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LIMPET tagging of Hawaiian odontocetes: assessing reproduction and estimating survival of tagged and non-tagged individuals

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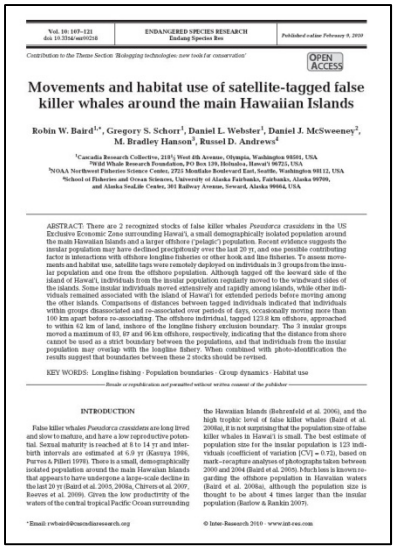
Presentation at the Workshop on Impacts of Cetacean Tagging: a review of follow up studies and approaches, Dunedin, New Zealand, December 8, 2013

Using LIMPET tags to assess odontocete movements and habitat use in Hawai‘i



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ENDANGERED SPECIES RESEARCH
Endang Species Res

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Contribution to the Theme Section 'Biologging technologies: new tools for conservation'

OPEN ACCESS

Movements and habitat use of satellite-tagged false killer whales around the main Hawaiian Islands

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ABSTRACT: There are 2 recognized stocks of false killer whales *Pseudorca crassidens* in the US Exclusive Economic Zone surrounding Hawai'i, a small demographically isolated population around the main Hawaiian Islands and a larger offshore ('pelagic') population. Recent evidence suggests the insular population may have declined precipitously over the last 20 yr, and one possible contributing factor is interactions with offshore longline fisheries or other hook and line fisheries. To assess movements and habitat use, satellite tags were remotely deployed on individuals in 3 groups from the insular population and one from the offshore population. Although tagged off the leeward side of the island of Hawai'i, individuals from the insular population regularly moved to the windward sides of the islands. Some insular individuals moved extensively and rapidly among islands, while other individuals remained associated with the island of Hawai'i for extended periods before moving among the other islands. Comparisons of distances between tagged individuals indicated that individuals within groups disassociated and re-associated over periods of days, occasionally moving more than 100 km apart before re-associating. The offshore individual, tagged 123.8 km offshore, approached to within 82 km of land, inshore of the longline fishery exclusion boundary. The 3 insular groups moved a maximum of 83, 87 and 96 km offshore, respectively, indicating that the distance from shore cannot be used as a strict boundary between the populations, and that individuals from the insular population may overlap with the longline fishery. When combined with photo-identification the results suggest that boundaries between these 2 stocks should be revised.

KEY WORDS: Longline fishing · Population boundaries · Group dynamics · Habitat use

INTRODUCTION

False killer whales *Pseudorca crassidens* are long lived and slow to mature, and have a low reproductive potential. Sexual maturity is reached at 8 to 14 yr and interbirth intervals are estimated at 6.9 yr (Kasuya 1986, Purves & Pilleri 1979). There is a small, demographically isolated population around the main Hawaiian Islands that appears to have undergone a large-scale decline in the last 20 yr (Baird et al. 2008, 2008a, Chivers et al. 2007, Reeves et al. 2009). Given the low productivity of the waters of the central tropical Pacific Ocean surrounding the Hawaiian Islands (Behrenfeld et al. 2006), and the high trophic level of false killer whales (Baird et al. 2008a), it is not surprising that the population size of false killer whales in Hawai'i is small. The best estimate of population size for the insular population is 123 individuals (coefficient of variation [CV] = 0.72), based on mark–recapture analyses of photographs taken between 2000 and 2004 (Baird et al. 2008). Much less is known regarding the offshore population in Hawaiian waters (Baird et al. 2008a), although the population size is thought to be about 4 times larger than the insular population (Barlow & Rankin 2007).

