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Movements and spatial use of satellite tagged odontocetes in the western main Hawaiian Islands: results of field work undertaken off O'ahu in October 2010 and Kaua'i in February 2011

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MOVEMENTS AND SPATIAL USE OF SATELLITE-TAGGED ODONTOCETES IN THE WESTERN MAIN HAWAIIAN ISLANDS: RESULTS OF FIELD WORK UNDERTAKEN OFF O‘AHU IN OCTOBER 2010 AND KAUA‘I IN FEBRUARY 2011

by

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14. ABSTRACT

In the first year of a 3-year effort, surveys were made of odontocetes off Oahu and Kauai to examine spatial use and residency patterns in the western half of the Hawaii Range Complex using satellite tags, as well as obtaining individual identification photographs and biopsy samples for assessment of population identity and structure. 43 groups of 10 odontocete species were encountered, 15 satellite tags were deployed on 3 species, 39 genetic samples of 6 species and over 23000 photographs were obtained. Satellite tags were deployed on individuals in 2 groups of pygmy killer whales. Habitat use of the 2 groups differed substantially, and may be related to residency of the groups. Most individuals in one group had been previously photo-identified off Oahu. This group spent most of its time along the shores of Oahu, primarily in water <1000 m. 17 individuals in the other group had been photo-identified, but none previously off Oahu. The tagged individual from this second group ranged more extensively off Oahu than individuals from the first group, and spent most of its time in water >1000 m. Short-finned pilot whales were also tagged. Again, considerable variation in movement patterns and habitat use were observed: some groups remained close to the tagging area, suggesting residency; others ranged widely over varying depths. The differing ranging patterns may have implications for exposure and responses to Navy exercises.

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Summary

Although considerable information is available on residency patterns and spatial use of odontocetes in the eastern half of the Hawai'i Range Complex (HRC), much less is known about odontocetes in the western half of the HRC. In the first year of a three-year effort we undertook surveys off O'ahu (in October 2010) and Kaua'i (in February 2011) to examine spatial use and residency patterns using satellite tags, as well as obtaining individual identification photographs and biopsy samples for assessment of population identity and structure. In 18 days of combined effort we encountered 43 groups of 10 species of odontocetes, deployed 15 satellite tags on three species, obtained over 23000 photographs for contribution to photo-identification catalogs, and obtained 39 genetic samples of six species. Location data were obtained from satellite tags for periods from 7.2 to 223 days (median = 36.8 days). Tags deployed on three Hawaiian insular false killer whales provided the most detailed dive data yet available for this species and movement data will be contributed to studies of critical habitat for this species. Satellite tags were deployed on individuals in two groups of pygmy killer whales, one of the least known species of delphinids world-wide and a rare species in Hawaiian waters. Habitat use of the two groups differed substantially, and may be related to the residency of the groups as evidenced from photo-identification data. Most individuals in one group had been previously photo-identified off O'ahu (12 of 15), some in up to three previous years, and the group spent the 30 days post-tagging along the south and west shores of O'ahu and off the western end of Penguin Bank, remaining primarily in water depths of less than 1000 m (median depth = 576 m). Although 17 individuals in the other group were photo-identified, none had been previously photographed off O'ahu, although one had been previously documented off each of Lana'i and Hawai'i. The tagged individual from this group moved repeatedly from less than 1000 m depth to over 3000 m depth off O'ahu, spending most of its time over the 7 days of tracking in water depths greater than 1000 m (median depth = 2487 m). Short-finned pilot whales were tagged both off O'ahu (six individuals) and Kaua'i (three individuals). As with the pygmy killer whales, considerable variation in movement patterns and habitat use were apparent with tagged short-finned pilot whales, with some groups remaining close to the area of tagging, suggesting residency, and others moving over very wide ranges and using a broad range in depths, illustrating different ranging patterns that may have implications for exposure and responses to Navy exercises. Combined, these studies provide the most detailed information yet available on spatial use and ranging patterns of both pygmy killer whales and short-finned pilot whales in the western half of the HRC.

Introduction

Considerable information is available on residency patterns and spatial use of a number of species of odontocetes in the eastern half of the Hawai'i Range Complex (HRC), particularly off the island of Hawai'i (e.g., Aschettino *et al.* in press; Baird *et al.* 2008a, 2008b, 2009, 2010, 2011; McSweeney *et al.* 2007, 2009; Schorr *et al.* 2009). Favorable working conditions have resulted in a concentration of research activities off the island, where the presence of very deep water (>2000 m) close to shore has facilitated research with a number of typically deep-water species, as well as with shallow-water species. One of the main findings of this work is that there are resident populations of more than half of the species of odontocetes found off the island

of Hawai'i, including short-finned pilot whales, pygmy killer whales, melon-headed whales, common bottlenose dolphins, rough-toothed dolphins, Blainville's beaked whales, Cuvier's beaked whales, and dwarf sperm whales (e.g., Aschettino *et al.* in press; Baird *et al.* 2008a, 2008b, 2009, 2010, 2011; McSweeney *et al.* 2007, 2009; Schorr *et al.* 2009). In addition to these resident populations, individuals of some species are known to regularly move among the islands (e.g., false killer whales), and at least one has two populations that use the area (melon-headed whales, which have both a resident population to the island of Hawai'i and a population that moves among all of the main Hawaiian Islands and into offshore waters [Aschettino *et al.* in press, Woodworth *et al.* in press]).

Less is known about residency and spatial use of odontocetes in the western half of the HRC. The smaller size of the islands (Kaua'i, Ni'ihau, O'ahu) results in smaller lee areas and thus less ideal working conditions, and the shallower slopes to the islands mean that deep water is further offshore and thus in less protected areas. Most of the research that has been done has focused on photo-identification and biopsy sampling (e.g., Baird *et al.* 2003, 2006; but see Baird *et al.* 2008c), and has identified the existence of some island-specific populations of more commonly-encountered species, like rough-toothed dolphins off Kaua'i/Ni'ihau (Baird *et al.* 2008a) and bottlenose dolphins off both Kaua'i/Ni'ihau and O'ahu (e.g., Baird *et al.* 2009; Martien *et al.* in press), but less is known about less-frequently encountered and/or deeper-water species. Navy exercises are concentrated in the western half of the HRC. Thus there is a need for additional information on residency patterns and spatial use of protected species in that area to be able to assess the likelihood of exposure to exercises and interpret potential reactions. One of the primary purposes of this project is to address this information gap. A number of tools is used to accomplish this, in particular deployment of medium-term Low Impact Minimally Percutaneous External-electronics Transmitter (LIMPET) satellite tags on a number of species of odontocetes. Importantly, photo-identification data is also used to interpret spatial use patterns, building on long-term photo-identification catalogs compiled from throughout the main Hawaiian Islands, and collection of genetic samples to contribute to studies of population structure. This report summarizes results from the first year of this effort, with field activities undertaken in two periods: October 2010 off the island of O'ahu, and February 2011 off the island of Kaua'i. In addition to support from N45 and the Naval Postgraduate School, these field efforts were supported in part by funding from the Pacific Islands Fisheries Science Center and by Commander, Pacific Fleet.

