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Movements of two satellite-tagged pygmy killer whales (*Feresa attenuata*) off the island of Hawai'i

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Pygmy killer whales (*Feresa attenuata*) are a rare tropical oceanic odontocete that are normally found close to shore only around oceanic islands (Donahue and Perryman 2009, McSweeney *et al.* 2009). In the Exclusive Economic Zone (EEZ) surrounding the Hawaiian Islands there is a single stock of pygmy killer whales recognized (Carretta *et al*. 2010). In the Hawaiian EEZ they are the third-least abundant of the 12 species of delphinids documented, with an estimated abundance of 956 individuals (CV = 0.83; Barlow 2006). Around the island of Hawai'i a long-term photo-identification study has identified a small population that exhibits high site fidelity (McSweeney *et al.* 2009). This species is encountered only infrequently (an average of once every 35 d on the water), and thus limited information is available to examine movements based on location records of photo-identified individuals. Only a small number of identification photos have been available from other islands in the main Hawaiian Islands so there has been little ability to assess movements among islands.

As part of a long-term research effort to examine odontocete movements, habitat use, ecology, and abundance (Baird *et al.* 2008, 2009, 2010), we remotely deployed two dorsal fin attached satellite tags on pygmy killer whales off the island of Hawai'i in 2008 and 2009, and report here on movements and habitat use of these two individuals. Given the accumulating evidence of multiple discrete populations of other, better studied, species of odontocetes around the main Hawaiian Islands (Chivers *et al.* 2007, 2010; Baird *et al.* 2008, 2009; Andrews *et al.* 2010; Courbis *et al.*[1]), information on movements of pygmy killer whales is relevant to assessing whether multiple stocks of this species also exist within the Hawaiian EEZ. While the sample size is small, because of the low encounter rate and the usual difficulty in approaching individuals close enough for tagging, it is unlikely we will be able to obtain additional movement data from this species any time soon. Information from the two tags represents the only information available on movements for this species and greatly increases information on habitat use.

The satellite tags were a small location-only SPOT5 tag (Wildlife Computers, Inc., Redmond, WA) in the Low Impact Minimally Percutaneous External-electronics Transmitter (LIMPET) configuration (Andrews *et al.* 2008, Schorr *et al.* 2009, Baird *et al.* 2010) with attachment darts that penetrated 4.5 cm into the dorsal fin. The tags were attached using a pneumatic rifle from a distance of 2.5–6 m. Based on predicted satellite overpasses and taking into account the potential battery life and attachment duration, the tag deployed in 2008 was set to transmit 15 h/d for periods from 2 to 4 h in duration with intervals between transmission periods ranging from 1 to 3 h. The tag deployed in 2009 was set to transmit 13 h/d for periods from 2 to 3 h with intervals from 1 to 4 h between transmission periods. Tagged whales and other individuals in the group were photo-identified and matched to a long-term photo-identification catalog (see McSweeney *et al.* 2009) to determine sighting history. Age class (adult, subadult) was estimated in the field based on body size relative to other individuals.

Data obtained from the Argos system was processed with the Douglas Argos-Filter v. 7.06 (available at http://Alaska.usgs.gov/science/biology/spatial/douglas.html, accessed January 2009) using two independent methods: distance between consecutive locations, and rate and bearings among consecutive movement vectors. Each location is assigned a "location class" by Argos, which reflects the estimated precision of the location, with the most precise locations being classes 3 and 2. We set the Douglas Argos-Filter to automatically retain location classes 3 and 2. Maximum rate of movement was set at 10 km/h. Depth and distance from shore for all locations which passed the Douglas Argos-filter were determined in ArcGIS v. 9.2 (ESRI, Redlands, CA) using a 50 × 50 m multibeam synthesis bathymetry model from the Hawai'i Mapping Research Group (available at http://www.soest.hawaii.edu/HMRG/multibeam/index.php, accessed June 2008). Rates of horizontal movements were calculated using the time and distance between pairs of consecutive locations obtained from 1 to 6 h apart. Shorter and longer intervals between locations were not used to reduce positive and negative biases associated with the variability in Argos location accuracy and reversals in movement direction, respectively. Minimum straight-line

[1]Unpublished data from S. Courbis, Biology Department, Portland State University, P.O. Box 751, Portland, OR.

Table 1. Percentage of locations of different Argos location classes by individual pygmy killer whale.

