study of the movement patterns of false killer whales (*Pseudorca crassidens*) in coastal and pelagic waters of the Northern Territory, Australia

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Abstract. The false killer whale (*Pseudorca crassidens*) is regarded as *Data Deficient* globally and in Australia. In most parts of its range, there is little information on its social behaviour, dispersal or ecology. The present study is the first assessment of its movement patterns in Australian waters, on the basis of satellite tracking of four individuals, in the Arafura and Timor Seas from late March to early July 2014. When initially tagged, the four individuals occurred in a single group; they then showed generally similar movement patterns and regularly re-associated. Total distance travelled by tagged individuals ranged from 5161 km (over a 54-day period) to 7577 km (104 days). Distance from land varied from 100 m to 188 km (median distance 24 km). Individual minimum convex polygons covered an area of 72 368 to 86 252 km^2, with a total overlap of 64 038 km^2. Water depths varied from 0.3 to 118 m (median 36 m). In total, 15% of records were in waters shallower than 10 m, and 26% of records were within 10 km of land. The present study indicated that false killer whales appear to regularly use coastal and pelagic waters in this region and, hence, should be afforded more conservation attention.

Additional keywords: Arafura and Timor Sea, dispersal, satellite tracking.

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Introduction

The false killer whale (*Pseudorca crassidens*) is generally considered to be an oceanic species that approaches land mostly where the continental shelf is narrow or around isolated oceanic islands with precipitous slopes and deep water nearshore such as in Hawai'i (Stacey *et al.* 1994; Bannister *et al.* 1996; Baird *et al.* 2008, 2010). However, some recent records indicate that it may, at least occasionally, also use neritic waters (Weir *et al.* 2013). Globally, the movement patterns and habitat associations of this species are poorly known, with an IUCN conservation status of *Data Deficient* (Taylor *et al.* 2008). Limited information on population size, movement patterns and their drivers, and other ecological characteristics, renders it difficult to identify priorities for its conservation and management in most parts of its range. Taylor *et al.* (2008) noted that the apparent rarity of this species makes it potentially vulnerable to low-level threats including commercial fisheries interactions, prey depletion, anthropogenic noise, boat strikes and pollution. The most studied populations occur around the main Hawaiian Islands where there is a small demographically isolated island-associated (insular) population and a larger offshore (pelagic) population (Baird *et al.* 2010). Recent evidence suggests that the insular population may have declined precipitously over the past 20 years (Baird 2009; Reeves *et al.* 2009; Oleson *et al.* 2010). The insular population of false killer whale of the main Hawaiian Islands was listed as *Endangered* under the US *Endangered Species Act* (ESA) in 2012. The ESA status review for this population noted that interactions with fisheries were ranked as one of the most important current and future threats for this population, although recognising that the level of certainty regarding these threats was low (Baird *et al.* 2010, 2015; Oleson *et al.* 2010).

The most recent review of its conservation status in Australian waters also considered the species to be Data Deficient (Woinarski *et al.* 2014). In Australia, the false killer whale has been recorded irregularly at many locations along the coast, but these records are mostly of strandings and it is generally not regarded as a coastal species (Bannister *et al.* 1996). However, no studies have been carried out on its ecology, movement patterns and habitat requirements in Australian waters. Partly because of this apparently limited and incidental occurrence in Australian coastal waters, this species is currently afforded only very superficial consideration in conservation policy and management in Australia. It is not recognised, and, hence, not given explicit protection, as a threatened species. However, it is given some limited protection under Australian legislation (the *Environment Protection and Biodiversity Conservation Act* 1999) as a listed 'marine species' (section 209) and as a 'migratory species' (section 248), but this recognition provides very little influence on conservation management and little leverage in consideration of approvals for proposed coastal developments (Bejder *et al.* 2012).

During a ~3-year study of coastal dolphins at Cobourg Marine Park, Northern Territory (Palmer *et al.* 2014), schools of false killer whales were recorded on several occasions. A review of collated records from Northern Territory coastal waters suggested that this species may occur in these shallow north Australian waters more widely and regularly than has been previously recognised (Palmer *et al.* 2009). The present study was stimulated by the recognition that this species may be a more regular inhabitant of these coastal waters, and that more information on its status and movement patterns in this region may be required to inform conservation management responses.

In the present study, satellite tracking was used to investigate the movement patterns of false killer whales in coastal waters of the Northern Territory. The objectives of the present study were to investigate the extent of movement over a ~4-month period (the approximate length of the transmitter life), and characterise locations of tagged individuals relative to water depth, proximity to shore and the location of other individuals. The approach used in the study is based on the successful use of telemetry in studies of this species around the Hawaiian Islands, to determine patterns of occupancy and movements, and to provide information on ecology, population structure, trends and critical use areas (Baird *et al.* 2010, 2012). These studies have been instrumental in conservation management and planning for this species in Hawaiian waters.