Methods

Surveys were undertaken off the island of O'ahu for 14 days in October 2010, based out of Ko'olina Marina, using a 27' Boston Whaler outfitted with a tower and bow pulpit. Efforts were made to cover as broad a range off the southern and southwestern shores of the island as possible, with efforts concentrated away from shallow (e.g., <200 m) nearshore areas, as weather conditions permitted. Observers scanned 360 degrees around the research vessel, which transited typically at speeds of 15-30 km h^{-1}. Surveys off the island of Kaua'i were undertaken for 4 days in February 2011 as part of a survey coordinated by NAVFAC Pacific. During the Kaua'i effort groups were located by three observers aboard the 96' *R/V Searcher*, and tagging operations were undertaken from a 15' rigid-hulled inflatable. During both field operations efforts were

made to obtain photographs of all individuals in groups of odontocetes encountered and biopsy samples of most species.

Two types of satellite tags were used: a small location-only SPOT5 tag (Wildlife Computers, Inc., Redmond, WA), or a Mk10-A SPLASH tag that recorded both information on location and diving behavior, both in the LIMPET configuration (Andrews *et al.* 2008; Schorr *et al.* 2009; Baird *et al.* 2010). Attachment darts penetrated 4.5 cm into the dorsal fin for small species (e.g., pygmy killer whales) or 7 cm into the dorsal fin for larger species (e.g., false killer whales, short-finned pilot whales). Tags were programmed to transmit for variable periods during the day corresponding to the periods with the best satellite overpasses.

Data obtained from the Argos system were processed with the Douglas Argos-Filter v. 7.08 (available at http://Alaska.usgs.gov/science/biology/spatial/douglas.html) 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^{-1} for pygmy killer whales and 15 km h^{-1} for short-finned pilot whales and false killer whales. Depth and distance from shore for all locations which passed the Douglas Argos-filter were determined in ArcGIS v. 9.2 (ESRI, Redlands, California) using a 50 m x 50 m multibeam synthesis bathymetry model from the Hawai'i Mapping Research Group (available at www.soest.hawaii.edu/HMRG/multibeam/index.php).

To determine whether individuals with overlapping tag data were acting in concert or independently, we calculated the straight-line distance (i.e., not taking into account potentially intervening land masses) between pairs of individuals when locations were obtained during a single satellite overpass. We used both the average distances between pairs of individuals and the maximum distance between pairs to assess whether individuals were acting independently.

Photographs of tagged and companion whales were added and compared to individual photo-identification catalogs for each species maintained by Cascadia Research Collective (e.g., Baird *et al.* 2008b; McSweeney *et al.* 2009). Previous sighting history of individuals within groups was examined to assess whether individuals were part of resident populations from the areas they were tagged or potentially part of offshore populations or individuals moving from other islands.

Results and Discussion

In field efforts off O'ahu in October 2010 we encountered 30 different groups of 10 different species of odontocetes, were able to collect 32 genetic samples (from six species) for studies of population structure, and took over 18000 photographs for individual identification and for species identification (Table 1). During the Kaua'i effort, where there were 13 encounters with four different species of odontocetes, we were able to collect seven genetic samples from two species, and took over 5500 photographs (Table 2). During the two field operations satellite tags were deployed on 15 individuals of three different species of odontocetes

(Table 3). Three tags were deployed on false killer whales from the Hawai'i insular population, including the first deployments of combination location/dive tags on this species. Although detailed analyses from the false killer whale tag deployments will be reported elsewhere (Baird *et al.* in prep), there are several points that warrant mentioning. These deployments were the second set of satellite tag deployments on false killer whales off the island of O'ahu --the first were deployed in October 2009; see Baird *et al.* 2010-- and greatly increase our understanding of movements of individuals from this population in the western half of the Hawai'i Range Complex. One of the individuals tagged (HIPc272) had been previously tagged off the island of Hawai'i (see Baird *et al.* 2010). A comparison of spatial use of this individual during the two different years illustrates differences in spatial use among years for this species (Figure 1). When tagged in 2008, HIPc272 spent the majority of its time on the leeward sides of the islands and moved from Hawai'i Island to O'ahu, whereas in 2010 this individual restricted its movements to the area from O'ahu to Maui, despite the fact that the tracking period was longer in 2010 (32 days) than in 2008 (26 days), and made extensive use of both the windward and leeward sides of the islands. Such an example of differences in movements of the same individual tagged in two different locations (in two different years) demonstrates that movements of individual false killer whales may be influenced by the location of where they were tagged and/or vary between years.

Three tags were deployed on pygmy killer whales off O'ahu, in two different groups. These tag deployments represent the first movement data available for this species away from the island of Hawai'i, and a substantial increase in what is known about spatial use of this species, both in Hawai'i and world-wide. Two of the individuals were tagged in the same group, although the tags were deployed five days apart. When this group was first encountered, identification photos were obtained from 15 distinctive individuals, 12 of which (80%) had been previously documented off the island of O'ahu in from two to four different years (Table 4). Both of the tagged whales had been previously photographed off O'ahu together in October 2008 and August 2009, and both were photographed together in December 2010 after the tags had come off. Three other individuals present in the group had also been previously photo-identified off O'ahu in 2007, 2008 and 2009 (the latter two years with the two whales who were tagged also present), all suggesting this group is resident to the island. Satellite data from the two individuals combined were available for 30 days post-tagging. The group moved from the southwest coast of O'ahu to off the south coast, and then spent the majority of their time in a small area off the western edge of Penguin Bank (Figure 2). The group was documented almost entirely in depths of less than 1000 m (median depth of location = 576 m; Figure 3). Identification photos were available from 17 distinctive individuals from the second group tagged, and two of those individuals (11.8%) had been previously documented, one off the island of Hawai'i and one off Lana'i (Table 4). The movement of one individual from Hawai'i to O'ahu represents the first inter-island movement documented from photo-identification data for this species. Prior to this effort, movement data were available from just two pygmy killer whales tagged off the island of Hawai'i. Both individuals were part of the same social group, although they were tagged four months apart, and both individuals remained strongly associated with the island (Baird *et al.* 2011). The overall low re-sighting rate and lack of previous records from O'ahu suggest the second group we tagged is not resident to the island. Satellite data from this group over a 7 day period showed a very different pattern than the first group tagged, with repeated movements from less than 1000 m depth to over 3000 m depth (Figure 2). Overall this

group used a much broader range of water depths (Figure 3) with a median depth of 2487 m. Combined, the results suggest that habitat use may depend strongly on whether the area is a core area for the group (e.g., O'ahu/Penguin Bank for FaTag5 and FaTag6) versus an area visited only rarely (FaTag7).

