

**MOVEMENTS AND HABITAT USE OF CUVIER'S AND BLAINVILLE'S BEAKED
WHALES IN HAWAII: RESULTS FROM SATELLITE TAGGING IN 2009/2010**

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Abstract

To assess movements and habitat use of beaked whales in Hawai'i, satellite tags were remotely-deployed on two adult female Cuvier's beaked whales (*Ziphius cavirostris*) and one adult female Blainville's beaked whale (*Mesoplodon densirostris*) between October 2009 and April 2010. All three individuals were photo-identified, but only one (a Cuvier's) had been previously documented off the island and was known to be part of the resident population. Location data for the Cuvier's beaked whales were received for 7.2 and 25.5 days, and location data for the Blainville's beaked whale were received for 20.5 days. All three individuals remained associated with the island of Hawai'i for the duration of tag attachments. Median water depth and distance from shore for the locations of the Blainville's beaked whale were 1,098 m and 23.2 km, respectively. Median water depths and distances from shore for the locations of the two Cuvier's beaked whales were 2,389 m and 14.4 km, and 1,970 m and 10.7 km. The shallower depths yet greater distances from shore for the Blainville's beaked whale were due to that individual spending its time off the northwest part of the island, where shallower water extends further from shore. Movements of the Blainville's beaked whale were restricted to the waters off the west and north side of the island, similar to earlier tagging results for this species that suggest the island-associated population rarely utilizes waters off the windward side of the island. One of the tags deployed on a Cuvier's beaked whale also recorded and transmitted information on dive depth (72 hours total). This is the first satellite-dive tag deployed on a beaked whale, and it more than doubled the sample size of dive data available for Cuvier's beaked whales in Hawai'i. As was found previously for two Cuvier's beaked whales tagged with time-depth recorders, long (maximum 86.9 min) and deep (maximum 1,752 m) dives were recorded both during the day and night, although there were diel differences in use of the water column.

Introduction

The use of remotely-deployed satellite tags has dramatically increased our understanding of habitat use and movements of Blainville's beaked whales (*Mesoplodon densirostris*) and

Cuvier's beaked whales (*Ziphius cavirostris*) in recent years (Schorr et al. 2008, 2009; Baird et al. 2009a). In Hawai'i such tagging has demonstrated that both species remain strongly associated with the island of Hawai'i for periods of weeks to months (Schorr et al. 2008, 2009; Baird et al. 2009a), supporting the existence of resident populations evident from photo-identification data (McSweeney et al. 2007). A tagged individual Blainville's beaked whale thought to be from an open-ocean population (based on photo-identification of the group and the location where it was tagged) exhibited long-distance offshore movements and strong differences in habitat use from the resident population (Baird et al. 2009a). Movement data from the resident population of Blainville's beaked whales has indicated an apparent preference for the west (leeward) side of the island of Hawai'i, while a much smaller sample size of movement data from Cuvier's beaked whales has indicated they appear to use the windward (east) side of the island of Hawai'i to some extent (Baird et al. 2009a). Such information can be used in predicting exposure of beaked whale populations to anthropogenic activities such as mid-frequency sonar or ocean thermal energy development and in determining appropriate areas to protect small resident populations.

Although the sample of movement data from satellite-tagged Blainville's beaked whales from the resident population off the island of Hawai'i is relatively large (8 individuals from 5 groups, for an average of 48 days, Schorr et al. 2009), the sample for Cuvier's beaked whales was small prior to this effort (only 4 individuals from 3 groups, with one tag transmitting for only 2.2 days, median = 17.4 days). This report summarizes results from field efforts in the latter half of 2009 and first half of 2010 with efforts focused on obtaining additional information on movements and habitat use of both Cuvier's and Blainville's beaked whales off the island of Hawai'i. During these efforts, several other species were also satellite tagged, and additional information was obtained through photo-identification, acoustic recording and biopsy efforts (results will be reported elsewhere).