Materials and methods

Tagging location

Port Essington and Port Bremer harbours are located within the Garig Gunak Barlu National Park and Cobourg Marine Park, ~220 km north-east of Darwin (Fig. 1). Both harbours

Fig. 1. Tagging locations: Tag A, Port Essington; Tags B–D, Port Bremer, Cobourg Peninsula, Northern Territory, Australia (the Cobourg Marine Park boundary is indicated by a dotted line).

comprise semi-enclosed former river valleys that were drowned during periods of sea-level rise and now form largely sheltered and deeply incised harbours. The harbours provide varied environments that are distinct from the open-water areas of the adjacent Van Diemen's Gulf and the Arafura Sea (Figs 1, 2). There are no major creeks or rivers flowing into either harbour and, consequently, there is restricted freshwater input. Tides range between 2 and 2.5 m, and turbidity is low compared with many other parts of the Northern Territory. Within the Marine Park and surrounding waters, there is little commercial shipping, almost no onshore development and limited aquaculture.

Study area

The total study area was contained within the coastal south-western Arafura Sea and the eastern limits of the Timor Sea (Fig. 2). The area is characterised by shallow coastal waters within the Australian continental shelf, with depths up to 90 m in the central and eastern study area, and up to 180 m in the west. Most regional temperature and salinity observations have been made in areas offshore that are influenced by freshwater runoff or upwelling from the Banda Sea. However, the largely coastal area with little freshwater input has year-round high water temperatures associated with the wet–dry tropical coastal environments (26–31°C; Godfrey and Mansbridge 2000), with salinity being typical of equatorial ocean water.

Hydrodynamic observations in the region are particularly sparse and conditions have been predicted mostly by using hydrodynamic modelling (Condie 2011). Tidal ranges are meso-tidal (2–4 m) for most of the study area; however, larger tidal amplitudes build in some areas towards the coast, with a gradual rise in bathymetry. Seasonal currents from the east to the Timor Sea are affected by south-easterly trade winds during the dry season (May to September) and north-westerly winds during the wet season (October to April), with lulls between monsoonal troughs. Throughout the dry season, a westerly running current extends along the coast from the Wessel Islands. It is met with a north-easterly current on the western side of Bathurst Island for that period. The meeting of the two opposing currents causes strong vertical upwelling and has been characterised with anomalously high chlorophyll-*a* concentrations to the west of Bathurst Island (Condie 2011).

Tagging

Satellite tags were deployed following the general methods of Baird *et al.* (2010), using a pneumatic projector at a distance of 5–10 m from a 5-m vessel that was moving parallel to the targeted individual. The tags contained an ARGOS-linked SPOT-5 (AM-S240C) location-only platform-transmitter terminal (Wildlife Computers, Redmond, Washington, USA) and were attached by means of two 68-mm-long titanium darts with backward-facing petals to hold them in place. The tag dimensions were 63 × 30 × 21 mm, with total weight of 49 g (Baird *et al.* 2012). Tags were duty cycled to transmit 9 h per day for 50 days, then every second day for the next 10 transmitting days (20-day span), then transmitting every 5th day for the remainder of the tag life.

Satellite-derived locations

Tagged false killer-whale locations were estimated by the Argos System (Collecte Localisation Satellites, Ramonville-Saint-Agne, France) using the least-squares method and were assessed for plausibility using the Douglas Argos-filter ver. 8.5 (available at http://alaska.usgs.gov/science/biology/spatial/douglas.html, accessed 1 December 2015). This filter includes several user-defined variables, including the following: maximum redundant distance (consecutive points separated by less than a defined distance are kept by the filter because Argos location errors rarely occur in the same place, so very close temporally consecutive points are assumed to be self-confirming); location classes (LCs) that are automatically retained (location classes were classified according to estimated error, including number of messages received during the pass, estimated error calculated by ARGOS locational data, with an error radius of >2 km Class A and Class B); maximum sustainable rate of movement; and the rate coefficient (Ratecoef) for assessing the angle created by three consecutive points. The rate coefficient algorithm takes into account that the farther an animal moves between locations, the less likely it is to return to or near the original location without any intervening positions, creating an acute angle characteristic of typical Argos error. We automatically retained locations separated from the next location by less than a maximum redundant distance of 3 km, as well as LC2 and LC3 locations (estimated error of <500 and <250 m respectively) (ARGOS 2014). LC1 locations (with estimated error of between 500 and 1500 m), as well as LC0 (estimated error of >1500 m), LCA (unbounded accuracy, 3 messages received) and LCB (unbounded accuracy, 1 or 2 messages received) were retained only if they passed the Douglas Argos-filter process). For maximum sustainable rate of movement, we used 20 km h^{-1}, based on maximum travel speeds noted during observations of fast-traveling false killer whales in Hawai'i (R. W. Baird, pers. obs.). We used the default Ratecoef for marine mammals (Ratecoef = 25).