Nine satellite tags were deployed on short-finned pilot whales, with six deployments (on three different days) off O'ahu and three (on two different days) off Kaua'i. An analysis of distance among tagged individuals that were either tagged on the same day or tagged on subsequent days but for which some individuals were in common between the two groups suggest that seven different social units were tagged (Table 5). Of the groups where tags were deployed, the proportion of individuals that had previously been photographically documented ranged from 0 to 94% (Table 4). Almost half of the distinctive individuals (9 of 21) in the first group of pilot whales tagged off O'ahu had been previously photo-identified off the island of Lana'i (Table 4). Individuals from this group remained strongly associated with O'ahu and the 4-island area (the islands of Moloka'i, Maui, Lana'i and Kaho'olawe) for the entire duration of tag transmissions (Figure 4), covering a 223 day span for one individual (GmTag43). Most of the time was spent off the leeward (west) shores of Lana'i and the south and west shores of O'ahu, with relatively little time spent on the north side of O'ahu or north of the 4-island area (Figure 4). Tagged individuals from this group were strongly associated with the slope, with most locations in depths of less than 3000 m (Figure 5; GmTag41 median = 1364 m, GmTag42 median = 1514 m, GmTag43 median =1488 m). Maximum distance moved from the tagging location for these individuals was 153 km. The relative lack of movements, strong association with the slope, and large proportion of individuals that had been previously photo-identified suggest this is a resident group to the O'ahu/4-islands area.

By contrast, the three individuals tagged off O'ahu on 19 October 2010 ranged widely both among the western main Hawaiian Islands almost as far as Nihoa in the northwestern Hawaiian Islands and offshore (Figure 6). While remaining within the HRC, one individual (GmTag44) crossed three management boundaries: the long-line exclusion zone around the main Hawaiian Islands, the Papahānaumokuākea Marine National Monument Boundary, and the U.S. Exclusive Economic Zone boundary surrounding Hawai'i (Figure 6). This is the first direct evidence that any species of odontocetes from the main Hawaiian Islands may utilize either waters within the Marine National Monument or international waters. A comparison of distances among these individuals indicated that the three individuals were likely from two different social units, with GmTag44 and GmTag45 remaining relatively close together (median = 2.4 km) for the nine days of overlap (Table 5). Although tagged only a couple of kilometers apart, GmTag44 and GmTag46 separated by 457 km (median distance apart = 164.1 km). Depths used by these individuals were almost entirely greater than 3000 m (GmTag44 median = 4616 m; GmTag46 median = 4331 m; Figure 5).

Three pilot whales were satellite tagged off the north side of Kaua'i on two consecutive days in February 2011. Two of the three individuals were tagged on the same day, although in different sub-groups. Photo-identification data revealed that one sub-group had no previous sightings (0 of 15 individuals; Table 4), while the other had 16 of 17 individuals previously documented, off the island of O'ahu (Table 4). Comparison of distances among individuals over the period of tag overlap also suggested that these individuals were from different social units,

with median distance apart of almost 20 km (Table 5, maximum distance apart = 199.6 km). Although analyses of depth use are not yet available for the individuals tagged off Kaua'i, overall ranging patterns did differ between the three individuals (Figure 7), with one moving to O'ahu and back, and another moving further west.

Results from this work represent a dramatic increase in what is known about spatial use and residency patterns of both short-finned pilot whales and pygmy killer whales in the main Hawaiian Islands, in particular in the western half of the HRC. The tags deployed on short-finned pilot whales off O'ahu that broadly utilized offshore waters provide evidence that individuals of this species in Hawai'i may have alternative spatial use strategies, with some remaining in restricted areas and primarily using slope habitats, and others roaming widely and using open-ocean habitats (Figure 4, Figure 6). Such results have implications for both the potential of exposure of groups to mid-frequency sonar from Navy exercises, and for their potential responses to exposure. Future additional incorporation of photographs of pilot whales from Kaua'i and O'ahu, and additional tag deployments, will allow for a more thorough understanding of the spatial use and residency patterns of this species in the western HRC, and assessment of responses of instrumented individuals to exercises.

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Table 1. Details of odontocetes sightings off O'ahu in October 2010.

Species	Date	Sighting #	Group size (best)	# genetic samples	# photos
Blainville's beaked whale	19-Oct-10	5	3	0	274
Blainville's beaked whale	20-Oct-10	2	4	0	55
Bottlenose dolphin	14-Oct-10	1	19	2	258
Dwarf sperm whale	20-Oct-10	3	1	0	0
False killer whale	15-Oct-10	2	28	3	2,030
False killer whale	22-Oct-10	2	19	1	1,437
Melon headed whale	18-Oct-10	2	1	0	2
Pantropical spotted dolphin	10-Oct-10	1	80	2	398
Pantropical spotted dolphin	10-Oct-10	4	45	0	113
Pantropical spotted dolphin	13-Oct-10	1	11	2	98
Pantropical spotted dolphin	13-Oct-10	2	65	1	37
Pantropical spotted dolphin	14-Oct-10	2	50	0	32
Pantropical spotted dolphin	18-Oct-10	3	85	2	173
Pantropical spotted dolphin	19-Oct-10	1	75	0	7
Pantropical spotted dolphin	19-Oct-10	2	40	0	18
Pantropical spotted dolphin	20-Oct-10	1	40	1	75
Pantropical spotted dolphin	21-Oct-10	1	120	2	166
Pantropical spotted dolphin	23-Oct-10	1	170	0	771
Pygmy killer whale	13-Oct-10	3	18	0	1,820
Pygmy killer whale	18-Oct-10	1	17	3	1,042
Pygmy killer whale	24-Oct-10	1	25	0	1,676
Rough-toothed dolphin	10-Oct-10	2	14	2	918
Rough-toothed dolphin	10-Oct-10	3	16	2	672
Rough-toothed dolphin	11-Oct-10	1	24	4	891
Short-finned pilot whale	15-Oct-10	1	32	0	2,390
Short-finned pilot whale	16-Oct-10	1	47	2	1,131
Short-finned pilot whale	19-Oct-10	3	56	2	1,207
Short-finned pilot whale	19-Oct-10	4	35	1	668
Spinner dolphin	15-Oct-10	3	25	0	8
Spinner dolphin	22-Oct-10	1	55	0	286

Table 2. Details of odontocetes sightings of odontocetes off Kaua'i in February 2011.