Methods

Small-boat based field efforts were undertaken in October 2009, December 2009, and April 2010 out of Honokohau Harbor on the west coast of the island of Hawai'i, using a 27'

Boston Whaler with a custom tower for elevated observers and a custom bow pulpit for tagging. The vessel searched for cetaceans along the west coast of the island, and efforts were made to maximize the spatial extent of survey effort given the logistic constraints of sea conditions and distance to the harbor. Emphasis was placed on working in locations and sea conditions that were most suitable for detecting and working with beaked whales. A team of 4-7 observers scanned 360 degrees around the research vessel and all observed groups of cetaceans were approached for species identification, estimation of group size and determination of location and behavior. All groups of beaked whales were followed as long as possible unless individuals showed strong avoidance reaction to the research vessel that indicated that further approaches would be unlikely to result in successful satellite tagging. Photographs were taken for species and individual identification and to document sex of individuals seen. Individual identification photos were compared to a long-term photo-identification catalog (see McSweeney et al. 2007). When groups could be approached close enough for tagging, we attempted to deploy satellite tags. When groups exhibited reactions that suggested that would not be approachable, efforts were re-focused on biopsy sampling which could be undertaken at much greater distances than satellite tagging.

Two types of satellite tags were used, a Wildlife Computers location-only SPOT-5 tag (the same as those used by Schorr et al. (2009) and Baird et al. (2010)), and a Wildlife Computers Mk10A tag that recorded and transmitted depth data as well as location information (satellite-dive tag). Based on species differences in the frequency and amount of time spent at the surface (Baird et al. 2008), expected maximum attachment durations and battery capacity of the tags, and the need for a greater number of transmission periods in order to obtain dive data from the Mk10A, the Blainville's SPOT-5 tag was set to transmit 10 hours per day, the Cuvier's SPOT-5 tag was set to transmit 16 hours per day, and the Mk10A was set to transmit 22 hours per day. Due to transmission limitations, the Mk10A was programmed to record depth every 2.5 minutes, as well as to record the duration, maximum depth and depth profile of all dives greater than 50 m. The tags were deployed using a pneumatic rifle as described by Schorr et al. (2009).

Data obtained from the ARGOS system was processed with the Douglas Argos-Filter v. 7.06 (available at Alaska.usgs.gov/science/biology/spatial/douglas.html) using two independent

methods: distance between consecutive locations, and rate and bearings among consecutive movement vectors. Location classes 3 and 2 were automatically retained. Maximum rate of movement was set at 10 km/h. Depth, distance from shore, and closest island 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).

Results and Discussion

Field operations were undertaken on 42 separate days, with a total of 303 hours of survey effort, covering 5,451 kilometers of trackline. Approximately 73% of survey effort (measured as number of hours) was spent in sea conditions that were favorable for sighting beaked whales (Beaufort 0, 1 or 2), and approximately 84% of the total survey effort was spent in depths where beaked whales are likely to be found (>500 m). During field operations there were 122 sightings of 13 species of odontocetes. Of these, there were 13 sightings of beaked whales, representing one sighting every 23.3 hours (419 km) of effort. Of the 13 sightings, there were 3 groups of Blainville's beaked whales (group size median = 2, range 2-3), and 10 groups of Cuvier's beaked whales (group size median = 1, range 1-3). We were able to obtain photographs from all groups of Blainville's beaked whales (2,720 photos) and 9 of the 10 groups of Cuvier's beaked whales (3,796 photos). We were able to obtain 3 biopsy samples of Blainville's beaked whales and 2 biopsy samples of Cuvier's beaked whales.

Location-only satellite tags were deployed on one adult female Blainville's beaked whale (HIMd168) in December 2009 (with locations received over a 21-day span) and one adult female Cuvier's beaked whale (HIZc068) in October 2009 (with locations received over a 26-day span). One satellite-dive tag was deployed on an adult female Cuvier's beaked whale (HIZc007) in April 2010 (with location and dive data received over an 8-day span). Details on tag deployments and data obtained are summarized in Table 1. Both Cuvier's beaked whales were alone when tagged, while the Blainville's beaked whale was in a group with two other individuals, an adult male and a juvenile. Although good quality photos were obtained of the tagged Blainville's and the juvenile, no good identification photographs were obtained of the adult male. One of the

Cuvier's beaked whales (HIZc007) had been photographically documented six times off the island of Hawai'i (in four different years) prior to tagging, while the other Cuvier's and the tagged Blainville's beaked whale had not been previously documented, so it was not possible to assess population identity (e.g., resident or open-ocean) based on photos. Although island-associated populations of both species are small (Baird et al. 2009b) and there are high re-sighting rates (McSweeney et al. 2007), new individuals are still regularly documented so it is not surprising that the two other tagged whales had not been previously documented. None of the individuals had been previously tagged.