The location records were matched to depth and distance to the nearest coast using ArcGIS vers. 10.2 (Environmental Systems Research Institute, Redlands, CA, USA). All datasets were projected into Australian Albers GDA94 (EPSG: 3577) with measurement units in metres. Water depth at the location record was derived from the 2009 bathymetric grid of Australia (0.0025° cells or 250-m resolution) and predicted tides. Tidal predictions were based on constituents supplied by the Australian Hydrographic Service and computed to 1-min accuracy using the t_predict component of the Matlab script t_tides (Pawlowicz *et al.* 2002). Tidal-station data from Australian Hydrographic Service and Bureau of Meteorology were both used as a source for tidal constituents to calculate the tide level at the time the satellite-tagged location was recorded. The lowest tide within March to July 2014 of each tide's prediction was set as the lowest astronomical tide datum, which was assumed to be zero chart datum at this point. The tide level was added to the bathymetric chart depth to provide an actual depth value at the time of satellite fix.

Variation of locational fixes across months in water depth and proximity to nearest land was graphed for all individuals combined, and the extent of monthly variation was assessed with

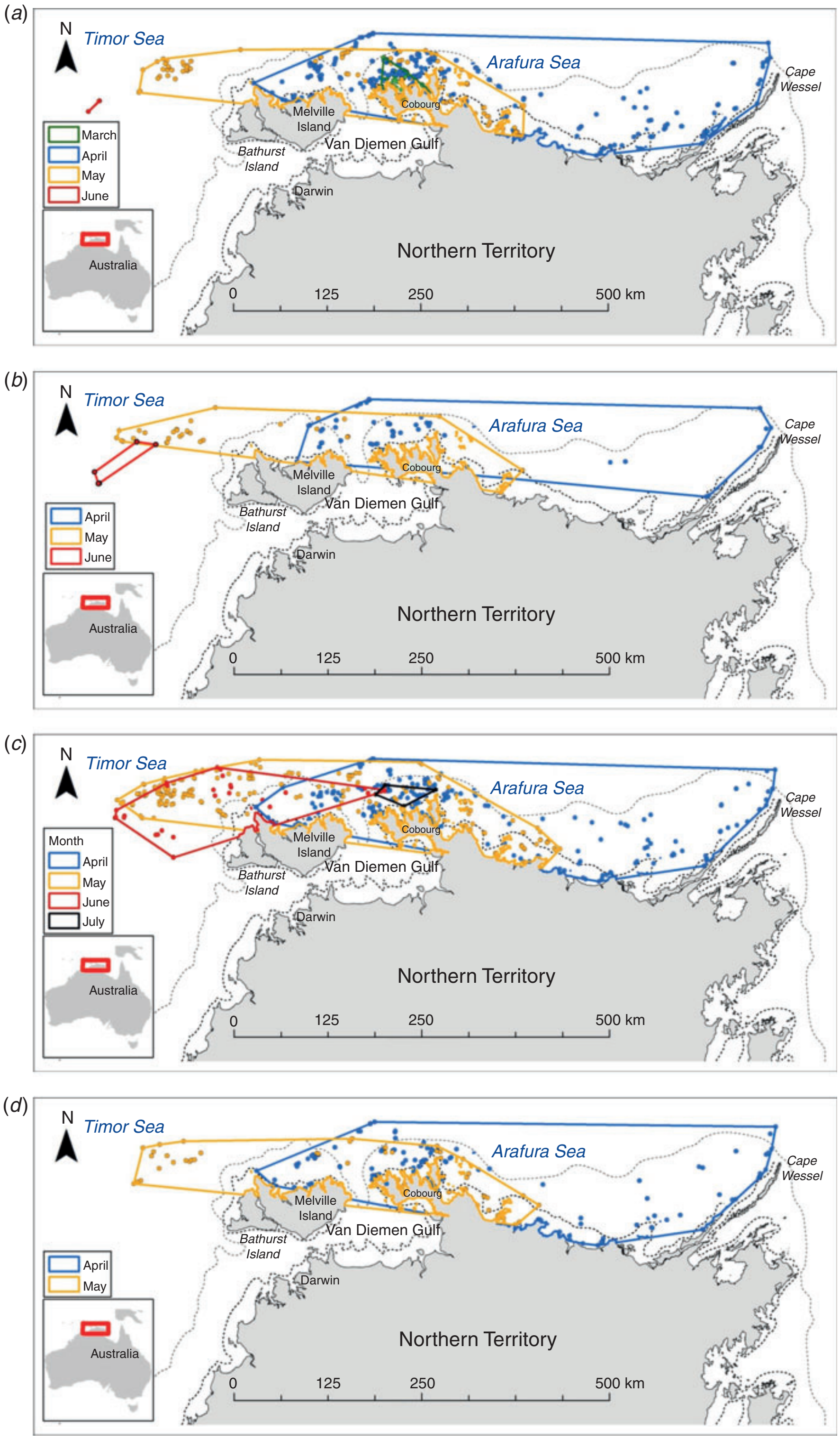

Fig. 2. Locations of four satellite-tagged false killer individuals (A–D) and patterns in monthly minimum convex polygons. Dates deployed in 2014: 27 March (Tag A) and 3 April (Tags B–D). Last location date: 23 June (Tag A), 5 June (B), 16 July (C) and 26 May (D). The 10- and 50-m water depth contours are shown.

Table 1. Summary details on satellite-tag deployments plus distances and depths, all derived from GIS analysis and filtered satellite locations

Tag ID	Tag duration period (2014)	Tag duration (days)	Mean distance from tag deployment (km)	Total distance travelled (km)	Depth (m) Min.	Depth (m) Median	Depth (m) Max.	Distance from shore (km) Min.	Distance from shore (km) Median	Distance from shore (km) Max.
A	27 March–23 June	89	181.2	6992.9	0.4	34.0	95.5	0.3	18.2	176.5
B	3 April–4 June	62	180.2	5161.06	0.7	40.0	118.3	0.2	27.8	180.3
C	3 April–15 July	104	181.9	7577.1	0.3	40.1	102.7	0.1	29.4	167.6
D	3 April–26 May	54	164.8	5579.7	0.5	33.5	108.7	0.2	21.0	188.1

a one-way ANOVA test. We did not consider 'individual' as a term in these analyses, given that some degree of co-location of individuals would have constrained the independence of these data.

Distance and area covered

The total distance covered (sum of linear distances across successive valid satellite fixes) was calculated for each of the four individuals. Maps of the distributional records for all four individuals were collated. A minimum convex polygon (MCP) that encompassed all records by month (and for the total sample period) was calculated for each individual (and for the four individuals collectively) in ArcGis, ver. 10.2. Overlaps in MCPs were also calculated across months, for each individual for the period of April–May.