Species	Date	Sighting #	Group size (best)	# genetic samples	# photos
Bottlenose dolphin	20-Feb-11	1	4	0	80
Bottlenose dolphin	20-Feb-11	2	1	0	34
Rough-toothed dolphin	17-Feb-11	1	2	0	104
Rough-toothed dolphin	17-Feb-11	2	12	2	450
Rough-toothed dolphin	18-Feb-11	2	4	2	139
Rough-toothed dolphin	18-Feb-11	3	5	0	142
Rough-toothed dolphin	18-Feb-11	4	5	1	116
Rough-toothed dolphin	18-Feb-11	5	3	0	52
Rough-toothed dolphin	19-Feb-11	2	18	0	407
Short-finned pilot whale	18-Feb-11	6	17	2	2,807
Short-finned pilot whale	19-Feb-11	1	8	0	46
Short-finned pilot whale	19-Feb-11	3	16	0	594
Spinner dolphin	19-Feb-11	5	55	0	621

Table 3. Information on satellite tag deployments during October 2010 and February 2011.

Species	Tag ID	Date deployed	Island tagged	Individual ID	Duration of signal (days)	Data type[1]
Pygmy killer whale	FaTag5	13-Oct-10	O'ahu	HIFa368	11.8	L
Pygmy killer whale	FaTag6	18-Oct-10	O'ahu	HIFa371	25.5	L
Pygmy killer whale	FaTag7	24-Oct-10	O'ahu	HIFa459	7.2	L
Short-finned pilot whale	GmTag41	15-Oct-10	O'ahu	HIGm1291	22.8	L
Short-finned pilot whale	GmTag42	16-Oct-10	O'ahu	HIGm1296	97.5	L
Short-finned pilot whale	GmTag43	16-Oct-10	O'ahu	HIGm1297	223[2]	L
Short-finned pilot whale	GmTag44	19-Oct-10	O'ahu	HIGm1317	58.0	L
Short-finned pilot whale	GmTag45	19-Oct-10	O'ahu	HIGm1324	9.3	L
Short-finned pilot whale	GmTag46	19-Oct-10	O'ahu	HIGm1187	53.1	L
Short-finned pilot whale	GmTag49	18-Feb-11	Kaua'i	HIGm1374	30.9	L
Short-finned pilot whale	GmTag50	18-Feb-11	Kaua'i	HIGm0180	36.8	L/D
Short-finned pilot whale	GmTag51	19-Feb-11	Kaua'i	HIGm1400	37.1	L
False killer whale	PcTag26	15-Oct-10	O'ahu	HIPc200	13.2	L/D
False killer whale	PcTag27	22-Oct-10	O'ahu	HIPc132	51.3	L
False killer whale	PcTag28	22-Oct-10	O'ahu	HIPc272	47.6	L/D

[1]L = Location-only; L/D = Location/Depth. [2]This tag last transmitted on 29 May 2011 and is on a once-every-five-day transmission schedule so may still be functioning as of the time of this report.

Table 4. Information on previous sighting histories of pygmy killer whale and short-finned pilot whale groups or sub-groups where individuals were satellite tagged. (See Table 3 for details.)

Tagged whales present	Date first tag deployed	# distinctive individuals photo-IDd	# (%) seen prior to field effort	Island(s) previously documented
FaTag5, 6	13-Oct-10	15	12 (80.0)	O'ahu
FaTag7	24-Oct-10	17	2 (11.8)	Hawai'i, Lana'i
GmTag41, 42, 43	15-Oct-10	21	9 (42.9)	Lana'i
GmTag44, 45	19-Oct-10	23	0 (0.0)	-
GmTag46	19-Oct-10	16	4 (25.0)	Kaua'i
GmTag49	18-Feb-11	15	0 (0.0)	-
GmTag50	18-Feb-11	17	16 (94.1)	O'ahu
GmTag51	19-Feb-11	12	1 (8.3)	O'ahu

Table 5. Distance (in km) among pairs of satellite tagged short-finned pilot whales tagged either on the same day (see Table 3) or on subsequent days when individuals from the first encounter were also present. For each set of whales both the median distance apart (above the diagonal) and the maximum distance apart (below the diagonal) are shown. Individuals with median distances apart of less than 5 km were considered to be part of the same social unit (highlighted in bold).

	GmTag41	GmTag42	GmTag43
GmTag41	-	12.8	11.8
GmTag42	47.4	-	**3.0**
GmTag43	42.9	24.5	-

	GmTag44	GmTag45	GmTag46
GmTag44	-	**2.4**	164.1
GmTag45	33.2	-	9.1
GmTag46	457.6	155.3	-

	GmTag49	GmTag50	GmTag51
GmTag49	-	19.8	43.3
GmTag50	199.6	-	30.5
GmTag51	313.4	197.9	-