Argos location class	Individual HIFa398	Individual HIFa279
3	5.8	5.8
2	21.1	14.4
1	20.2	37.6
0	13.5	23.1
A	20.2	11.0
B	19.2	8.1

distance (*i.e.*, not taking into account potential intervening land masses) from the tagging locations were calculated for all points.

A subadult-sized pygmy killer whale (HIFa398 in our catalog) was tagged on 6 December 2008. The individual had not been previously documented in our photo-identification catalog although the group that it was in (12 individuals) contained seven individuals that had been previously documented. An adult-sized pygmy killer whale (HIFa279 in our catalog) was tagged on 8 April 2009. This individual had first been documented in our photo-identification catalog in January 2007 and had been seen on eight occasions prior to tagging (including at the time HIFa398 was tagged). HIFa398 was also present in the group when HIFa279 was tagged. For HIFa398, 104 locations that passed the filter were received over the 11 d span of signal contact (Table 1). Seven locations for HIFa398 plotted on land. For HIFa279, no locations were received for the first 2 d after tagging, but after that 173 locations that passed the filter were received over a 20 d span (Table 1). Fifteen locations from HIFa279 plotted on land. Given the steep slope of the bathymetry in the areas where most of the locations were received and the close proximity to shore in general (see below), locations that plotted on land were used in travel speed calculations.

Both individuals remained strongly associated with the island of Hawai'i over the period that signals were received from the tags (Fig. 1). Median distance from shore was 4.07 km for HIFa398 (range = 0.03–14.08 km) and 4.66 km for HIFa279 (range 0.05–19.9 km). Both individuals moved out of the study area of McSweeney *et al.* (2009) around the south point of the island and along the southeast coast of the island (Fig. 1). HIFa398 remained south of the location where it was tagged over the 11 d period, moving a maximum straight line distance away from the tagging location of about 106 km, although HIFa398 reversed course back towards the tagging location on several occasions (Fig. 2). HIFa279 moved a maximum straight-line distance of 79 km from the tagging location, spending time both south and north of the tagging location and repeatedly reversing direction (Fig. 2). Median depth of locations was 1,093 m for HIFa398 (range = 6–2,270 m) compared to 977 m for HIFa279 (range = 8–2,842 m). The shallowest depths recorded should be taken with caution given the steep slope of the bathymetry and known error associated with Argos satellite locations.

