

**Assessment of re-sighting rates of previously dart-tagged false killer whales and short-finned pilot whales in Hawai'i: a preliminary report taking into account re-sightings of social groups**

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## Introduction

Understanding the impacts of invasive research techniques is critical to ensure that such research activities will not have detrimental effects on populations under study. In Hawaiian waters we have been using remotely-deployed dorsal-fin attached Low-Impact Minimally-Percutaneous External-electronics Transmitter (LIMPET) satellite tags (Andrews et al. 2008) to examine movements and habitat use a number of species of odontocetes (see e.g., Schorr et al. 2008, 2009; Baird et al. 2010, 2011a, 2011b; Woodworth et al. 2011). Early re-sightings of previously tagged individuals of several species with complete healing of the tag attachment sites suggested that impacts of tagging were minimal (Hanson et al. 2008), however an assessment of re-sighting rates of tagged versus untagged individuals has not yet been undertaken.

With funding from the National Oceanographic Partnerships Program (NOPP) and the Office of Naval Research, we are conducting follow-up studies on tagged whales to assess the effects of tagging on survival and reproduction. These studies are utilizing information from several species for which there are both reasonably large samples of previously tagged individuals (in particular false killer whales and short-finned pilot whales), and for which there are long-term photo-identification catalogs available for assessment of social organization and re-sighting rates. There are resident populations of both of these species around the main Hawaiian Islands, individuals are easily approached and the majority are distinctive, and encounter rates are high enough that there is a relatively high potential for re-sightings. Both false killer whales and short-finned pilot whales exhibit strong social bonds (Baird et al. 2008, 2011c; Mahaffy et al. 2011), although groups encountered in the field are often larger aggregations that include one or more smaller, more stable, social units. Given such social clustering, when assessing re-sighting rates it is important to take into account not only re-sightings of tagged individuals, but whether their social group has been re-sighted. For example, with southern resident killer whales, re-sighting a specific pod (or sub-pod) member is likely only if that pod (or sub-pod) has been seen, since individuals rarely leave their pod long-term. In this report we examine re-sighting rates of tagged individual false killer whales and short-finned pilot whales, taking into account whether their social group (defined below) was also documented in the interim.

## Methods

In addition to assessing existing photos, NOPP funding supported field efforts in 2010 and 2011 to obtain additional photographs of all previously tagged species, and field efforts are also planned for October/November 2011 and for 2012. As well as NOPP funded field efforts, we are also obtaining follow-up photos from field projects funded from other sources (NMFS PIFSC, N45/NPS) and utilizing photos taken by other researchers and individuals working on the water in Hawai‘i when available. During encounters we attempt to obtain photos for individual identification of all individuals present; however, the quality or number of photos provided from other sources is often limited and only permits us to identify a small number of the individuals present in an encounter. Additionally, in some encounters we are unable to photo-identify all individuals present due to inclement weather conditions, time of day, or sightings of other higher priority species that result in ending encounters prematurely. Such differences in the completeness of photographic coverage of groups encountered have implications for the likelihood of re-sighting tagged individuals even when other members of their social group are documented.

Analyses of photo-identification data were undertaken to identify social groups for both Hawaiian insular false killer whales and short-finned pilot whales off the island of Hawai‘i. Methods available to assess social groupings within a population depend on sample size of sightings available, and in general sample sizes of sightings of short-finned pilot whales are almost an order of magnitude larger than for false killer whales. For the purposes of this analysis we have defined three different levels of social groupings:

*Social unit.* Following Whitehead (2008) we define a social unit, or unit, as a group of individuals in nearly permanent association, and base this on shared longitudinal sighting histories (Ottensmeyer and Whitehead 2003). For our purposes we defined units as those composed of key individuals seen  $\geq 8$  times in  $\geq 4$  years and their constant companions  $\geq 5$  times in  $\geq 3$  years. Thus, determining units requires a reasonably long-time series and a reasonably large sample size of encounters. We have been able to define unit membership for commonly seen short-finned pilot whales, but sample sizes are currently insufficient to define unit membership for false killer whales.

*Social cluster.* Social clusters, or clusters, are based on association data and determined using modularity (Q), which “indicates how well a population can be delineated into communities or social units” (Whitehead 2008), using SOCPROG 2.4. When Q is greater than or equal to 0.3 the population can be considered to be subdivided into clusters following Newman’s (2006) eigenvector-based method for maximizing modularity (see also Newman 2004). We term them clusters because of their appearance when represented visually in a social network (produced using Netdraw 2.097). Clusters can be assessed regardless of sample size, but cluster membership may change when new analyses are undertaken with larger sample sizes. This is particularly the case for individuals who were only seen on one or a couple of occasions in earlier analyses; individuals seen more often are unlikely to change cluster assignment as sample sizes increase. Clusters may contain one or more units, and one or more sub-clusters (see below).