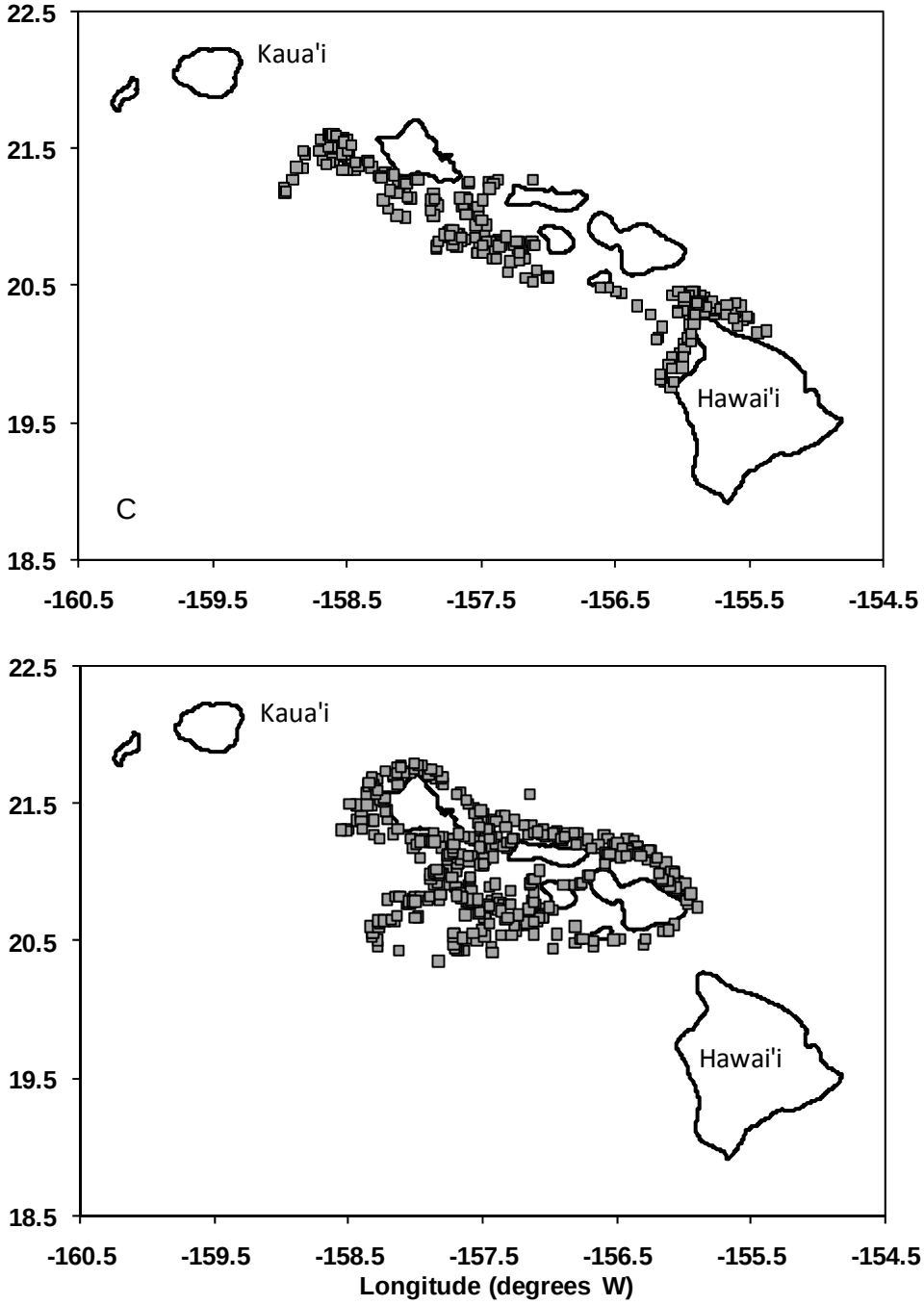

Figure 1. Maps showing spatial use patterns of false killer whale HIPc272 tagged off the island of Hawai'i in 2008 (**top**, 26 days of movements in September 2008) and off O'ahu in 2010 (**bottom**, 32 days of movements in October and November 2010).