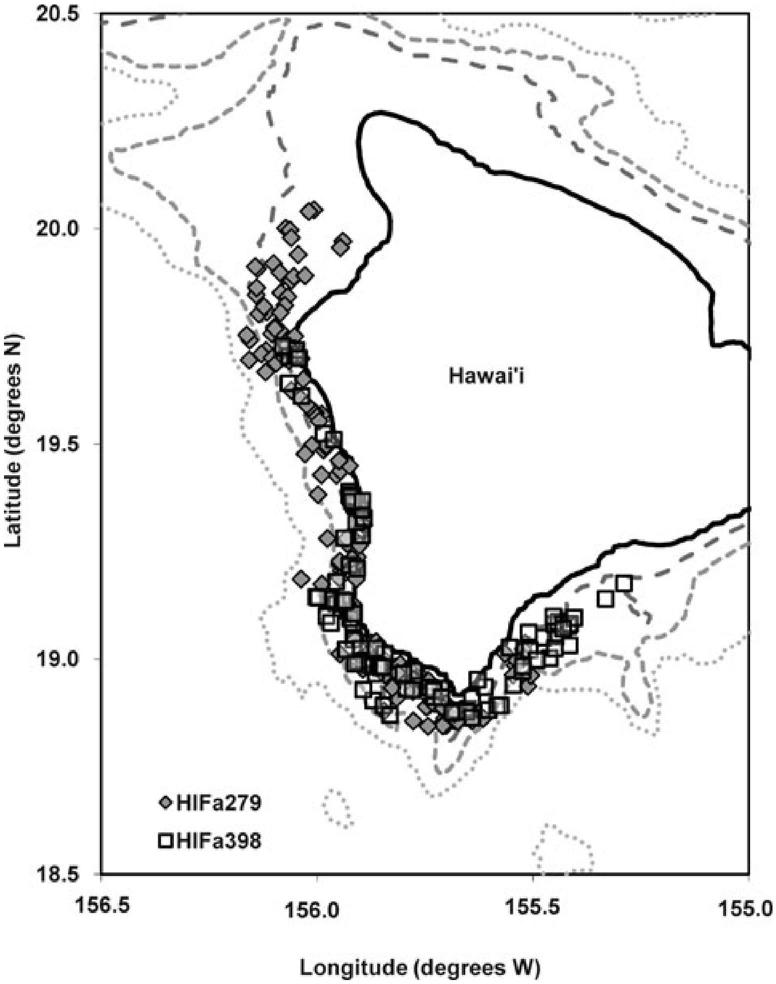

Figure 1. Map of the island of Hawai'i showing filtered locations of two satellite-tagged pygmy killer whales. The 1,000 m, 2,000 m, and 3,000 m depth contours are shown.

Median travel speed was 3.1 km/h for HIFa398 ($n = 73$ intervals) and 2.7 km/h for HIFa279 ($n = 112$ intervals). There is one report in the literature of supposed pygmy killer whales traveling at 30 km/h (Castro 2004), however photographic documentation from that sighting indicates the group seen were false killer whales (*Pseudorca crassidens)* rather than pygmy killer whales (Baird 2010). Median travel speeds documented were lower than has been documented for satellite tagged false killer whales (Baird *et al.* 2010) or melon-headed whales (*Peponocephala electra*; Schorr *et al.*[2]).

[2]Unpublished data from G. S. Schorr, Cascadia Research Collective, 218 1/2 W. 4th Avenue, Olympia, WA.

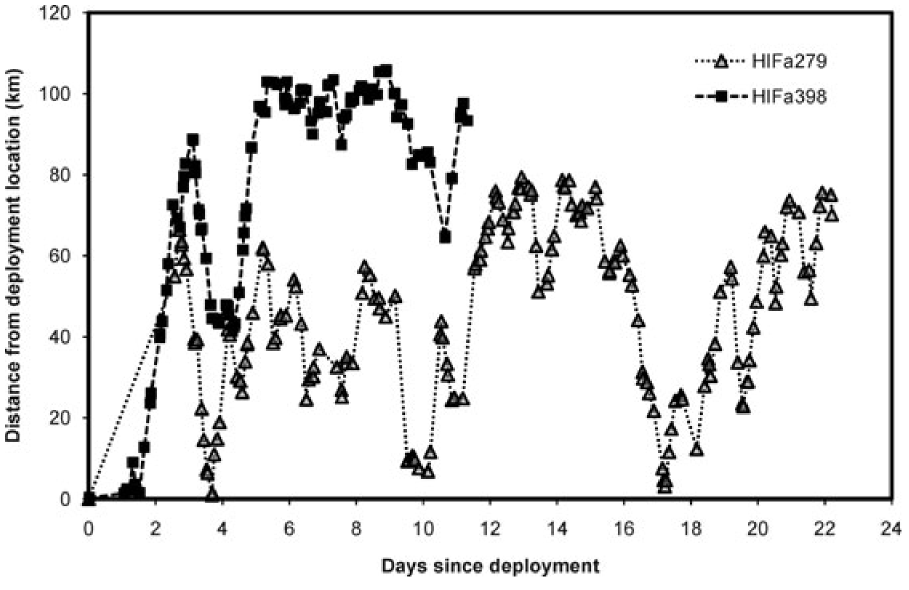

Figure 2. Straight-line distance from the tagging location over time for two pygmy killer whales. HIFa398 remained south of the tagging location for the duration of signal contact while HIFa279 moved south of the tagging location for the first 3 d then north until day 10, south again until day 17, north for approximately 1 d, and then remained south of the tagging location for the rest of signal contact. Note the greatest distances are negatively biased when the individuals were along the southeast coast of the island (see Fig. 1).

Although our sample size is small, just two individuals tracked over 10 and 22 d, this represents the first information on movements available for this species. McSweeney *et al.* (2009) had noted that high resighting rates of photo-identified individuals indicated a small island-associated population, with individuals repeatedly documented in the area for up to 21 yr. That the two tagged whales remained strongly associated with the island for the period that we have locations corroborates this, providing further evidence that these individuals may be resident to the island and that there may be multiple stocks within the Hawaiian EEZ, rather than a single stock as currently recognized (Carretta *et al.* 2010). Given the relatively short duration of the present observations, more data (*e.g.*, population genetics) is needed to confirm this hypothesis.

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