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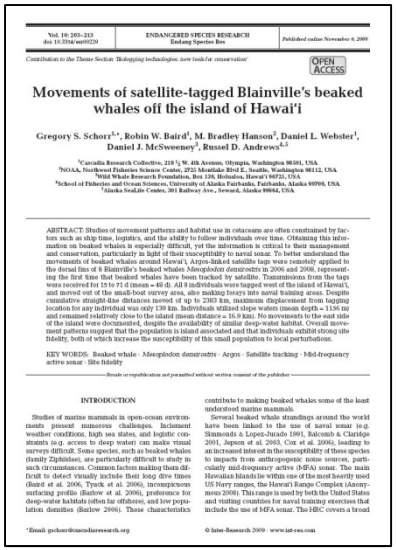

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Contribution to the Theme Section 'Biologging technologies: new tools for conservation'

OPEN ACCESS

Movements of satellite-tagged Blainville's beaked whales off the island of Hawai'i

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ABSTRACT: Studies of movement patterns and habitat use in cetaceans are often constrained by factors such as ship time, logistics, and the ability to follow individuals over time. Obtaining this information on beaked whales is especially difficult, yet the information is critical to their management and conservation, particularly in light of their susceptibility to naval sonar. To better understand the movements of beaked whales around Hawai'i, Argos-linked satellite tags were remotely applied to the dorsal fins of 8 Blainville's beaked whales *Mesoplodon densirostris* in 2006 and 2008, representing the first time that beaked whales have been tracked by satellite. Transmissions from the tags were received for 15 to 71 d (mean = 40 d). All 8 individuals were tagged west of the island of Hawai'i, and moved out of the small-boat survey area, also making forays into naval training areas. Despite cumulative straight-line distances moved of up to 2383 km, maximum displacement from tagging location for any individual was only 139 km. Individuals utilized slope waters (mean depth = 1196 m) and remained relatively close to the island (mean distance = 16.9 km). No movements to the east side of the island were documented, despite the availability of similar deep-water habitat. Overall movement patterns suggest that the population is island associated and that individuals exhibit strong site fidelity, both of which increase the susceptibility of this small population to local perturbations.

KEY WORDS: Beaked whale · *Mesoplodon densirostris* · Argos · Satellite tracking · Mid-frequency active sonar · Site fidelity

INTRODUCTION

Studies of marine mammals in open-ocean environments present numerous challenges. Inclement weather conditions, high sea states, and logistic constraints (e.g. access to deep water) can make visual surveys difficult. Some species, such as beaked whales (family Ziphiidae), are particularly difficult to study in such circumstances. Common factors making them difficult to detect visually include their long dive times (Baird et al. 2006, Tyack et al. 2006), inconspicuous surfacing profile (Barlow et al. 2006), preference for deep-water habitats (often far offshore), and low population densities (Barlow 2006). These characteristics contribute to making beaked whales some of the least understood marine mammals.

Several beaked whale standings around the world have been linked to the use of naval sonar (e.g. Simmonds & Lopez-Jurado 1991, Balcomb & Claridge 2001, Jepson et al. 2003, Cox et al. 2006), leading to an increased interest in the susceptibility of these species to impacts from anthropogenic noise sources, particularly mid-frequency active (MFA) sonar. The main Hawaiian Islands lie within one of the most heavily used US Navy ranges, the Hawai'i Range Complex (Anonymous 2008). This range is used by both the United States and visiting countries for naval training exercises that include the use of MFA sonar. The HRC covers a broad

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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

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Short Note

Open-Ocean Movements of a Satellite-Tagged Blainville's Beaked Whale (*Mesoplodon densirostris*): Evidence for an Offshore Population in Hawai'i?