Coincidence of individual locations

Given the strong social relationships documented by photo-identification data from Hawai'i (Baird *et al.* 2008, 2010, 2012), we calculated the straight-line distance (i.e. not including potentially intervening land masses) between all combinations of pairs of individuals when locations were obtained during a single satellite overpass (~10 min). We used both the average distances between pairs of individuals and the maximum distance between pairs to assess the extent to which individuals were acting independently.

Results

A group of approximately 10 false killer whales was encountered opportunistically on 27 March 2014, during a boat-based survey for coastal dolphins in Port Essington (Fig. 1). One of these individuals (A) was tagged; and locational data for this individual were used to relocate this individual within a group of ~20–30 individuals at Port Bremer (Fig. 1) on 3 April 2014; another three individuals were tagged from this group (Fig. 1).

Locational information was obtained for periods of 54–104 days for the four tagged individuals (Fig. 2, Table 1). After filtering through the Douglas Argos-filter, 240 Class A and 1348 Class B records were excluded and 1465 valid locations were retained. The data were most substantial for the months April and May and, less so, for June; there were few records for one individual only in March (all in the last week) and July (all in the first week).

The tracking information showed that all tagged animals moved east from their original tagging location in Cobourg to Cape Wessel in April, then westward back to around Cobourg and surrounding waters during April–May, further west during June, and the last remaining tagged individual (Tag B) travelled east back to Cobourg in the beginning of July (Fig. 2). Minimum longitudinal distances travelled by individuals ranged from 5161 km over 54 days (Tag B) to 7577 km over 104 days (Tag C; Table 1).

Table 2. Total minimum convex polygon (MCP) by individual

Tag ID	Total MCP area (km^2)
A	83 895
B	72 368
C	82 949
D	86 252
Total area of overlap	64 038

Table 3. Overlap in minimum convex polygons (MCPs) (km^2) among individuals and across month

Note that pair-wise comparisons are given only once in the table (e.g. AB) and redundant combinations (e.g. BA or BB) are signified with dashes

Month	Tag ID	B	C	D
April	A	63 806	51 637	51 678
	B	–	56 783	70 962
	C	–	–	56 790
May	A	31 633	29 074	31 990
	B	–	27 083	30 787
	C	–	–	27 063

Individual MCPs by month highlighted that individuals used a similar space during the course of the tagging period (Fig. 2, Tables 2, 3). All records were within the Australian exclusive economic zone (AEEZ; 200 nautical-mile limit). Over the tracking period, the total (MCP) area for all four individuals spanned 102 387 km^2, with a total overlap across the four individuals of 64 038 km^2 (Fig. 2, Tables 2, 3).