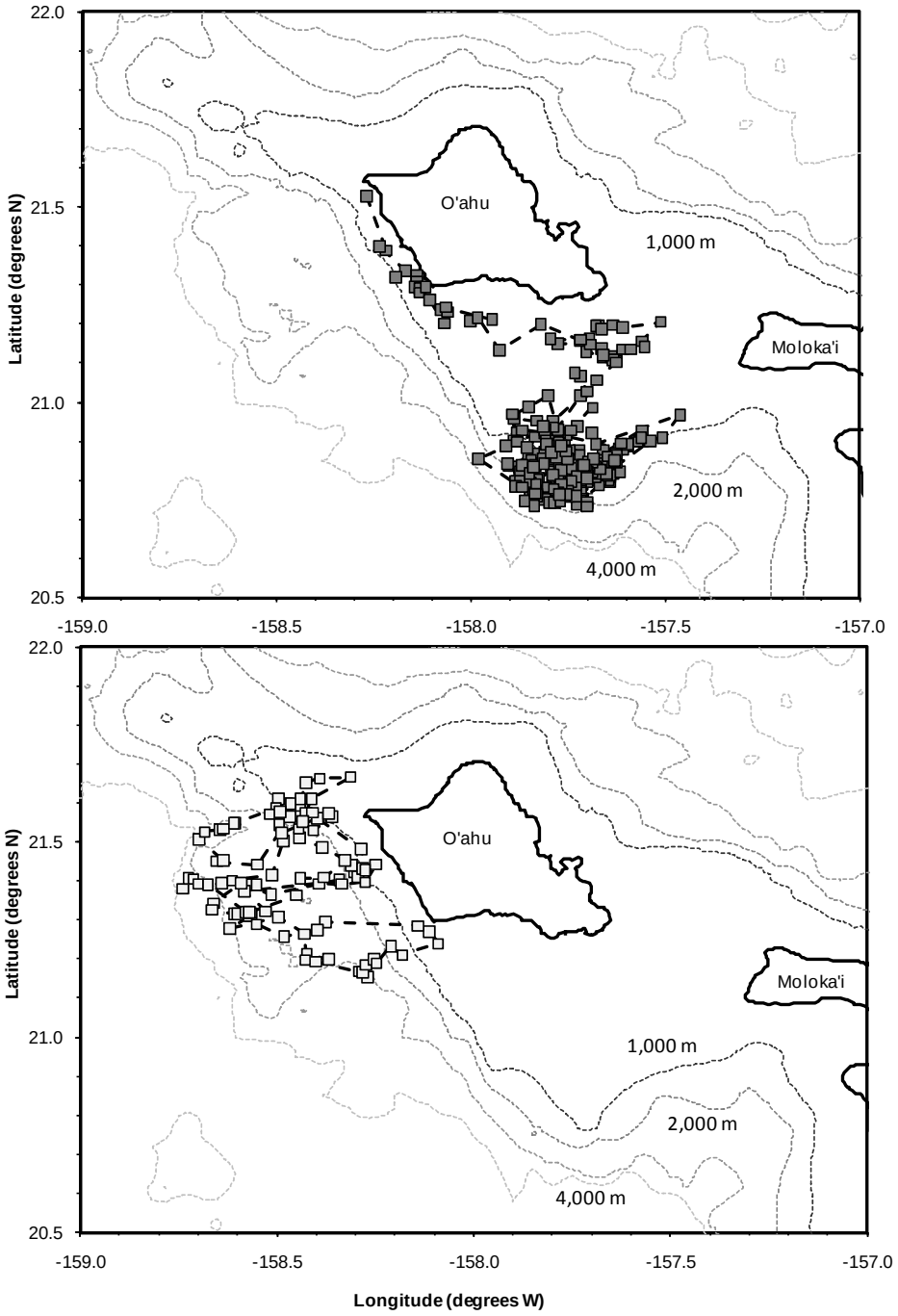

Figure 2. Locations of satellite-tagged pygmy killer whales tagged off O'ahu in October 2010. **Top.** Combined track of individuals tagged 13 October 2010 and 18 October 2010, with total span of movement data over 30 days. Individuals from this group had been previously documented off O'ahu in 2007, 2008 and 2009. **Bottom.** Individual tagged 24 October 2010, with movement data over 7.2 days. None of the individuals in this group had been previously documented off O'ahu, although one individual had been photographed off Hawai'i and one had been recorded off Lana'i. Dotted lines connect consecutive locations but do not necessarily reflect travel routes.

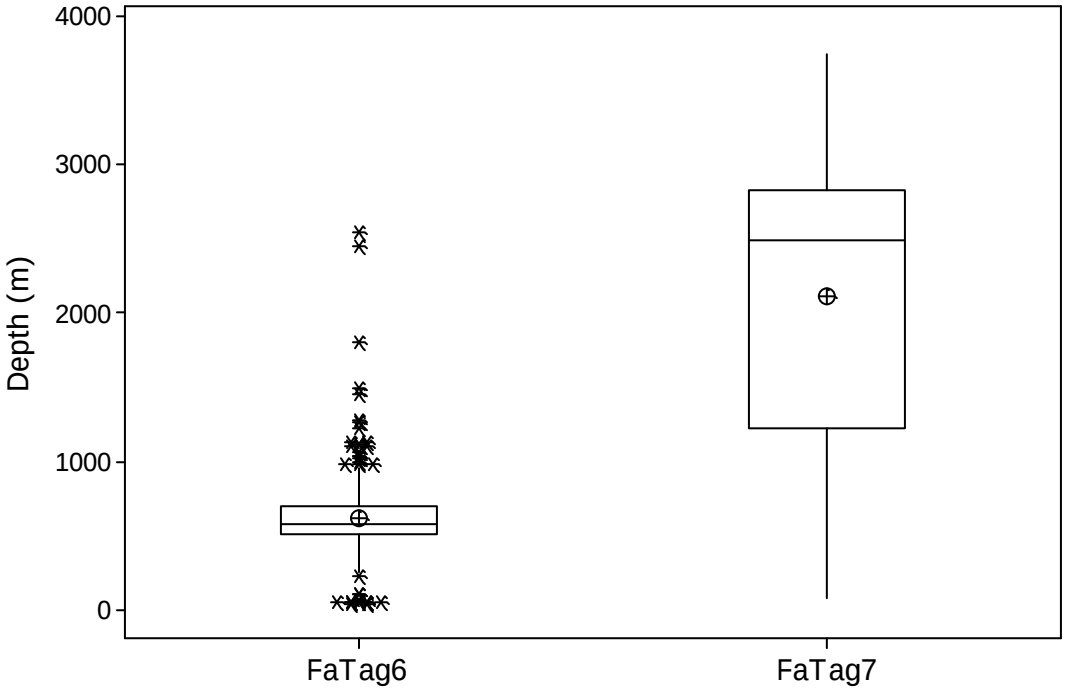

Figure 3. Boxplot showing depth for data from two pygmy killer whales tagged off the island of O'ahu in October 2010. Symbol in middle of box represents mean value; middle horizontal line represents median. The box bottom is at the 25th percentile and the top is at the 75th percentile.