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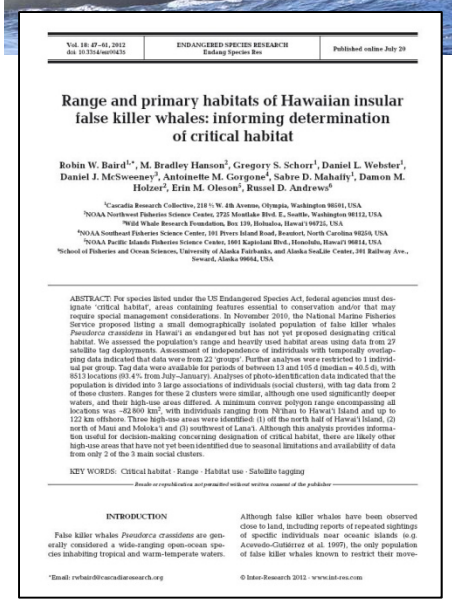
In Hawaiian waters, a single stock of Blainville's beaked whale (*Mesoplodon densirostris*) is recognized, extending throughout the U.S. Exclusive Economic Zone (EEZ) surrounding the archipelago and into adjacent international waters (Carretta et al., 2011). Abundance within the entire EEZ around Hawai'i was estimated at 2,872 individuals based on a large vessel sighting survey (Barlow, 2006), with a single on-effort sighting near the western boundary of the EEZ (Hamilton et al., 2009). There is, however, considerable uncertainty associated with this estimate (CV = 1.17; Barlow, 2006), and there is recent evidence that individuals documented around the main Hawaiian Islands may not be part of an open-ocean population (McSweeney et al., 2007; Schorr et al., 2009). Individual Blainville's beaked whales instrumented with satellite tags off the island of Hawai'i have remained strongly associated with the island, primarily using slope habitat, for the entire duration of satellite tag transmissions (up to 71 d; Schorr et al., 2009). Schorr et al. (2009) noted a mean distance from shore of 16.9 km (range 4.4 to 27.7 km) and a mean depth of 1,156 m (range 480 to 1,455 m) for six satellite tagged individuals, over periods ranging from 15 to 71 d (median = 43 d), with from 26 to 405 locations per individual (median = 195 locations/individual). Although these individuals moved a cumulative distance of at least 1,000 km over the duration of their tag attachments, median distances of locations from the tagging location for the different individuals ranged from 19.9 to 91.8 km, and the maximum distance any individual moved from where it was tagged was only 139 km (Schorr et al., 2009). Combined with long-term resightings of distinctive individuals off the island (McSweeney et al., 2007), such results suggest the existence of an island-resident population. Mark-recapture population estimates based on photo-identification data suggest this island-resident population is quite small, with approximately 140 individual Blainville's beaked whales (CV = 0.30) using the area off the island of Hawai'i over a 4-y period (Baird et al., 2008b).

While Blainville's beaked whales are generally thought to be distributed throughout tropical oceanic waters (Jefferson et al., 2008), research efforts to examine movements and spatial use have focused on studies of animals around oceanic islands (Claridge, 2004; Schorr et al., 2009; Tyack et al., 2011). Northern Bahamian data on the movements or habitat use of individual Blainville's beaked whales in the open ocean, away from land habitats. In Hawaiian waters, there have been few sightings of Blainville's beaked whales in the open ocean (Carretta et al., 2011), and thus limited opportunities to study this species in such habitats. Here, we report on the movements of a Blainville's beaked whale satellite tagged off the island of Hawai'i but thought to be from an open-ocean population, rather than the resident island-associated population. Using photo-identification data on this species in the area since 1995 (McSweeney et al., 2007) and sighting information from our study of odontocetes off the island since 2002 (Baird et al., 2008, 2009a), we compare sighting characteristics and photo-identification results from the tagged group with other sightings of Blainville's beaked



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Range and primary habitats of Hawaiian insular false killer whales: informing determination of critical habitat

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ABSTRACT: For species listed under the US Endangered Species Act, federal agencies must designate 'critical habitat', areas containing features essential to conservation and/or that may require special management considerations. In November 2010, the National Marine Fisheries Service proposed listing a small demographically isolated population of false killer whales *Pseudorca crassidens* in Hawai'i as endangered but has not yet proposed designating critical habitat. We assessed the population's range and heavily used habitat areas using data from 27 satellite tag deployments. Assessment of independence of individuals with temporally overlapping data indicated that data were from 22 'groups'. Further analyses were restricted to 1 individual per group. Tag data were available for periods of between 13 and 105 d (median = 40.5 d), with 8513 locations (93.4% from July–January). Analyses of photo-identification data indicated that the population is divided into 3 large associations of individuals (social clusters), with tag data from 2 of those clusters. Ranges for these 2 clusters were similar, although one used significantly deeper waters, and their high-use areas differed. A minimum convex polygon range encompassing all locations was ~82 800 km², with individuals ranging from Ni'ihau to Hawai'i Island and up to 122 km offshore. Three high-use areas were identified: (1) off the north half of Hawai'i Island, (2) north of Maui and Moloka'i and (3) southwest of Lana'i. Although this analysis provides information useful for decision-making concerning designation of critical habitat, there are likely other high-use areas that have not yet been identified due to seasonal limitations and availability of data from only 2 of the 3 main social clusters.