The median distance between tidal-station location and satellite-tag locations was 19.7 km, with a minimum of 500 m and a maximum of 77.4 km, with 25th and 75th percentiles of 12.6 and 31.1 km respectively. For false killer-whale locations, water depth and distance to land varied among months, with March–April records being in shallower seas and closer to land than were May, June and July records (Fig. 3). This variation among months was significant for depth (ANOVA; $F = 40.0$,

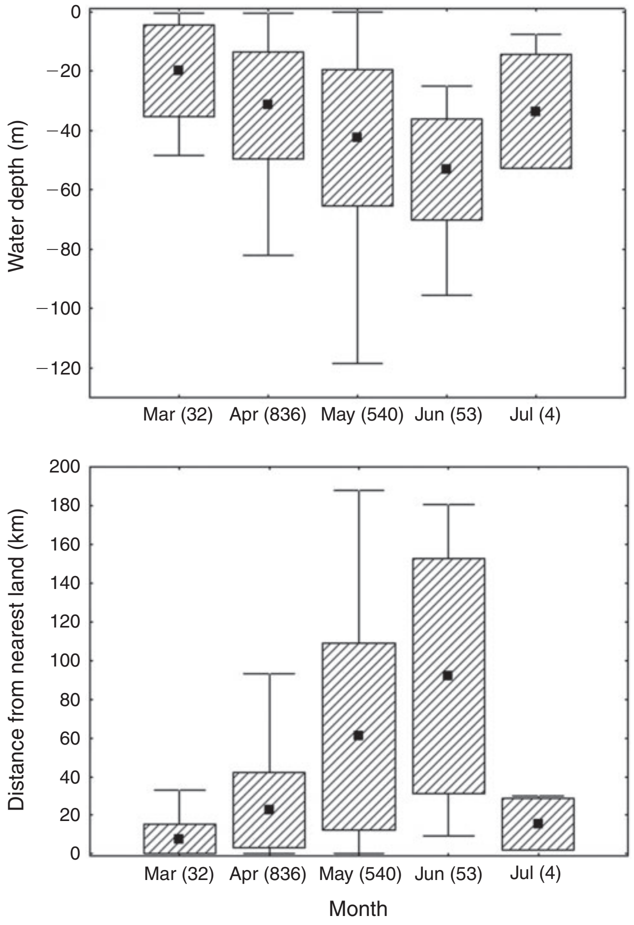

Fig. 3. Monthly variation in water depth (top) and distance from nearest land (bottom) for all records of all four individuals. Small black boxes represent means, hatched boxes represent standard deviations, and whiskers represent minimum and maximum. Samples sizes are given in parentheses after month name; note the very small sample size for July.

d.f. $= 4$, $P < 0.0001$) and proximity to shore (ANOVA; $F = 135.7$, d.f. $= 4$, $P < 0.0001$). Across all months, the median depth for false killer-whale locations was 36.2 m (range 0.3–118 m; standard deviation 20.9); 15% of records were in waters shallower than 10 m and 25% of records were in waters shallower than 20 m. The median distance from land was 23.9 km (range 0.1–188 km; standard deviation 40.8) and 26% of records were within 10 km of land. The four tagged individuals exhibited broadly similar depth and distance-from-shore profiles (Table 1).

Mean distance apart for all possible pairs of the four tagged false killer whales ranged from 10.9 to 20.4 km, and the maxima for all possible pairs ranged from 103.0 to 137.8 km. However, individual pairs of whales regularly came within 1 km of each other (e.g. Individuals A and D came within 1 km on 21 occasions during the period of tag overlap), and all four individuals showed generally similar patterns of movements relative to the location where they were first tagged, generally moving as a loosely defined group through the range of tag locations. As evident also in Fig. 2, some sites (such as the original tagging location in the Port Essington–Port Bremer area and surrounding waters) appeared to be used repeatedly over much of the sampling period.

Discussion

The present study has provided the first assessment of movement patterns of false killer whales in Australian waters. Before considering this information further, we note several caveats. All data in the study were derived from only four individuals (that were at times co-occurring), followed over a relatively brief period (7–12 weeks); these patterns may not be representative of other social groups, other seasonal conditions or other years. The study was exploratory, and represents a foundation for further more intensive research. However, it does present by far the most substantial reporting of movement patterns for this species in Australia and the southern hemisphere, and relates to an environmental setting that is a notable contrast to that of the best studied population of this species, in the isolated oceanic Hawaiian Islands.

The movement patterns of the four individuals were largely consistent during the satellite tracking (Fig. 2). Total distances travelled by each tagged individual were substantial (Table 1), with these distances similar to total distances recorded for satellite-tagged false killer whales in Hawaiian waters over comparable periods (Baird *et al.* 2010).

