

Assessing reproduction and estimating survival of odontocetes tagged with LIMPET tags: case studies from Hawai'i

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Using LIMPET tags to assess odontocete movements and behavior in Hawai'i

2006-2017
306 deployments (12 species)
• 9 resident (8 with photo-ID catalogs)

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Endang Species Res

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CONTRIBUTOR TO THE THOSE SERIES: Biological Invasions: new tools for conservation

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

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Short Note

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

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

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Nowhere to go: noise impact assessments for marine mammal populations with high site fidelity

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ABSTRACT: An awareness of the effects of anthropogenic noise on marine mammals has grown, research has branched from evaluating physiological responses, including injury and mortality, to considering effects on behavior and acoustic communication. Most mitigation efforts attempt to minimize injury by excluding animals to noise-free or noise-reduced areas. Recent experiments demonstrate that this approach is inadequate or even counterproductive for small, localized marine mammal populations, but when displacement of animals may avoid noise harm. Some surveys within the range of harbor porpoise phenomena in California and New England (California) have led to the development of noise-reduction measures to explicitly consider biological fitness passed by displacement during phasing, monitoring, and mitigation. Consistency of displacement may permit increased survival and fecundity. This paper reviews ranging surveys with associated effects on survival and reproduction. In some cases, such as the critically endangered Humpback whale, displacement by noise activities like exploring the environment is difficult to avoid in heavily built areas. Similar concerns about military and industrial activities exist for island-associated species such as the sooty terns of the Hawaiian Islands. The Hawaiian Island-associated species such as the humpback whale, sperm whale, and pilot whale, and whales ranging to coastal habitats, such as the critically endangered western grey whale, all have associated populations. We present a expanded framework Zipline categorization system that incorporates the effects of anthropogenic noise on marine mammals and provides a more robust means of assessing and avoiding potential harm associated with both displacement and direct effects of intense anthropogenic noise exposure.

KEY WORDS: Anthropogenic noise, Marine mammals, Injunct assessment, Mitigation, Monitoring, Small populations

INTRODUCTION
In 1970, Richardson et al. (1970, Southall et al. 2007) and 81 remains a fairly novel term in g. (NRPD 2010). In this paper we follow the tradition of (Southall et al. 2010), in which a sound is considered to be 'noise' if it has the potential to mask or interfere with natural communication sounds. The authors and editors of the IJES are the US Government, 2017. Open Access under Creative Commons Attribution License. No distribution or reproduction is permitted. Author and Publisher retain copyright. www.plosone.org

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

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

Evidence of an Island-Associated Population of False Killer Whales (*Pseudorca crassidens*) in the Northwestern Hawaiian Islands¹

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ABSTRACT: Two populations of false killer whales, *Pseudorca crassidens*, are recognized from Hawai'i waters: the Hawaiian insular population, an island-associated population found around the main Hawaiian Islands, and the Hawai'i large 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

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Characterizing a Foraging Hotspot for Short-Finned Pilot Whales and Blainville's Beaked Whales Located off the West Side of Hawai'i Island by Using Tagging and Oceanographic Data

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ABSTRACT: Satellite tagging data for short-finned pilot whales (*Globophaxia macrorhynchus*) and Blainville's beaked whales (*Mesoplodon denirostris*) were used to identify one insular foraging region off the Kona coast of Hawai'i Island. Single-batch active acoustic surveys and oceanographic model output were used in generalized additive models (GAM) and mixed models to characterize the oceanography of these regions and to examine relationships between whale density and the environment. The regions of highest density for pilot whales and Blainville's beaked whales were located between the 1000 and 2500 m isobaths and the 200 and 2000 m isobaths, respectively. Both species were associated with slope waters, but given the topography of the area, the horizontal distribution of beaked whales was narrower and located at shallower waters than that of pilot whales. The key oceanographic parameters characterizing the foraging regions were bathymetry, temperature at depth, and a high density of midwater micronekton scattering at 70-140 to 400-600 m depths that likely represent the island-associated deep mesopelagic boundary community and serve as prey for the pilot whales. Thus, our results suggest that off the Kona Coast, and potentially around other main Hawaiian Islands, the deep mesopelagic boundary community is key to a food web that supports insular cetacean populations.