All three satellite tagged individuals remained closely associated with the island of Hawai'i over the duration of time that locations were received from the tags (Figure 1). For both Cuvier's beaked whales all locations were closest to the island of Hawai'i. While 11 of the 86 filtered locations (12.8%) from the Blainville's beaked whale were closer to the island of Maui, the tagged whale remained on the slope of the island of Hawai'i (Figure 1). The Blainville's beaked whale was found in shallower depths than the Cuvier's beaked whales (Table 1), yet was further from shore on average because that individual spent its time off the northwest part of the island, where shallower water extends further from shore (Figure 1). Although the three tagged individuals moved as far as 62 km (HIMd168), 119 km (HIZc068) and 65 km (HIZc007) from where they were originally tagged, both HIMd168 and HIZc068 returned close to the location where they were tagged approximately 14 and 9 days post-tagging, respectively (Figure 2). Based on photo-identification data we were only able to confirm that one of the three tagged individuals was a known member of the island-associated populations of these two species, but the movement and depth data suggests that the other two individuals are also members of the island-associated populations. One Blainville's beaked whale from the open-ocean population has been previously satellite tagged, and that individual moved 900 km west of the island in a 19-day period, utilizing much deeper water (median depth = 4,702 m [Baird et al. 2009a]). As with previous tag deployments on Blainville's beaked whales from the resident population (Schorr et al. 2009), movements of the tagged Blainville's in December 2009 were restricted to the west and north side of the island, suggesting that this population rarely uses waters off the east side of the island of Hawai'i.

The Mk10A tag deployed on the Cuvier's beaked whale is the first satellite-dive tag to be deployed on a beaked whale and provided the longest dive time series ever recorded for a Cuvier's beaked whale¹. Prior to this deployment a total of 34 hours of dive data were available from two Cuvier's beaked whales in Hawai'i tagged with suction-cup attached time-depth recorders (Baird et al. 2006, 2008). From the Mk10A, a total of 71.7 hours of dive data over a 117 hour period was obtained (Figure 3), including a 40.29 hour stretch of continuous data and then periods of data with gaps of 2 to 14 hours. Received data were close to evenly split between the day (48.1%) and night (51.9%). In general dive patterns were similar to those reported by Baird et al. (2006, 2008); this individual exhibited deep (maximum 1,752 m) and long (maximum 86.9 min) dives during both the day and night (Table 2). We compared day and night time diving parameters for reference to our earlier assessment of diel variation in behavior (Baird et al. 2008) and found that the diel differences in diving parameters varied in the same direction as in the previous study for nine of the 10 variables examined (Table 2).

For Cuvier's beaked whales we now have location data from six different individuals for a combined period of 105 days (including information from this study and the satellite tag deployments on one individual in 2006, two individuals in 2008 (Schorr et al. 2008), and one individual in April 2009 (Baird et al. 2009a)). All six individuals have remained close to the island of Hawai'i for the entire time the tags were functioning (Figure 1; Figure 4 in Schorr et al. 2008; Figure 2 in Baird et al. 2009). To date all species of odontocetes around the main Hawaiian Islands that have been compared genetically to populations elsewhere have exhibited evidence of genetic differentiation either within the main Hawaiian Islands or between the main Hawaiian Islands and populations elsewhere (Andrews et al. 2010; Chivers et al. 2005, 2007, 2010; Courbis et al. 2009; Martien and Baird 2006). For Cuvier's beaked whales, our satellite data suggests the population may be resident to the island and thus potentially distinct from surrounding populations of this species. This conclusion is further supported by the long-term site fidelity evident from photo-identification data (McSweeney et al. 2007) and preliminary genetic evidence (Dalebout 2008).

¹ Since this deployment Cascadia Research has deployed two additional Mk10A tags on Cuvier's beaked whales in California with longer attachment duration.

