

Population parameters of Blainville's and Cuvier's beaked whales

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LONG TERM GOALS

Beaked whales appear to be specifically sensitive to some acoustic sources, which can lead to mass strandings. The lack of knowledge about the population dynamics and reproductive parameters of these animals impedes the assessment of the population effects of stranding mortalities. The goal of this project is to continue a long-term photo-ID study started in the Canary Islands in 2003, in order to obtain a sufficient sample size for demographic modeling. This information will greatly augment the sparse knowledge of beaked whale population biology, facilitating the assessment of possible population effects of human impacts.

OBJECTIVES

The overall objectives of the project are the following:

1. To assess the spatial fidelity of beaked whales to the study area in the Canary Islands.
2. To estimate population size and analyze the dynamics of the local populations of Blainville's and Cuvier's beaked whales over a 12 year period.
3. To study medium and long term individual associations and individual site-fidelity.
4. To obtain life history parameters of Blainville's beaked whales from long-term photoID data

APPROACH

Determining when noise causes biologically significant effects requires making the transition from individual impacts, including mortalities, to population-wide effects. For this to be achieved it is essential to obtain data on vital rates and demographic parameters of the affected species (PCAD model, NRC 2005). Beaked whales (fam. Ziphiidae) are the most common taxa involved in mass strandings recorded in coincidence with naval exercises. However, because of their distribution in deep oceanic waters, they are usually difficult to study.

El Hierro (Canary Islands) holds resident populations of Blainville's and Cuvier's beaked whales in deep waters close to the shore (Aguilar de Soto 2006). This allows us to perform low-cost shore-

based research on these species. The combined effort of observers from a coastal cliff and from a boat enables effective detection of groups of beaked whales occurring in the study area. The land and boat-based stations communicate by VHF radio and once a group is detected the boat approaches it to photograph the animals and obtain data on the composition and behavior of the group.

PhotoID studies performed by ULL since 2003, largely with NOPP/ONR funding, have produced one of the largest individual catalogs available for these species. This catalog is freely accessible on-line at www.cetabase.info and can be used by any entity or individual with beaked whale data, in the Canary Islands or elsewhere. Long-term monitoring provides an ideal opportunity to study social structure and demography in populations expected to be limited by natural variables such as habitat carrying capacity. Re-sightings of reproductive adults provide life-history data such as reproduction rates, essential to assess the recovery capacity of the species after mass mortalities.

Co-investigators on the project come from the University of La Laguna (N. Aguilar de Soto) and the University of Saint Andrews (P. Hammond). N. Aguilar directs and performs the scientific tasks, supervises researchers contracted to participate in the cruises and performs data analysis. P. Hammond is a qualified adviser, as a leader in the field of population abundance estimates and population dynamics of marine mammals, with an ample publication record in these subjects.

WORK COMPLETED

Field work and data collection

Since the signature of the agreement ONR-ULL in May 2012 we have performed eleven seasonal photoID surveys off El Hierro, according to plan. Four of these cruises took place since the last report in September 2013, summing 38 days of fieldwork performed in October-November 2013 (11 days) and in February (9 days), May (8 days) and July (10 days) 2014. In total, 35 days (92%) had good conditions to work at sea and photoID was achieved in 31 days (10, 5, 8 and 8 respectively) of one or both resident ziphiid species in the waters of the island: Blainville's and Cuvier's beaked whales.

To study the connectivity and movements of the individual populations of beaked whales in the archipelago we obtained photos from entities gathering information on cetacean sightings from all the Canary Islands: Gran Canaria, Tenerife, La Gomera, La Palma and the eastern islands of Fuerteventura and Lanzarote.

Meetings

The two IPs of the project met for data analysis in three occasions (March, April and June 2014) at the University of St. Andrews.

Online photoID catalogue (www.cetabase.info)

PhotoID data obtained during this project have been uploaded to CETABASE after each seasonal survey. The database holds now 162 Blainville's and 134 Cuvier's beaked whales individual pages. Some of these animals may be the same individual because whales are identified by different regions of the body. The minimum number of individual whales of the database is given by the whales for which the same part of the body has been photographed with enough quality and this body area has sufficient marks as to be individually recognizable.