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5. Biologically Important Areas for Cetaceans Within U.S. Waters – Hawai'i Region
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ABSTRACT: Of the 18 species of odontocetes known to be present in Hawaiian waters, small resident populations of 11 species—eight species whales, Blainville's beaked whale, Cuvier's beaked whale, pygmy killer whale, short-finned pilot whale, melon-headed whale, false killer whale, porpoised spotted dolphins, spinner dolphins, rough-toothed dolphins, and common bottlenose dolphins—have been identified, based on two or more lines of evidence, including results from small boat sightings and survey effort photo-identification, genetic analysis, and satellite tagging. In this review, we integrate existing published and unpublished information along with expert judgment for the Hawai'i region of the U.S. Exclusive Economic Zone and territorial waters to identify and support the biological importance of key areas for bottlenose dolphins, and one reproductive area for humpback whales. The geographic extent of the BIA in Hawaiian waters ranges from approximately 700 to 1,200 km². BIA designations enhance existing information already available to scientists, managers, policy-makers, and the public. They are intended to provide synthesized information in a transparent format that can be readily used toward analysis and planning under U.S. statutes that require the characterization and minimization of impacts of anthropogenic activities on marine mammals. (Odontocete BIA in Hawai'i) are based around the main Hawaiian Islands and populations of the island of Hawai'i, including a large, deep, broad level of research effort and fishery control that would reduce populations of other island areas in Hawaiian waters suggest that further BIA designations may be necessary as more detailed information becomes available.

THE LIVES OF HAWAII'S DOLPHINS AND WHALES

NATURAL HISTORY AND CONSERVATION

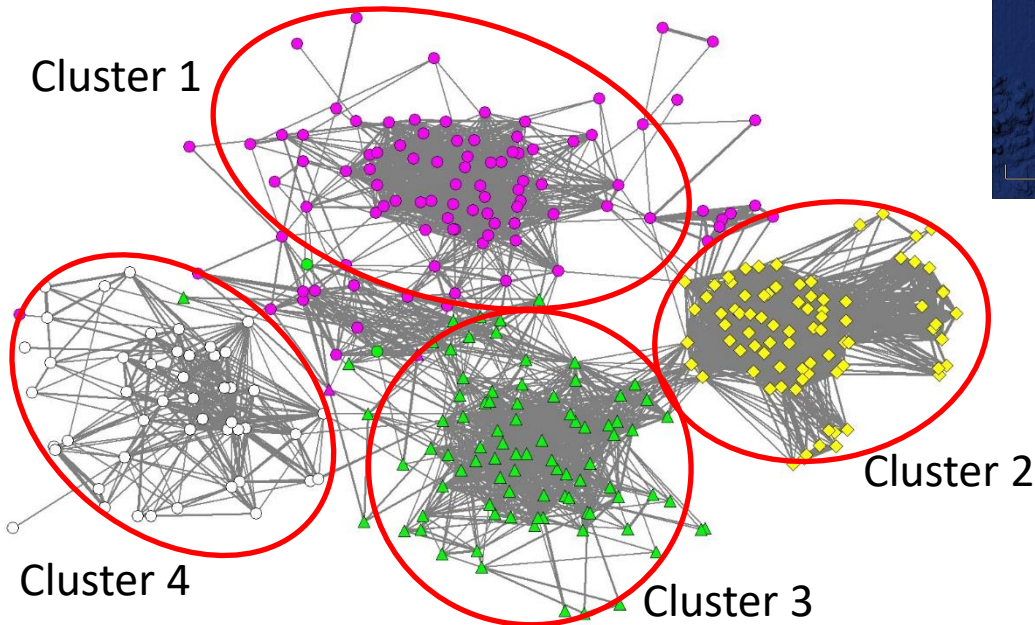
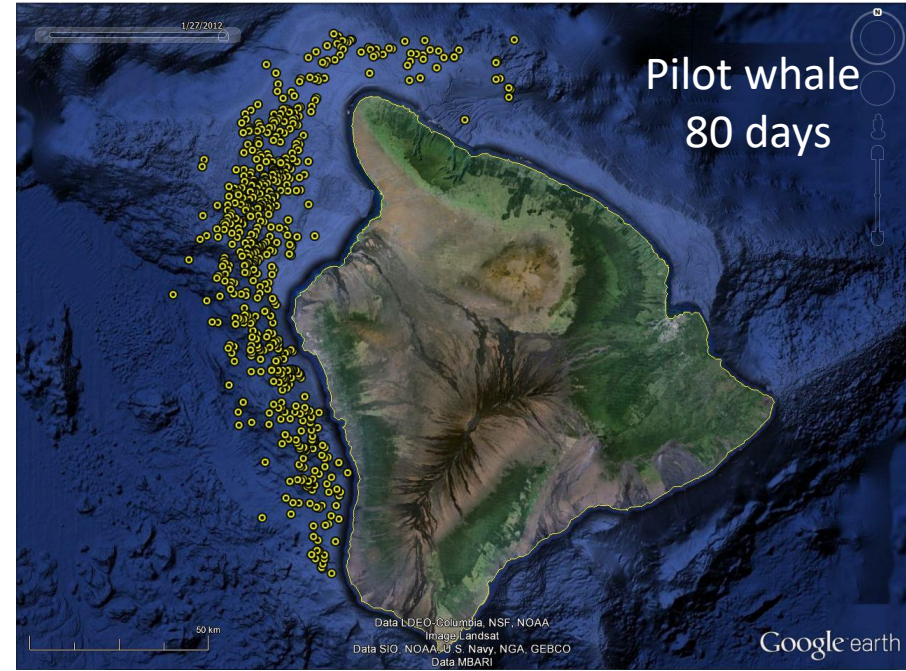
Robin W. Baird