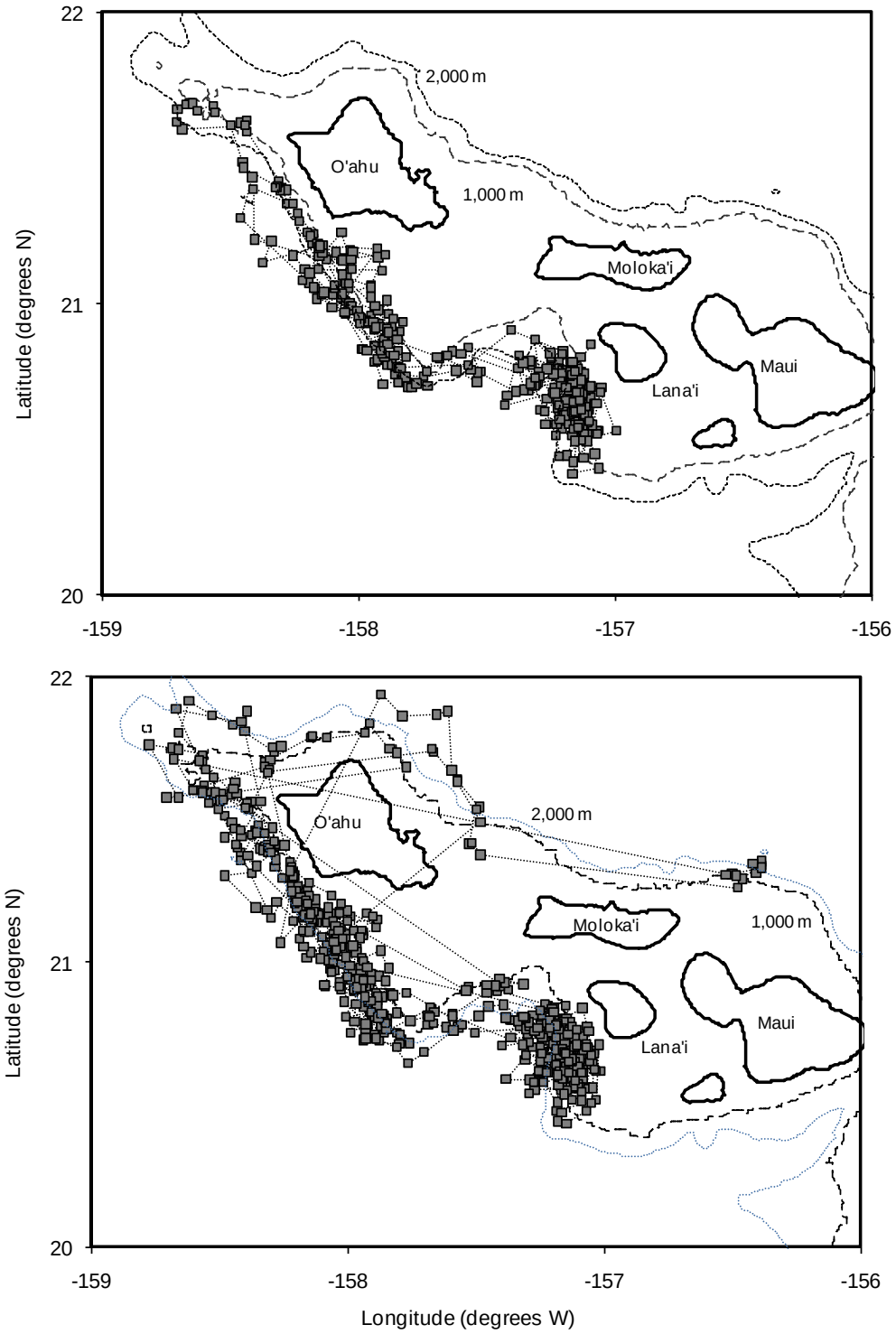

Figure 4. Movements of two short-finned pilot whales tagged off O'ahu on 16 October 2010. **Top.** GmTag42. **Bottom.** GmTag43. Dotted lines connect consecutive locations but do not necessarily reflect travel routes.

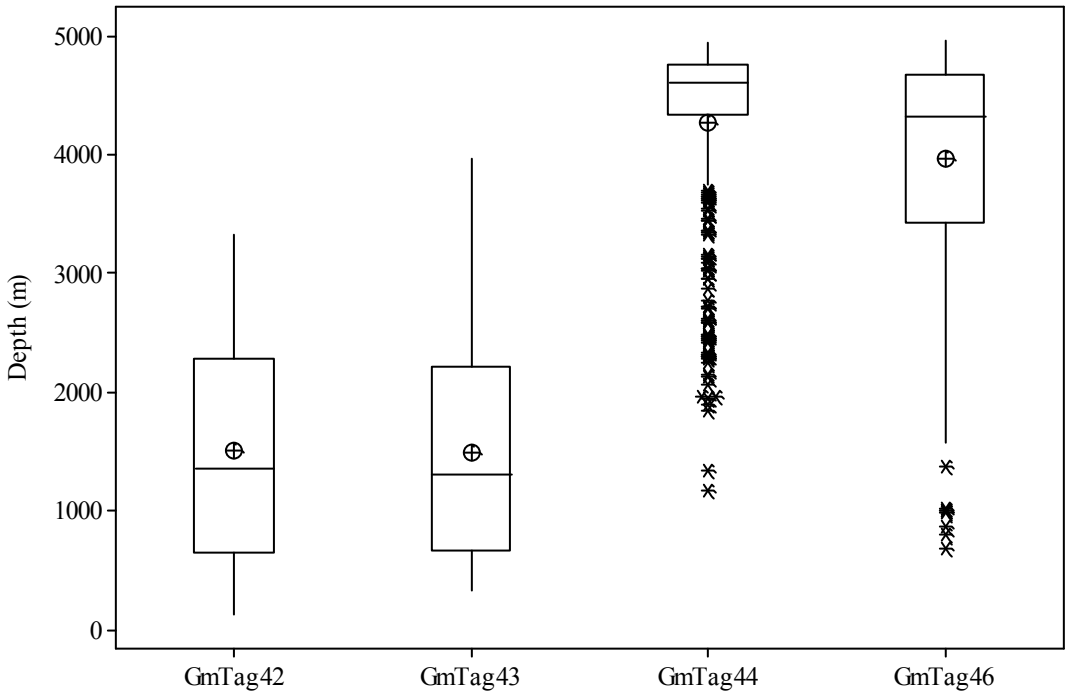

Figure 5. Boxplot showing depth for data from four short-finned pilot whales tagged off the island of O'ahu in October 2010. Individuals GmTag42 and GmTag43 were tagged in the same group 16 October 2010, while GmTag44 and GmTag46 were tagged in two groups separated by 2 kilometers on 19 October 2010. Symbol in middle represents mean value; middle horizontal line represents median. The box bottom is at the 25th percentile and the top is at the 75th percentile.