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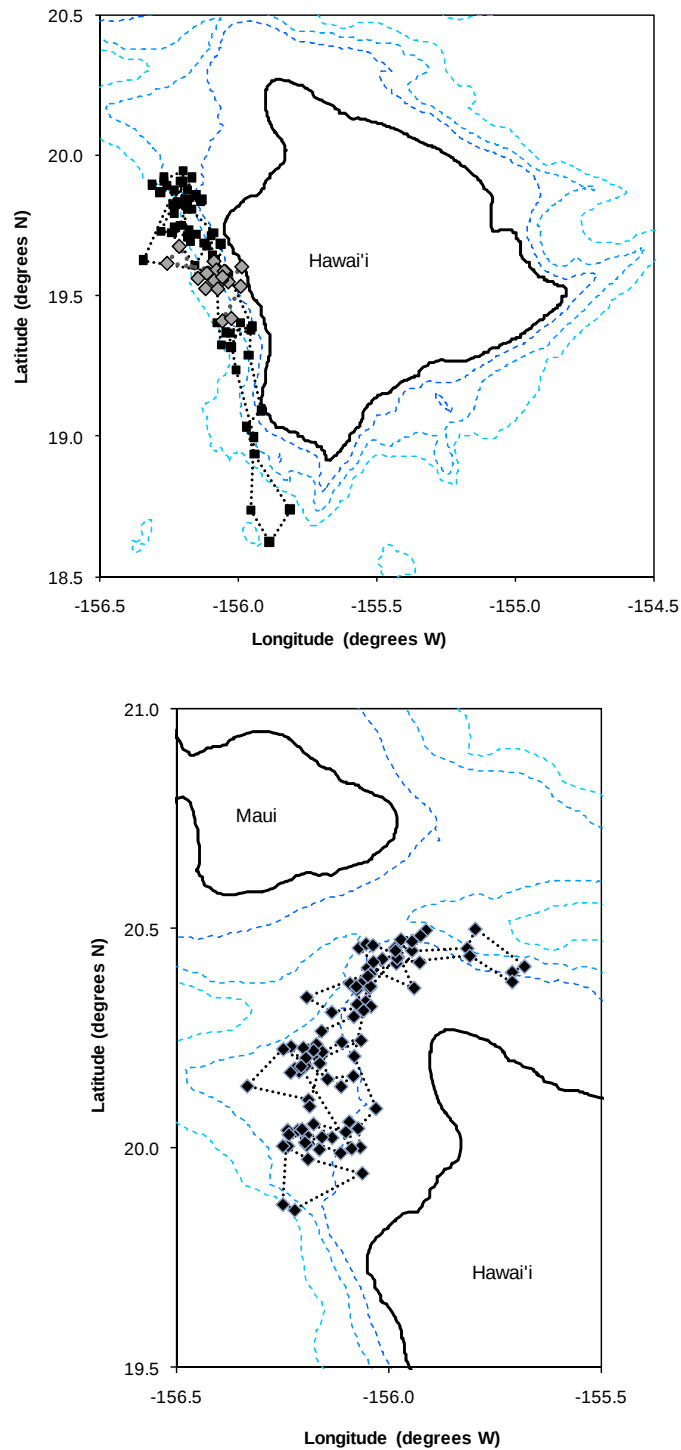


Figure 1. Locations of satellite tagged Cuvier's beaked whales (top) and a Blainville's beaked whale (bottom) after processing locations through the Douglas Argos-filter. The 25-day track of HIZc068 is indicated with black squares, and the 7-day track of HIZc007 is indicated with grey diamonds. Consecutive locations are joined by dashed lines but are not meant to indicate travel route between locations. The 1,000 m, 2,000 m and 3,000 m depth contours are shown.