Do LIMPET tags influence odontocete reproduction and survival?

NOPP grant - Improving attachments of remotely-deployed dorsal fin-mounted tags: tissue structure, hydrodynamics, in situ performance, and tagged-animal follow-up 2009-2013

PI: Russ Andrews

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



Comparison of rates of survival and reproduction of tagged versus non-tagged individuals

- For some species (i.e., pilot whales, false killer whales) must take social group into account, as re-sighting probability varies by group
- Quantitative comparison of reproductive rates problematic given sample size, long inter-birth intervals, and time frame of study, but can address reproduction on a coarser scale (i.e., are females reproducing post-tag loss)

Limitations to assessing reproduction post-tagging

- Bias towards tagging males (avoiding females with small calves), and for some species targeting larger individuals (i.e., pilot whales, false killers)
- Sex not known for all (females based on genetics, close association with small calf, or morphology, e.g., beaked whales)
- Long intervals between re-sightings
- Some species associate with calves for limited period (Blainville's beaked whales < 3 years)
- Long inter-birth interval (pilot = 5 years; false killer = 6-7 years)
- Post-reproductive phase for some (pilot/false killer)



Species	# females seen ≥ 1 year post-tagging	# with calves post-tag loss	Mean (\bar{x}) # years (y) seen post-tag loss (with or without calves)
Blainville's beaked	6	3	w/calves seen $\bar{x}=5.3$ y, without =1.3 y
Cuvier's beaked	5	3	w/calves seen $\bar{x}=3$ y, without =2 y
Bottlenose dolphin	1	1	seen 1 y
Pygmy killer whale	3	3	seen $\bar{x}=5.3$ y
False killer whale C1	10	3	w/calves seen $\bar{x}=6.3$ y, without =3.2 y
False killer whale C3	5	0*	seen $\bar{x}=2.0$ y
Short-finned pilot	16	3	w/calves seen $\bar{x}=3.3$ y, without =3.3 y