Comparisons of mean distance apart for all possible pairs of the four false killer whales, along with the marked degree of overlap among individuals in MCPs, suggested that some group cohesion was maintained, possibly through acoustic contact over large distances (Janik 2000). Behavioural studies have demonstrated that dolphins use vocal communication (whistles) to maintain group cohesion over large distances (Janik 1997; Janik and Slater 1998); however, the limits of such communication are not known for false killer whales. It is possible that false killer whale group cohesion in northern Australia is maintained over longer distances by ongoing acoustic contact as well as intervening (untagged) individuals because 20–30 individuals were observed during the second encounter.

The results reported here indicate that this species uses coastal and pelagic waters across much of the shallow Arafura and Timor Seas. This habitat use contrasts notably with most previous studies that have typically reported a distinct preference for deep oceanic waters (Stacey and Baird 1991). A notable exception to this general pattern is the genetically distinct nearshore false killer whale population that occurs around the main Hawaiian Islands; however, this population mostly occurs in deep waters (>500 m) and uses shallow (<100 m) waters only occasionally (Baird *et al.* 2008, 2010, 2012; Martien *et al.* 2014). Perhaps a habitat use more similar to that reported here is the recent recognition of use by false killer whales of shallow continental shelf habitats off Costa Rica (Douglas *et al.* 2011), northern New Zealand (Zaeschmar *et al.* 2014), and in the eastern tropical Atlantic off western Africa (Weir *et al.* 2013).

Although the results reported here indicate broad-scale movements across this study period, there is little basis for understanding the causes of such movements. In this region, there is marked seasonality in winds, currents, air temperature and rainfall, and the location data suggested that false killer whales may be responding to some of these seasonal influences or to spatial and temporal variation in the abundance of prey species associated with this seasonality.

Although the data presented here demonstrate a very extensive pattern of movement, they also indicate that there are some areas across this broad extent in which locational records are concentrated. This is particularly the case for the Cobourg Marine Park and surrounding waters, which was the location at which all four individuals were initially tagged, and to which they returned over at least parts of this sampling period (e.g. Fig. 2). The repeated use of this area as shown through the present intensive but brief study is consistent with the recent review of the very limited previous observational records of this species in the Northern Territory waters (Palmer *et al.* 2009), and this consistency suggests that this area may represent a significant location for this population, and that the locational pattern described in our brief study may be representative of patterns occurring over longer periods.

The data presented here and the few records reported previously (Palmer *et al.* 2009) illustrate the challenges in collecting information in this largely remote and isolated region. The present study demonstrated that satellite tracking provides an insightful and time-efficient technique for gathering movement data in this logistically challenging region. Given the exploratory nature of the study, and the unresolved nature of factors influencing the movement patterns observed here, further satellite tracking is merited so as to inform conservation management and marine planning. The indication in the present study, and in the previous sightings review (Palmer *et al.* 2009), is that some particular coastal sites may be important to false killer whales. The identification of such sites and subsequent observations from these areas (including through the use of photo-identification) may allow for substantial increase in information about social cohesion and of the factors that influence spatial use.

In the coastal waters of northern Australia, policies and conservation planning for management of marine biodiversity are limited. Marine conservation planning has focussed largely on species with typically small home ranges, such as the Australian snubfin (*Orcaella heinsohni*) and Australian humpback (*Sousa sahulensis*) dolphins that potentially occur in a series of discrete subpopulations in many localities (Department of Sustainability Environment Water Population and Communities 2011*a*). Conservation planning for such species may be reasonably straightforward through the establishment of carefully located representative marine protected areas, fisheries exclusion areas and careful placement of highly localised developments. However, as reported elsewhere for large cetacean species with extensive dispersal (Hooker *et al.* 1999, 2011), such responses are unlikely to be effective for highly mobile species such as the false killer whale. The observed movement patterns in the present study indicated that this species (1) is unlikely to be well protected by a single small reserve or a network of discrete and small protected areas, and (2) may be exposed to some threats across the broad range used by individuals from anthropogenic activities within the Australian Economic Zone and coastal waters (e.g. interaction with fisheries, coastal development and oil and gas industries). With respect to interactions with and impacts of potential threats, the current evidence base is very sparse. Although fisheries regulations mandate the reporting of cetacean by-catch in these waters, the only by-catch record for false killer whales was documented during the Taiwanese gill-net operations off northern Australia (Harwood *et al.* 1984; Harwood and Hembree 1987), and there have been no reported interactions of this species with other potential threat factors in this region.