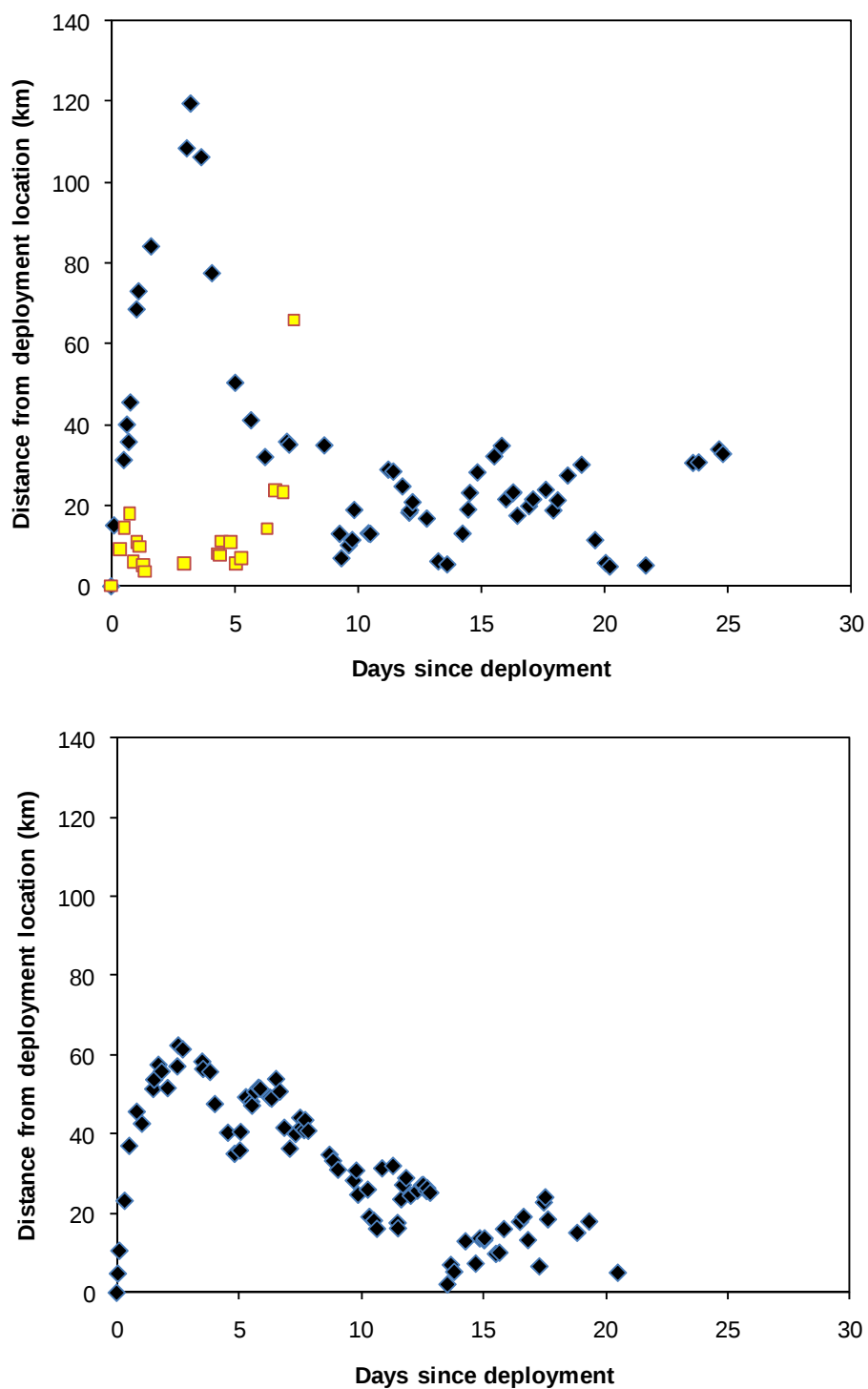


Figure 2. Distance from tagging location over time for the two Cuvier's beaked whales (top – yellow squares = HIZc007, black diamonds = HIZc068) and a Blainville's beaked whale (bottom). The scale on both are equivalent for comparison purposes.