*Sub-cluster.* When individuals within a cluster have been seen on more than one occasion, sub-clusters can be assessed by restricting analyses noted above to a specific cluster, and if  $Q \geq 0.3$  sub-cluster number and membership is determined using the value for maximum modularity.

Thus a cluster may be composed of only one or of multiple sub-clusters. The presence of sub-clusters was only assessed in cases where tagged whales were not re-sighted post-tag loss to determine whether sub-clusters exist and whether other sub-cluster members were re-sighted. It is possible that sub-clusters may be approximately equivalent to units, although young individuals (i.e., <4 years of age) may be assigned to a sub-cluster even though their sighting history is too short for them to be considered a unit member.

## Results and Discussion

### *False killer whales*

For Hawaiian insular false killer whales, seven social clusters (Figure 1) were identified using modularity ( $Q=0.63$ ; Baird et al. 2011c). Of the seven, one cluster (cluster 1) is seen most often, representing approximately 70% of all sightings of Hawaiian insular false killer whales from 1986-2010. Two clusters (cluster 2 and 3) are seen less often but typically at least once per year, and the remaining four clusters are seen infrequently, a situation similar to pod-specific differences in sighting rates for northern resident killer whales (Ford 2006), albeit with much smaller overall sizes for false killer whales. Of the 27 individual Hawaiian insular false killer whales that have been satellite tagged, 16 were from cluster 1, and all 16 individuals from this cluster have been re-sighted after tag loss<sup>1</sup>. Of the 15 tag deployments on individuals from cluster 1 prior to October 2010, re-sighting periods (from the date tagged until the most recent sighting) have ranged from 295 to 1,470 days (median = 828 days). Seven of the remaining 9 individual false killer whales that have been tagged are from cluster 3; two of the four of those tagged prior to December 2010 have been re-sighted post-tag loss. There were only two sightings of cluster 3 individuals in 2010 and no individuals from cluster 3 have been documented since December 2010 (when three individuals from cluster 3 were tagged), thus the lack of re-sightings of the other individuals is not surprising. The remaining four individuals were classified as members of several smaller infrequently seen clusters, and those individuals have not been re-sighted.

### *Short-finned pilot whales*

Although we have tagged short-finned pilot whales off three different islands (Kaua'i, O'ahu, Hawai'i), the majority of our tagging effort (41 of 51 tag deployments) and re-sighting effort has been focused off the island of Hawai'i. Of the 10 tags deployed on individuals off Kaua'i or O'ahu, nine were deployed between October 2010 and February 2011 and there are few encounters from those islands after February 2011 for the assessment of re-sighting rates. Sample sizes are currently insufficient to assess unit membership off O'ahu or Kaua'i. Thus our re-sighting analyses are restricted to individual short-finned pilot whales tagged off the island of Hawai'i. Forty-one LIMPET tags have been deployed on 38 individual short-finned pilot whales off the island of Hawai'i, with deployments between April 2006 and December 2010.

Photographs to assess social organization and re-sightings of tagged whales have been matched through 2010, however there are 13,300 photographs from 35 encounters with pilot whales from the island of Hawai'i from 2011 that have not yet been matched, thus the assessment of re-sightings and time intervals for when individuals were last seen since they were tagged is only complete through 2010. Social network analyses indicate that all 38 tagged

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<sup>1</sup> Two of these 16 individuals have been tagged twice, one has been re-sighted after tag loss for both tagging events, the second was re-sighted after tag loss after the first tagging, but not yet the second.

individuals can be linked through shared associations within a single social network that currently contains 491 distinctive individuals. Within this social network 17 social clusters were determined using modularity ( $Q=0.78$ ), and 9 social units have been identified.

Of the 41 deployments, tagged individuals have been re-sighted post-tag loss<sup>2</sup> for 30 deployments (range from 11-1,689 days post-tag loss, median = 538 days). However, for the remaining 11 deployments, there have been no sightings of the social unit or sub-cluster that the tagged whale is a member of. Thus taking into account only those individuals whose social unit or sub-cluster have been seen post-tag loss, all 30 individuals have been re-sighted.

### Conclusions

Overall our high within-cluster 1 re-sighting rates of Hawaiian insular false killer whales, and re-sightings of all short-finned pilot whales tagged off the island of Hawai'i for which their social unit or sub-cluster has been seen post-tag loss, imply that remotely-deployed LIMPET satellite tags have little or no impact on survival of these species over periods of up to several years post-tagging. In addition, these analyses illustrate how critical large sample sizes of photo-identification data are to assess re-sighting rates of previously tagged social odontocetes like false killer whales and short-finned pilot whales. The ability to define social groups based on large numbers of encounters and identifications has been vitally important to this assessment. Matching of other photos currently available from 2011 and photos to be obtained in planned field work in 2011 and 2012 will increase the sample size available both for determination of social units and sub-clusters and of re-sightings of previously tagged whales, allowing for a more robust assessment of the potential impacts of LIMPET tagging on individuals.