*One Cluster 3 individual appeared pregnant when last seen



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



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

False killer whales



- 267 distinctive & very distinctive individuals photo-IDd between 2007 and March 2017, in four different social clusters
- Included capture histories of 37 individuals tagged between 2007-2016 (total of 41 deployments, four whales tagged twice)
- Two analyses undertaken: 1) all four social clusters considered*; 2) cluster 1 only (~68% of records, 28 of 41 tag deployments)

*Cluster as a co-variate

Survival estimation

- Modeling in R-Mark 2.1.12
- Cormack-Jolly-Seber model to estimate apparent survival (Φ) and capture probability (p)
- Parameter estimation for tagged individuals only performed after they were tagged
- 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) if necessary

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	Δ QAICc	weight
Phi(.)p(~Time)	10	1309.570	0.000	0.652
Phi(~Tag)p(~Time)	11	1310.824	1.254	0.348
Phi(.)p(.)	2	1352.300	42.730	0.000
Phi(~Tag)p(.)	3	1353.628	44.058	0.000

Short-finned pilot whales



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

Phi (apparent survival)	estimate	se	Lower CL	Upper CL
Tagged	0.901	0.060	0.709	0.972
Not tagged	0.869	0.015	0.836	0.896

But survival estimates low for a relatively long-lived species

Short-finned pilot whales



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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	Δ QAICc	weight
Phi(.)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

Phi (apparent survival)	estimate	se	Lower CL	Upper CL
Tagged	0.966	0.033	0.795	0.995
Not tagged	0.961	0.012	0.930	0.979



False killer whales

Approach 1 (all four clusters)

30 models run with a combination of effects

Phi (Apparent survival)	p (Capture probability)
null model	null model
Cluster	Time
Tag	Cluster
Tag + Cluster	Tag
Acute Effect	Tag + Cluster
	Time + Cluster

Top 5 models shown (100% of model weight)

Model	# par	AICc	Δ AICc	weight
Phi(.)p(~Time + Cluster)	14	1726.82	0.00	0.49
Phi(~Tag)p(~Time + Cluster)	15	1728.41	1.59	0.22
Phi(~Acute Effect)p(~Time + Cluster)	15	1728.46	1.63	0.22
Phi(~Cluster)p(~Time + Cluster)	17	1731.87	5.05	0.04
Phi(~Tag + Cluster)p(~Time + Cluster)	18	1732.85	6.02	0.02



False killer whales

Approach 1 (all four clusters)

Model average estimates of apparent survival

Phi (apparent survival)	estimate	se	Lower CL	Upper CL
Cluster 1 tagged	0.962	0.026	0.857	0.990
Cluster 1 not tagged	0.960	0.015	0.919	0.980
Cluster 2 tagged	0.932	0.020	0.881	0.962
Cluster 2 not tagged	0.927	0.017	0.886	0.953
Cluster 3 tagged	0.933	0.018	0.888	0.962
Cluster 3 not tagged	0.928	0.014	0.895	0.951
Cluster 4 tagged	0.933	0.019	0.885	0.962
Cluster 4 not tagged	0.927	0.016	0.890	0.952

Capture probabilities by cluster

Cluster	Mean capture probability (p)
1	0.61
2	0.21
3	0.27
4	0.30



False killer whales

Approach 2 (cluster 1 only)

9 models run with a combination of effects

Phi (Apparent survival)	p (Capture probability)
null model	null model
Tag	Tag
Acute Effect	Time

Top 3 models shown (100% of model weight)

Model	# par	QAICc	Δ QAICc	weight
Phi(.)p(~Time)	11	608.96	0.00	0.52
Phi(~Tag)p(~Time)	12	610.52	1.55	0.24
Phi(~Acute Effect)p(~Time)	12	610.59	1.62	0.23



False killer whales

Approach 2 (cluster 1 only)

Model average estimates of apparent survival

Phi (apparent survival)	estimate	se	Lower CL	Upper CL
Tagged	0.938	0.018	0.892	0.965
Not tagged	0.933	0.015	0.894	0.957

Take home: survival of tagged and untagged false killer whales and short-finned pilot whales not significantly different*

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