Publication of results of the ONR funded cetacean research in El Hierro in 2014

Peer reviewed papers

1. Martín, L. Miller, P., Aguilar de Soto, N., Johnson, M. Gait switches and fast twitches: biomechanical strategies for long diving in beaked whales. *Journal of Experimental Biology* (in review in *Journal of Experimental Biology*)
2. Madsen, P., Aguilar Soto, N., Tyack, P. Johnson, M. (2014) What is a beaked whale? *Current Biology* 24 - 16, pp.pR728 - R730. 2014.
3. Tobeña, M.; Escáñez, A., Rodríguez, Y, López, C. Ritter, N., Aguilar de Soto, N. (2014) Inter-island movements of common bottlenose dolphins *Tursiops truncatus* among the Canary Islands: online catalogues and implications for conservation and management. *African Journal of Marine Science*. <http://dx.doi.org/10.2989/1814232X.2013.873738>
4. Four papers in preparation, to be submitted before the end of the project in May 2015

International Conferences

1. Aguilar de Soto, N., Madsen, P., Johnson, M. Sharing the wealth, a cost-benefit analysis of niche segregation in deep-diving pilot and beaked whales. Oral presentation at the 5th International Biologging Conference. Strasbourg, France. September 2014
2. Johnson, M., Madsen, P., Aguilar de Soto, N. Where's the air? Sound recording tags on deep diving whales reveal nasal air movements. Oral presentation at the 5th International Biologging Conference. Strasbourg, France. September 2014
3. Martín, L., Miller, P., Aguilar de Soto, N., Johnson, M. A new insight into biomechanics and energetics: Magnetometer and/or gyroscope?. Poster at the 5th International Biologging Conference. Strasbourg, France. September 2014
4. Aguilar de Soto, N., Madsen, P., Arranz, P., Johnson, M. From metabolism to social life: ten years of research on the acoustic ecology of deep-diving cetaceans in the Canary Islands. Oral presentation at the International Conference of Marine Sciences. Gran Canaria. June 2014
5. Schiavi, A., Aguilar de Soto, N., Reyes, C., Martín V. Inter-island movements of Blainville's and Cuvier's beaked whales the Canary Islands. Poster at the International Conference of Marine Sciences. Gran Canaria. June 2014.
6. Reyes, C., Schiavi, A., Aguilar de Soto, N. An insight into the populations of Blainville's and Cuvier's beaked whales off El Hierro (Canary Islands): abundance estimation. Oral presentation at the International Conference of Marine Sciences. Gran Canaria. June 2014.

RESULTS

SITE-FIDELITY OVERCOMES VOLCANIC ERUPTIONS IN EL HIERRO

Use of the area

Beaked whales were observed in the coastal waters of El Hierro in 97% of the 35 total days of effort performed from October-November 2013 to July 2014. This is consistent with the results of the previous years of study since 2003 and suggests that the population in El Hierro is not declining, as it has been observed in other areas (Moore & Barlow 2013). The total number of cetacean sightings from land was 525. From these, 382 (73%) were from beaked whales and 28% of this were approached by the boat and identified to species level, being 71% and 29% from Blainville's and Cuvier's beaked whales, respectively.

Individual database

From September 2013 to August 2014 a total of 27 individual adult Blainville's and 21 adult Cuvier's beaked whales with recognizable marks were photographed, often in more than one season. Of these, 17 of the Blainville's and 16 of the Cuvier's beaked whales had been previously observed in the island, while 5 Blainville's and 3 Cuvier's were new to the marked population. In addition we observed 5 calves of Blainville's beaked whales (of which 3 were re-sightings) and 2 calves of Cuvier's beaked whales, being one of them a re-sighting.

The minimum number of marked adult individuals since 2003, i.e. animals with regular to very good photos and good recognizable marks in the same area of the body, comprises 69 Blainville's and 61 Cuvier's beaked whales. As in previous years, we observe that some 50% of the animals of both species are observed only once. The remaining animals can be observed up to 10 of the 12 years of study. These individuals form can be considered as the core residents in El Hierro, albeit many individuals show time-lags between sightings of two years. This may be due to the difficulties inherent in photographing beaked whales, but may reflect that the whales leave the area temporarily also. However, they do not seem to mix with other island-associated sub-populations (see results of connectivity below)

Life history

Blainville's beaked whale

The analysis of the photoID data supports the following best estimates of life history parameters for the population in El Hierro: i) age of sexual maturity and first birth for females: $\approx 9-10$ and $10-11$ years, respectively; ii) inter-calf interval: ≈ 3 years (i.e. the new calf is born 3 years after the birth-year of the previous calf) and as low as two years in one case where the first calf was missing (death?); iii) weaning age: 2-3 years.

These parameters were obtained from a long-term series of photo-ID data of several females and mother calf-pairs. Although the results have a limited sample size, they are consistent with the observations of Claridge (2013) on the Bahamas population of the same species. The history of recaptures of **seven** females allowed us to obtain estimates of inter-calf interval and age of weaning, and one young female was monitored until first reproduction.