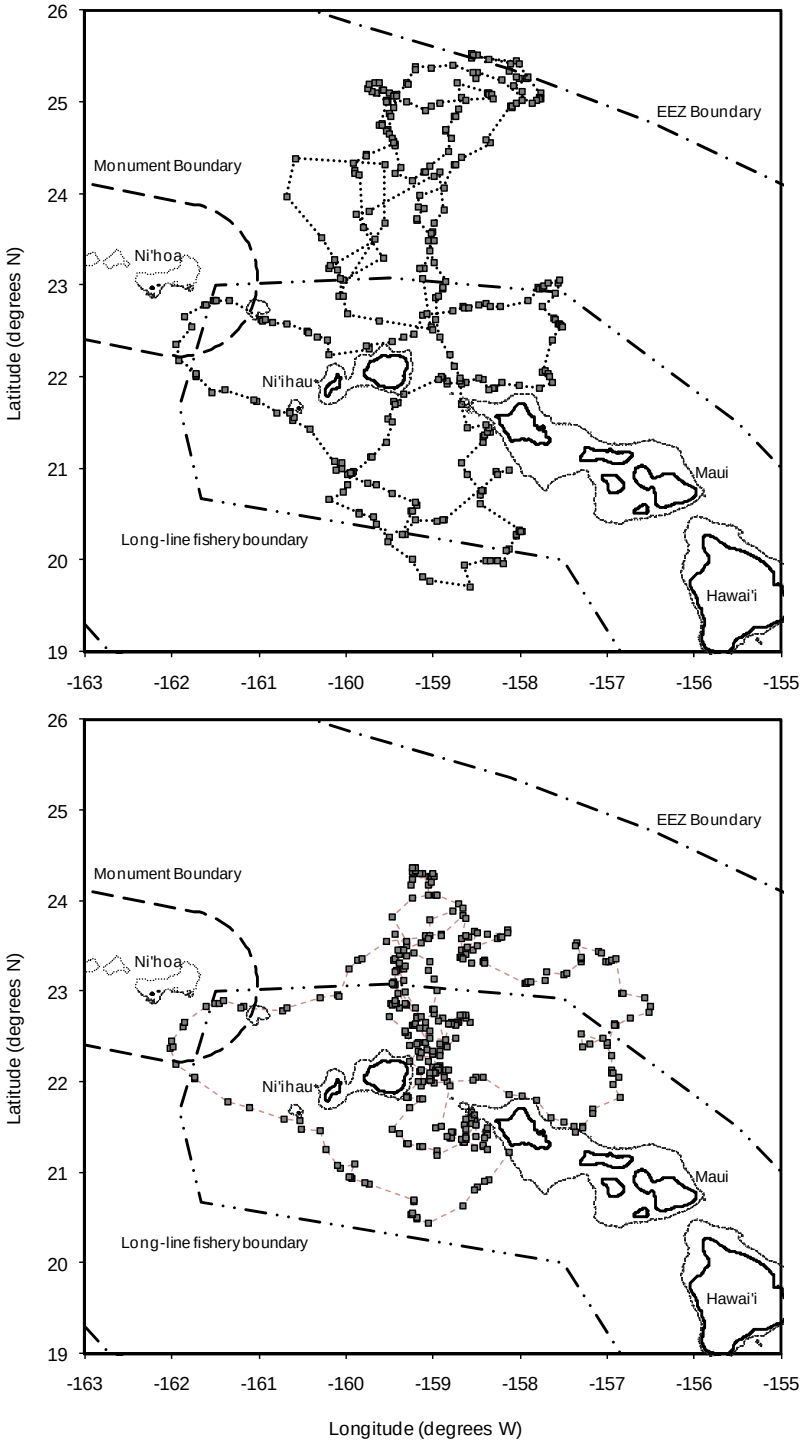

Figure 6. Movements of two short-finned pilot whales tagged (in separate groups) off O'ahu on 19 October 2010. **Top.** A 58-day track from GmTag44. **Bottom.** A 53-day track from GmTag46. The 1000 m depth contour is shown. Dotted lines connect consecutive locations but do not necessarily reflect travel routes.

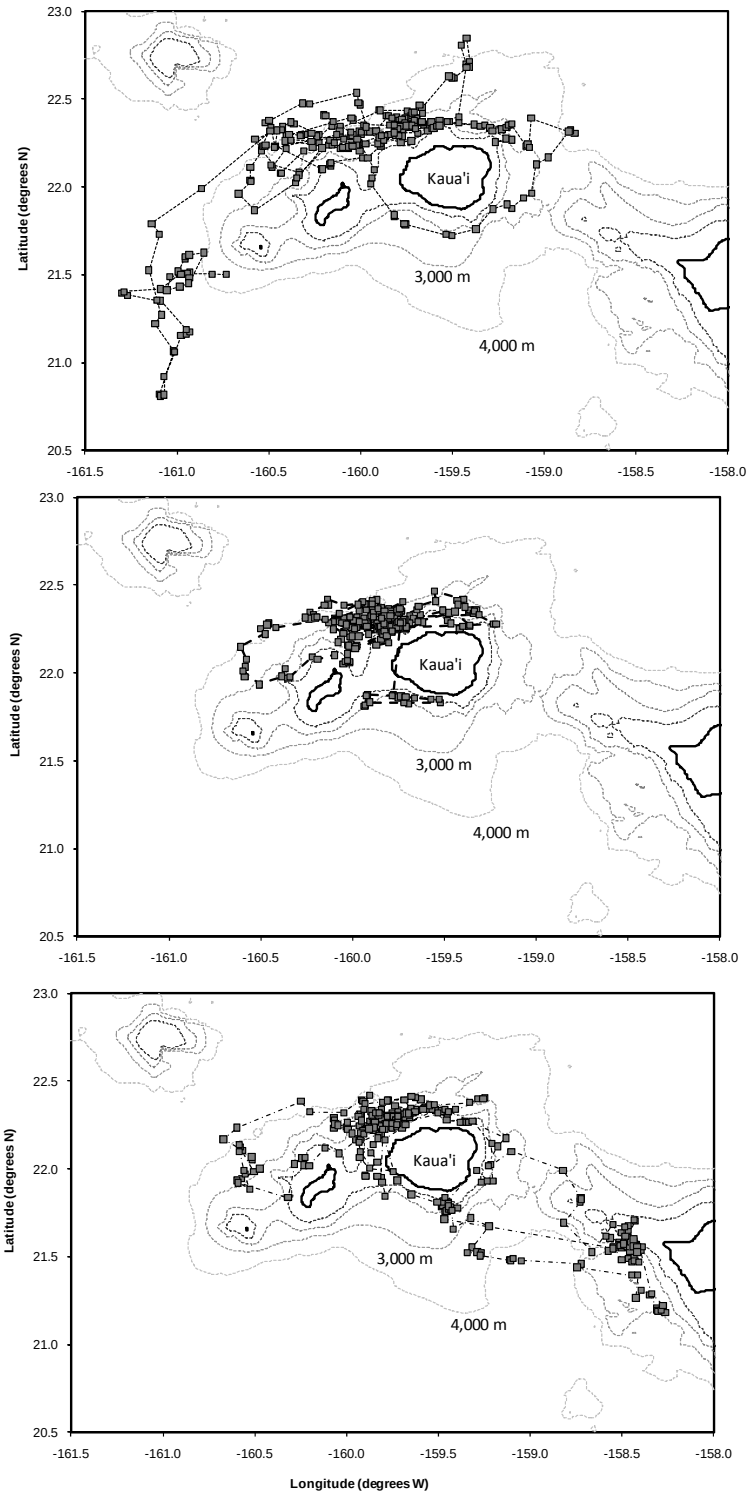

Figure 7. Movements of three satellite-tagged pilot whales tagged off Kaua'i in February 2011. **Top.** GmTag49, tagged 18 Feb. 2011, showing 30.9 days of movements. **Middle.** GmTag50, tagged 18 Feb. 2011, showing 36.8 days of movements. **Bottom.** GmTag51, tagged 19 Feb. 2011, showing 37.1 days of movements. Dotted lines connect consecutive locations but do not necessarily reflect travel routes.

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