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<sup>2</sup> Or loss of tag signal; in some cases tags may have stopped transmitting due to battery failure.

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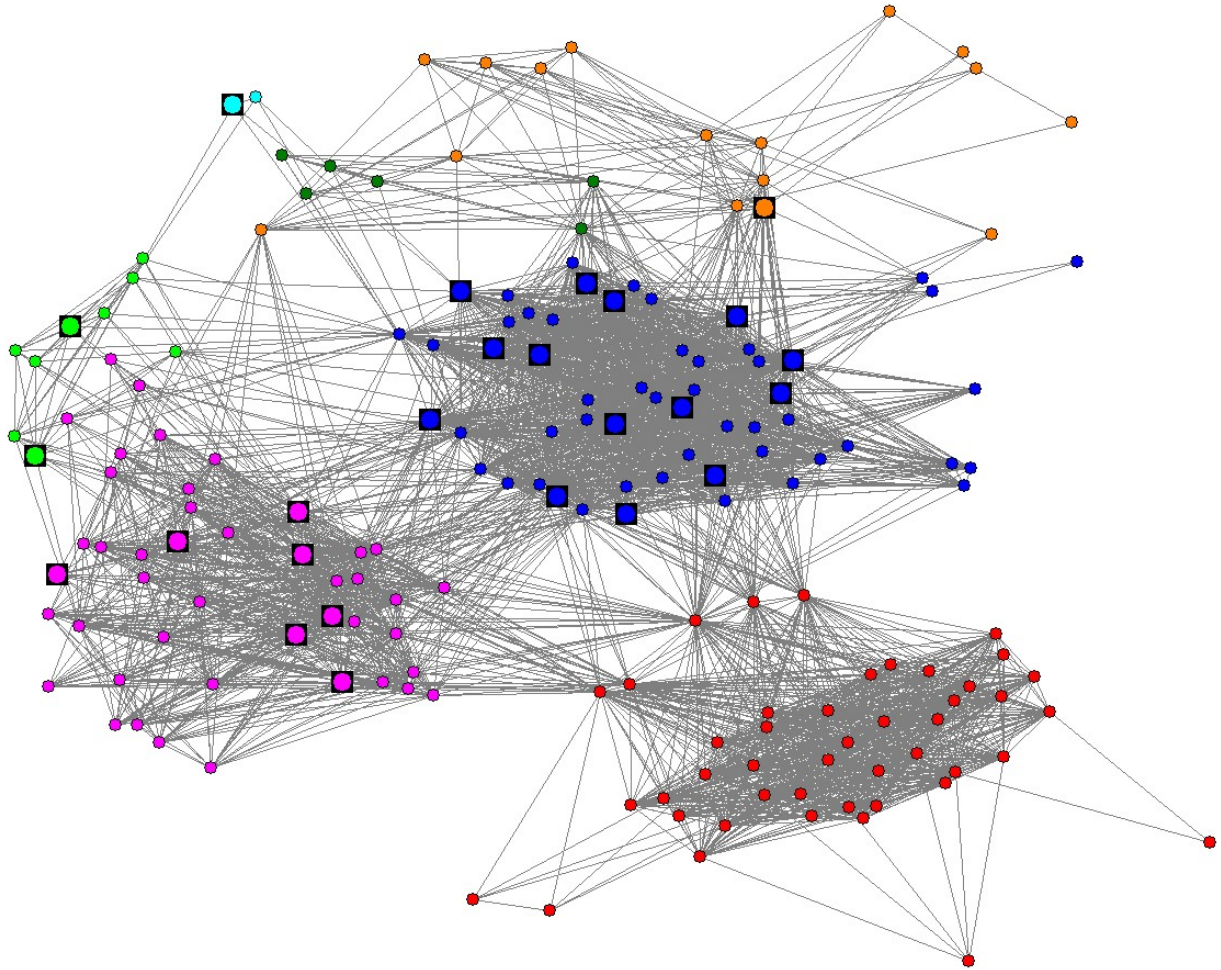


Figure 1. A social network of distinctive and very distinctive Hawaiian insular false killer whales using photo-identification data available from 2000 through September 2011. Layout determined using spring embedding with minor changes made to avoid overlap of points. Satellite tagged individuals are highlighted with large symbols. Individuals assigned to clusters using modularity with cluster membership indicated by color: cluster 1 – blue; cluster 2 – red; cluster 3 – pink; other clusters not numbered.