Potential long-term kin associations between females. Unknown paternity.

The composition of the groups of beaked whales changes with time, resembling a fission-fusion society typical of delphinids. However, some individuals seem to have preferred companions and the factors influencing the degree of inter-individual association are still unknown. In matrilineal species such as killer whales mothers seems to play an important role for the long-term survival of their offspring, even when the offsprings have reached adult size. Blainville's beaked whales often form social groups of several females and young, often associated to a male. These may last one or two years and then the individuals disperse and join other groups.

Our database includes only one case of a female monitored from juvenile to first reproduction. This female weaned at some 2-3 years old, in 2005, and associated with other subadult individuals for six years. Then, in 2011 she re-associated with her mother and with a female-calf pair. It is unknown if the association with the mother was random, given the moderate size of the resident adult female population, or purposeful. The group of four was seen with different males in the course of two years (2011-2012). In 2013 both females were associated with calves of around one year of age. At this time the group composition was more stable: a usual harem with an associated male which was observed with the group until the group was last seen in July 2014. However, this male was not observed with the group in 2011-2012, when the females must have got pregnant, raising questions about his paternity of the calves in the group. It needs to be considered that it is

possible that he associated with the females and that this association passed unnoticed, given that we only perform four cruises per year, but we have observed the same pattern in other cases.

The observations of this group raise questions requiring further data gathering: i) a potential role of inter-female kin relationship in the composition of the groups; and ii) the role of males in harem groups. Males may guard females until they get ready to mate again, or may have brief encounters with females and then join the group when females give birth to guard their offspring.

Strong associations among whales, often during yearly periods, confirm the visual observations of strong group coordination in whales diving and surfacing together. However, groups were observed to split and their members were then associated with other whales. A sub-adult female was observed in groups with two different males within one month, suggesting that females actively choose a harem to join, or that sub-adult whales associate with harems without immediate reproductive activity. The data indicate that females breed with different males for consecutive calves, forming different harem groups with new individuals, and in some cases with females with whom they had previously associated. Again, this raises the question of potential female kin support, calling for a genetic analysis of social structure.

Cuvier's beaked whales

The analysis of the photoID data supports the following best estimates of life history parameters for the population in El Hierro: i) inter-calf interval: ≈ 4 years ; ii) weaning age: 3,5 years. These results were gathered with a limited sample size of focal follows of only two females that were associated with two or more calves during the study period. In contrast with Blainville's beaked whales, often forming groups of 2 to 4 females with young, most of the times that a calf of Cuvier's beaked whale is sighted, the group is conformed solely by the mother and the calf or by two mother-calf pairs.

These data show the increasing value of long-term monitoring of beaked whale populations in order to understand their social structure and obtain accurate life-history parameters. These data are essential in order to improve models such as New et al. (2013) and feed transfer functions for PCAD models of population-level impact of acoustic sources.

Connectivity

It is important to coordinate the analysis of photoID data in different islands in order to determine if beaked whales in the Canary Islands constitute: i) a metapopulation in the archipelago, with individuals moving among different areas of concentration but forming a single reproductive stock, or ii) local populations with site-fidelity to the different islands and little genetic interchange. Each option has different demographic and management implications. In the first case the total archipelagic population would be smaller than the estimates obtained by summing the abundance in the local areas of concentration, but the population would be more resilient to local impacts because impacted animals can be replaced by individuals from other areas. In contrast, if there is little or no connectivity among local areas, the population of each island would be more vulnerable to impacts.

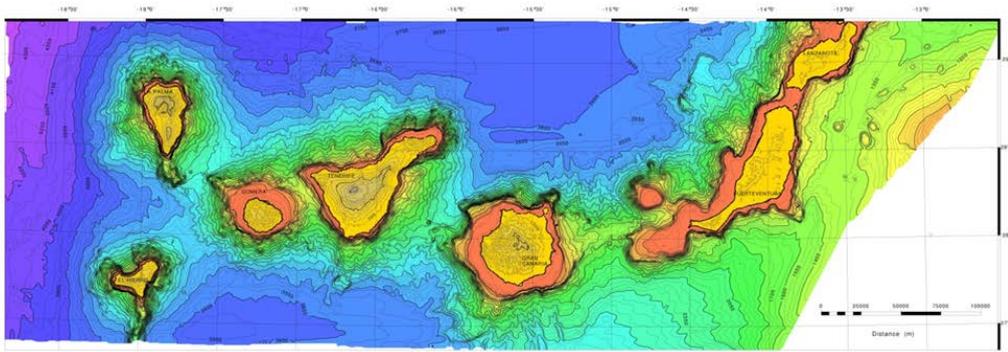


Figure 1. The Canary Islands archipelago. Observe the steep bathymetry of El Hierro, the most western and meridional of the islands, which explains the vicinity of the populations of beaked whales to the coast.