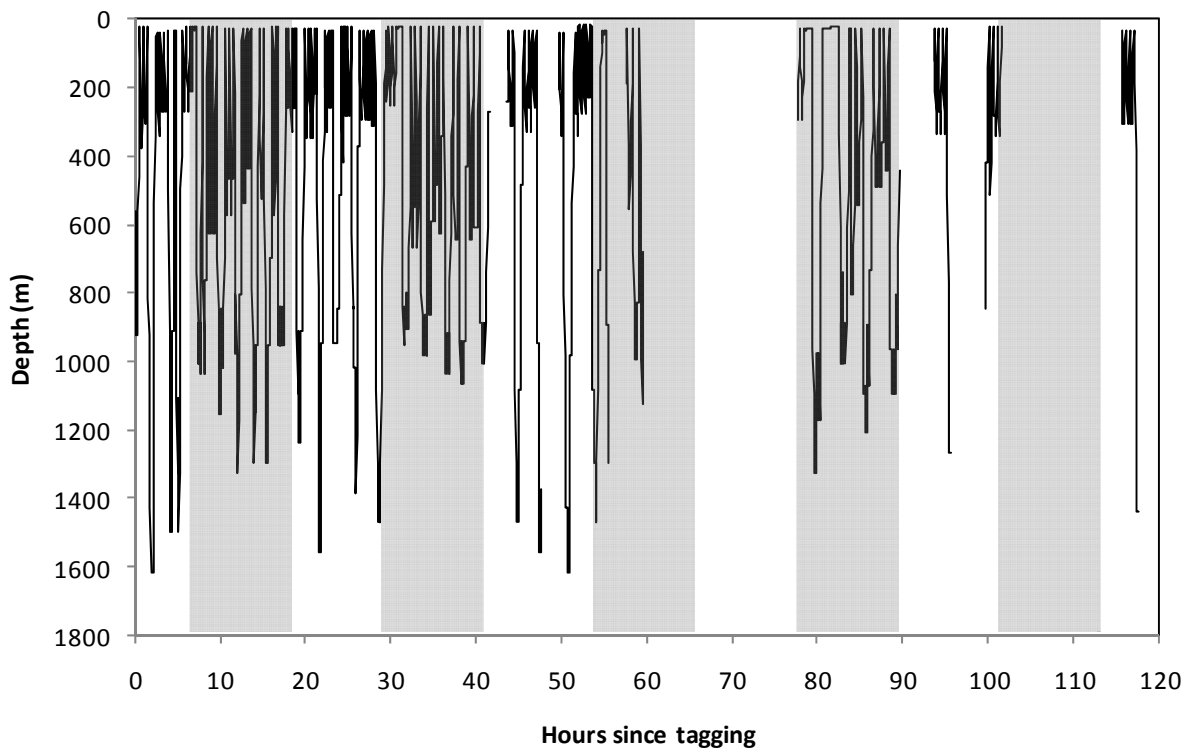


Figure 3. Dive data from an adult female Cuvier's beaked whale (HIZc007) tagged with a Mk10A satellite-dive tag. Night-time periods are indicated with shading. Gaps in the line represent periods when no dive data was received via the Argos satellite system.

Table 1. Details on data from satellite tags deployed on beaked whales in Hawai'i between October 2009 and April 2010. Md = *Mesoplodon densirostris*. Zc = *Ziphius cavirostris*.

Catalog ID	Tag Type	Date tagged	# days transmit	# filtered locations	% locations LC2 or LC1 ^A	Median depth (m)	Median distance to shore (km)
HIMd168	SPOT 5	21-Dec-09	20.5	86	24.7	1,098	23.2
HIZc068	SPOT 5	22-Oct-09	25.5	60	30.5	2,389	14.4
HIZc007	Mk10A	19-Apr-10	7.2	20	31.6	1,970	10.7

^ANo LC3 locations were obtained.

Table 2. Comparison of diving parameters during the day and night for an adult female Cuvier's beaked whale (HIZc007). The percentage change from day to night from two Cuvier's beaked whales tagged with suction-cup attached TDRs (from Baird et al. 2008) is presented for comparison.

Variable	Day	Night	% change from day to night	% change from Baird et al. 2008
Longest time < 50 m (min)	5.73	112.27	94.9	94.8
% time < 50 m	14.1	19.9	29.1	70.4
% time > 500 m	30.2	51.7	41.6	17.6
% time between 22 and 72 m	12.1	16.9	28.4	37.7
Dive rate (# dives/h) 100-600 m	1.1	0.78	-41.0	-325.0
Dive rate (# dives/h) > 800 m	0.38	0.51	25.5	13.9
Mean duration (min) > 800 m	63.27	60.27	-5.0	-7.0
Mean depth (m) > 800 m	1,592	1,144	-39.2	-8.4
Maximum duration (min)	78.4	86.93	9.8	-17.1
Maximum depth (m)	1,752	1,464	-19.7	-11.4