The present study has provided valuable information and a platform for future studies on false killer whales in northern Australia. To enhance the conservation management of this species, further evidence is required relating to

1. whether false killer-whale populations in the shallow waters of northern Australia are small demographically isolated (insular) populations from the offshore populations.
2. whether the movement patterns reported here are consistent across other months and years, and with other social groups of false killer whales elsewhere in northern Australian coastal waters.
3. the ecological drivers of the movement patterns described here; and
4. the extent of overlap between areas used by this species and the incidence and severity of some current and future potential threats.

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References

ARGOS (2014). Argos user's manual: worldwide tracking and environmental monitoring by satellite. Available at http://www.argos-system.org/manual/ [Verified 12 August 2014].

Baird, R. W. (2009). A review of false killer whales in Hawaiian waters: biology, status, and risk factors. Report prepared for the US Marine Mammal Commission under Order number E40475499. Marine Mammal Commission, Silver Spring, MD, USA.

Baird, R. W., Gorgone, A. M., McSweeney, D. J., Webster, D. L., Salden, D. R., Deakos, M. H., Ligon, A. D., Schorr, G. S., Barlow, J., and Mahaffy, S. D. (2008). False killer whales (*Pseudorca crassidens*) around the main Hawaiian Islands: long-term site fidelity, inter-island movements, and association patterns. *Marine Mammal Science* **24**, 591–612. doi:10.1111/J.1748-7692.2008.00200.X

Baird, R. W., Schorr, G. S., Webster, D. L., McSweeney, D. J., Hanson, M. B., and Andrews, R. D. (2010). Movements of satellite-tagged false killer whales around the main Hawaiian Islands. *Endangered Species Research* **10**, 107–121. doi:10.3354/ESR00258

Baird, R. W., Hanson, M. B., Schorr, G. S., Webster, D. L., McSweeney, D. J., Gorgone, A. M., Mahaffy, S. D., Holzer, D. M., Oleson, E. M., and Andrews, R. D. (2012). Range and primary habitats of Hawaiian insular false killer whales: informing determination of critical habitat. *Endangered Species Research* **18**, 47–61. doi:10.3354/ESR00435

Baird, R. W., Mahaffy, S. D., Gorgone, A. M., Cullins, T., McSweeney, D. J., Oleson, E. M., Bradford, A. L., Barlow, J., and Webster, D. L. (2015). False killer whales and fisheries interactions in Hawaiian waters:

evidence for sex bias and variation among populations and social groups. *Marine Mammal Science* **31**, 579–590. doi:10.1111/MMS.12177

Bannister, J. L., Kemper, C. M., and Warneke, R. M. (1996). 'The Action Plan for Australian Cetaceans.' (Australian Nature Conservation Agency: Canberra, ACT, Australia.)

Bejder, L., Hodgson, A. J., Loneragan, N. R., and Allen, S. J. (2012). Coastal dolphins in north-western Australia: the need for re-evaluation of species listings and shortcomings in the environmental impact assessment process. *Pacific Conservation Biology* **18**, 22–25. doi:10.1071/PC120022

Condie, S. A. (2011). Modelling seasonal circulation, upwelling and tidal mixing in the Arafura and Timor Seas. *Continental Shelf Research* **31**, 1427–1436. doi:10.1016/J.CSR.2011.06.005

Department of Sustainability Environment Water Population and Communities (2011a). 'Marine Bioregion Plan for the North Marine Region.' (Department of Sustainability, Environment, Water, Population and Communities: Canberra, ACT, Australia.)

Douglas, A. B., Garita Alpizar, F., Acevedo-Gutierrez, A., Baird, R. W., and Calambokidis, J. (2011). False killer whales show fidelity to Costa Rican waters. In 'Abstracts of the 19th Biennial Conference on the Biology of Marine Mammals', 27 November–2 December 2011, Tampa, FL, USA. p. 82. (Society for Marine Mammalogy: Anacortes, WA, USA.)

Godfrey, J. S., and Mansbridge, J. V. (2000). Ekman transports, tidal mixing, and the control of temperature structure in Australia's northwest waters. *Journal of Geophysical Research* **105**, 24021–24044. doi:10.1029/2000JC900104

Harwood, M. B., and Hembree, D. (1987). Incidental catch of small cetaceans in the offshore gillnet Fishery in Northern Australian waters: 1981–1985. *Report of the International Whaling Commission* **37**, 363–367.

Harwood, M. B., McNamara, K. J., Anderson, G. R. V., and Walter, D. G. (1984). Incidental catch of small cetaceans in a gillnet fishery in northern Australian waters. *Report of the International Whaling Commission* **34**, 555–559.