KEY WORDS: Critical habitat · Range · Habitat use · Satellite tagging

INTRODUCTION

False killer whales *Pseudorca crassidens* are generally considered a wide-ranging open-ocean species inhabiting tropical and warm-temperate waters. Although false killer whales have been observed close to land, including reports of repeated sightings of specific individuals near oceanic islands (e.g. Acevedo-Gutiérrez et al. 1997), the only population of false killer whales known to restrict their move-

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Evidence of an Island-Associated Population of False Killer Whales (*Pseudorca crassidens*) in the Northwestern Hawaiian Islands[1]

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Abstract: Two populations of false killer whales, *Pseudorca crassidens*, are recognized from Hawaiian waters: the Hawaiian insular population, an island-associated population found around the main Hawaiian Islands; and the Hawai'i pelagic population, found in offshore waters. This species has not been previously documented near the Northwestern Hawaiian Islands. During a 2010 large-vessel survey throughout the Exclusive Economic Zone (EEZ) surrounding the Hawaiian Islands, false killer whales from 11 encounters were individually photo-identified, and photos were compared among encounters and with a catalog of false killer whales from the main Hawaiian Islands. Individuals from three of the encounters, all in the Northwestern Hawaiian Islands within the eastern part of the Papahānaumokuākea Marine National Monument, were the only ones documented that matched with false killer whales previously seen around the main Hawaiian Islands, and the matches were to individuals documented off Kaua'i in 2008 that were of unknown population membership. Two individuals from one of these three 2010 encounters were instrumented with satellite tags attached to dorsal fins, and their movements were documented over 4.6 and 52 days. Movements of the tagged individuals ranged from French Frigate Shoals to Middle Bank (between Nihoa and Ni'ihau) and included shallow nearshore waters and deep waters to 147 km from land. Combined, the photo-identification and satellite-tagging results suggest that there is a second island-associated population of this species in Hawai'i that primarily uses the Northwestern Hawaiian Islands, with a range that overlaps with that of the main Hawaiian Islands insular population.

Two populations or stocks of false killer whales, *Pseudorca crassidens*, have recently been recognized in Hawaiian waters (Chivers et al. 2007, 2010, Baird et al. 2008, Carretta et al. 2012). An insular, or island-associated, population is found around the main Hawaiian Islands, and a pelagic, or open-ocean, population has been documented in offshore waters (Chivers et al. 2007, 2010, Baird et al. 2008, Carretta et al. 2012). Based on movements of satellite-tagged individuals, the range of the Hawaiian insular population extends throughout the main Hawaiian Islands from Ni'ihau in the west to Hawai'i Island in the east, and movements out to 122 km from shore have been documented (Baird et al. 2010, 2012).