Hooker, S. K., Whitehead, H., and Gowans, S. (1999). Marine protected area design and the spatial and temporal distribution of cetaceans in a submarine canyon. *Conservation Biology* **13**, 592–602. doi:10.1046/J.1523-1739.1999.98099.X

Hooker, S. K., Cañadas, A., Hyrenbach, D., Corrigan, C., Polovina, J. J., and Reeves, R. R. (2011). Making protected area networks effective for marine top predators. *Endangered Species Research* **13**, 203–218. doi:10.3354/ESR00322

Janik, V. M. (1997). Whistle matching in wild bottlenose dolphins. *The Journal of Acoustical Society of America* **101**, 3136. doi:10.1121/1.419266

Janik, V. M. (2000). Source levels and the estimated active space of bottlenose dolphin (*Tursiops truncatus*) whistles in the Moray Frith, Scotland. *Journal of Comparative Physiology* **186**, 673–680. doi:10.1007/S003590000120

Janik, V. M., and Slater, P. B. J. (1998). Context-specific use suggests that bottlenose dolphin signature whistles are cohesion calls. *Animal Behaviour* **56**, 829–838. doi:10.1006/ANBE.1998.0881

Martien, K. K., Chivers, S. J., Baird, R. W., Archer, F. I., Gorgone, A. M., Hancock-Hanser, B. L., Mattila, D., McSweeney, D. J., Oleson, E. M., Palmer, C., Pease, V., Robertson, K. M., Schorr, G. S., Schultz, M. B., Webster, D. L., and Taylor, B. L. (2014). Nuclear and mitochondrial patterns of population structure in north Pacific false killer whales (*Pseudorca crassidens*). *The Journal of Heredity* **105**, 611–626. doi:10.1093/JHERED/ESU029

Oleson, E. M., Boggs, C. H., Forney, K. A., Hanson, M. B., Kobayashi, D. R., Taylor, B. L., Wade, P. R., and Ylitalo, G. M. (2010). Status review of Hawaiian insular false killer whales (*Pseudorca crassidens*) under the *Endangered Species Act*. US Department of Commerce, NOAA Technical Memorandum, NOAA–TM–NMFS–Pacific Island Fisheries Science Centre-22, Honolulu, HI, USA.

Palmer, C., Fitzgerald, P., Wood, A., Harley, S., and McKenzie, A. (2009). False killer whales *Pseudorca crassidens*: regular visitors to Port Essington and Darwin Harbour in the Northern Territory, Australia. *Northern Territory Naturalist* **21**, 49–53.

Palmer, C., Brooks, L., Parra, G. J., Rogers, T., Glasgow, D., and Woinarski, J. C. Z. (2014). Estimates of abundance and apparent survival of coastal dolphins in Port Essington Harbour, Northern Territory, Australia. *Wildlife Research* **41**, 35–45. doi:10.1071/WR14031

Pawlowicz, R., Beardsley, B., and Lentz, S. (2002). Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE. *Computers & Geosciences* **28**, 929–937. doi:10.1016/S0098-3004(02)00013-4

Reeves, R. R., Leatherwood, S., and Baird, R. W. (2009). Evidence of a possible decline since 1989 in false killer whales (*Pseudorca crassidens*) around the main Hawaiian Islands. *Pacific Science* **63**, 253–261. doi:10.2984/049.063.0207

Stacey, P. J., and Baird, R. W. (1991). Status of the false killer whale, *Pseudorca crassidens*, in Canada. *Canadian Field Naturalist* **105**, 189–197.

Stacey, P. J., Leatherwood, S., and Baird, R. W. (1994). *Pseudorca crassidens*. *Mammalian Species* **456**, 1–6. doi:10.2307/3504208

Taylor, B. L., Baird, R. W., Barlow, J., Dawson, S. M., Ford, J., Mead, J. G., di Sciara, N., Wade, P., and Pitman, R. L. (2008). *Pseudorca crassidens* (False Killer Whale). In 'IUCN Red List of Threatened Species', ver. 2008, e.T18596A8495147. (International Union for Conservation of Nature and Natural Resources.) Available at http://www.iucnredlist.org/details/full/18596/0 [Verified 24 November 2014].

Weir, C. R., Collins, T., Cross, T., Gill, A., Elwen, S., Unwin, M., and Parnell, R. J. (2013). False killer whale (*Pseudorca crassidens*) in continental shelf habitat off Gabon and Côte d'Ivoire (Africa). *Marine Biodiversity Records* **6**, e65. doi:10.1017/S1755267213000389

Woinarski, J. C. Z., Burbidge, A. A., and Harrison, P. L. (2014). 'The Action Plan for Australian Mammals 2012.' (CSIRO Publishing: Melbourne, Vic., Australia.)

Zaeschmar, J. R., Visser, I. N., Fertl, D., Dwyer, S. L., Meissner, A. M., Halliday, J., Berghan, J., Donnelly, D., and Stockin, K. A. (2014). Occurrence of false killer whales (*Pseudorca crassidens*) and their association with common bottlenose dolphins (*Tursiops truncatus*) off northeastern New Zealand. *Marine Mammal Science* **30**, 594–608. doi:10.1111/MMS.12065