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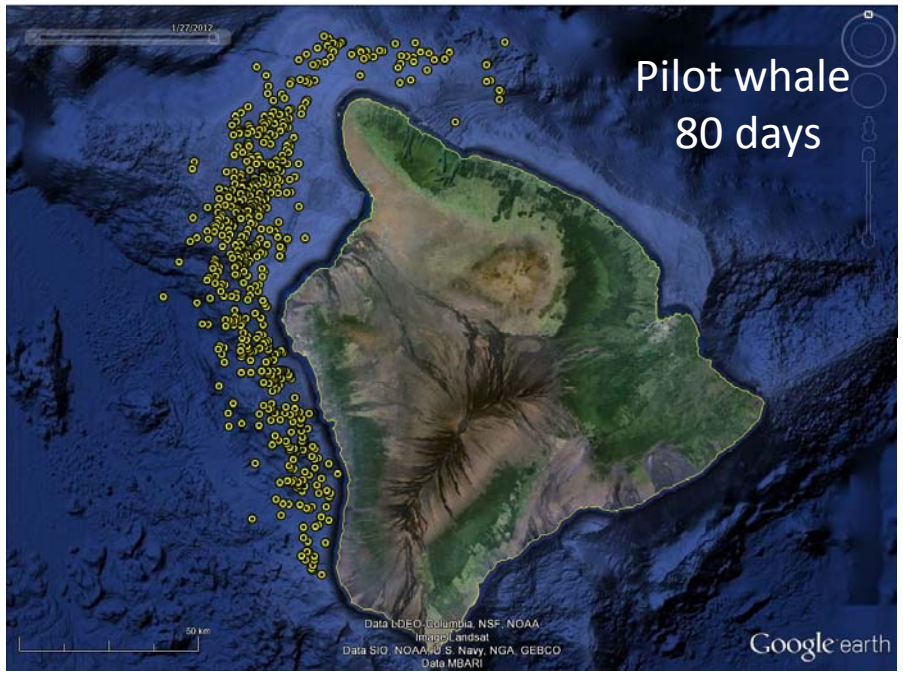
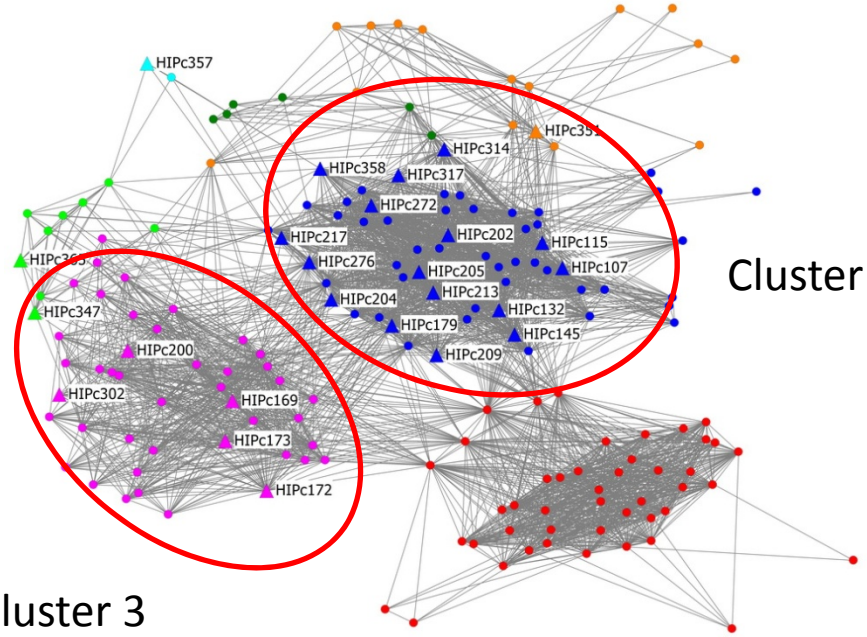
Do LIMPET tags influence odontocete survival and reproduction?

NOPP grant - Improving attachments of remotely-deployed dorsal fin-mounted tags: tissue structure, hydrodynamics, in situ performance, and tagged-animal follow-up

PI: Russ Andrews

- Resident populations
- Long-term photo-identification catalogs
- Social clusters identified





Cluster 1

Cluster 3

Baird et al. 2012

Limitations for assessing reproduction post-tagging

- Bias towards tagging males (avoiding females with small calves, targeting larger individuals)
- Long inter-birth interval for most species
- Long intervals between re-sightings

Females with calves born since tagging:

- Pygmy killer whales (1 of 3 known or suspected females)
- Cuvier's beaked whales (2 of 3 females that have been re-sighted)

Re-sightings post-tag loss

- Pygmy killer whales – 5 of 7 (71%) tagged prior to 2011 re-sighted at 2.8 – 4.6 years*
- Melon-headed whales, Kohala resident stock – 2 of 3 (67%) tagged prior to 2012 re-sighted at 0.8 to 2.7 years*
- Cuvier's beaked whales – 6 of 10 (60%) re-sighted at 0.75 – 1.9 years* (3 of 4 females re-sighted)
- Blainville's beaked whales, insular population – 7 of 10 re-sighted at 0.01 – 3.66 years* (6 of 7 females re-sighted at 0.77 – 3.66 years*)

*post-tag loss

False killer whales

- 142 distinctive & very distinctive individuals photo-IDs between 2003 and 2013, with 1,280 records
- Included capture histories of 24 individuals tagged between 2007-2011 (total of 25 deployments, one whale tagged twice)
- Two analyses undertaken: 1) all three social clusters considered* (tags deployed in clusters 1 and 3 only); 2) cluster 1 only (~50% of records, 16 of 25 tag deployments)

*Cluster as a co-variate

Short-finned pilot whales

- 620 distinctive & very distinctive individuals photo-IDd between 2003 and 2013, with 6,094 records, in 34 social clusters
- Included capture histories of 46 individuals tagged between 2006-2012, in 15 social clusters
- Five tagged twice (51 deployments)
- Two analyses undertaken: 1) all individuals considered; 2) only social clusters (15) with tagged individuals considered*

*Cluster as a co-variate

Survival estimation

- Modeling in R-Mark 2.1.5
- Cormack-Jolly-Seber model to estimate apparent survival (Phi) and capture probability (p)
- Number of models run including a time-varying tag effect as a covariate
- Overdispersion computed using TEST1 and TEST2 in program RELEASE
- Model selection with Akaike Information Criteria for small samples after accounting for overdispersion (QAICc)

False killer whales

Approach 1 (all three clusters)
16 models run with a combination of effects

Phi (Apparent survival)	p (Capture probability)
null model	null model
cluster	time
tag	cluster
cluster + tag	time + cluster

Top 4 models shown (100% of model weight)

Model	# par	QAICc	ΔQAICc	weight
Phi(~1)p(~Cluster + time)	14	557.033	0.000	0.666
Phi(~Tag)p(~Cluster + time)	15	559.053	2.020	0.243
Phi(~Cluster)p(~Cluster + time)	17	561.606	4.573	0.068
Phi(~Cluster + Tag)p(~Cluster + time)	18	563.749	6.716	0.023

False killer whales

Approach 1 (all three clusters)

Model average estimates of apparent survival

Parameter	estimate	se	Lower CL	Upper CL
Phi (cluster 1 + tag)	0.953	0.045	0.740	0.993
Phi (cluster 1)	0.962	0.015	0.917	0.983
Phi (cluster 2 + tag)	-	-	-	-
Phi (cluster 2)	0.963	0.016	0.916	0.984
Phi (cluster 3 + tag)	0.953	0.045	0.742	0.993
Phi (cluster 3)	0.962	0.015	0.917	0.983

Capture probabilities by cluster

Cluster	Mean capture probability (p)
1	0.56
2	0.28
3	0.27

False killer whales

Approach 2 (cluster 1 only)
6 models run with a combination of effects

Phi (Apparent survival)	p (Capture probability)
null model	null model
tag	time

All 6 models shown

Model	# par	QAICc	ΔQAICc	weight
Phi(~1)p(~time)	11	247.729	0.000	0.663
Phi(~Tag)p(~time)	12	249.846	2.117	0.230
Phi(~1)p(~Tag)	3	252.491	4.762	0.061
Phi(~Tag)p(~Tag)	4	254.154	6.425	0.027
Phi(~1)p(~1)	2	255.642	7.912	0.013
Phi(~Tag)p(~1)	3	257.280	9.551	0.006

False killer whales

Approach 2 (cluster 1 only)
Model average estimates of apparent survival

Parameter	estimate	se	Lower CL	Upper CL
Phi (Tag)	0.971	0.047	0.573	0.999
Phi (.)	0.961	0.027	0.859	0.990

Short-finned pilot whales

Approach 1 (all 34 clusters)
4 models run with a combination of effects

Phi (Apparent survival)	p (Capture probability)
null model	null model
tag	time

All models shown

Model	# par	QAICc	ΔQAICc	weight
Phi(~1)p(~time)	10	1309.570	0.000	0.652
Phi(~Tag)p(~time)	11	1310.824	1.254	0.348
Phi(~1)p(~1)	2	1352.300	42.730	0.000
Phi(~Tag)p(~1)	3	1353.628	44.058	0.000

Short-finned pilot whales

Approach 1 (all 34 clusters)
Model average estimates of apparent survival

Parameter	estimate	se	Lower CL	Upper CL
Phi (tag)	0.901	0.060	0.709	0.972
Phi (~1)	0.869	0.015	0.836	0.896

But survival estimates low for a relatively long-lived species

Short-finned pilot whales

Approach 2 (15 clusters w/ tagged individuals)
16 models run with a combination of effects

Phi (Apparent survival)	p (Capture probability)
null model	null model
Cluster	time
Tag	Cluster
Cluster + tag	Tag

Top 3 models shown (100% of model weight)

Model	# par	QAICc	ΔQAICc	weight
Phi(~1)p(~Cluster)	17	630.772	0.000	0.733
Phi(~Tag)p(~Cluster)	18	632.793	2.021	0.267
Phi(~Cluster)p(~Cluster)	32	645.077	14.305	0.001

Short-finned pilot whales

Approach 2 (15 clusters with tag deployments)
Model average estimates of apparent survival

Parameter	estimate	se	Lower CL	Upper CL
Phi (tag)	0.966	0.033	0.795	0.995
Phi (~1)	0.961	0.012	0.930	0.979

Take home: survival of tagged and untagged individuals not significantly different*

*Power to detect an effect is very low, given average capture probability, proportion of population tagged