There are not dedicated beaked whale research programs in the islands of Gran Canaria, Tenerife, La Gomera and La Palma, where the whales are observed less frequently than off El Hierro. In spite of this, we gathered photos from whale watch operators and other entities, summing 74 individual whales in total (61 Blainville's and 13 Cuvier's beaked whales). Of these, 40 and 10 individuals of each species, respectively, had enough marks and were photographed with sufficient quality as to be analyzed. In the eastern Canary Islands: Fuerteventura and Lanzarote, beaked whales are seen regularly, albeit further from the coast than in El Hierro. In these islands there is a photoID catalogue maintained by SECAC (Society for the study of cetaceans in the Canary Islands). The catalogue contains 36 Blainville's and 66 Cuvier's beaked whales with sufficient body marks and with photos of enough quality as to perform photoID analysis. In addition, there is a small catalogue of Gervais beaked whales (*Mesoplodon europaeus*) in the oriental islands, including re-sightings. This species has never been observed alive in El Hierro, where it is known only by a stranding of two sub-adult females in 2006.

There have been no confirmed matches between any of the islands, excepting the most Eastern islands of Lanzarote and Fuerteventura (Figure 2). The shelf of these islands forms a continuous because the islands are part of the same volcanic building. Given that beaked whales have not been observed to feed in the shelf, these two islands form a unique study area for the species in the context of the Canary Islands. In contrast, re-sightings of individual beaked whales are common within each area and can be recorded several years apart.

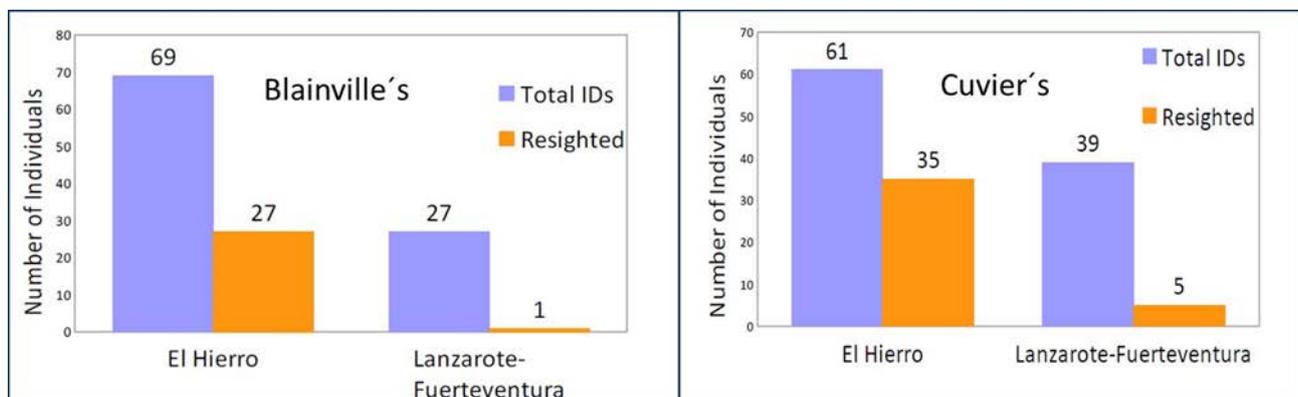


Figure 2. Number of Blainville's and Cuvier's beaked whales identified and re-sighted in two study areas in the most West (El Hierro) and East (Fuerteventura-Lanzarote) of the Canary Islands. Out of 196 individuals, no matches were observed among these two areas.

Although our sample size is relatively small (246 individuals of the two species in all islands), the results of a previous study show that 20% of 313 bottlenose dolphins photo-identified in the central and western Canary Islands have been observed in two or more islands, and thus are considered travelers (Tobeña et al. 2014). This suggests that we would have observed movements among islands for beaked whales if these occur. Our results suggest that an important part of the beaked whale population in the Canary Islands has strong site-fidelity for specific preferred areas around the slope of different islands, and thus these sub-populations should be managed as separated units for their conservation.

The lack of connectivity among islands within the same archipelago has been observed for Cuvier's and Blainville's beaked whales in Bahamas also (Claridge, 2013), in spite of satellite data from Hawaii and California showing that these species are able of travelling large distances. The apparent isolation of beaked whales in different islands is in apparent contradiction with our previous and current finding of beaked whales in the channels among islands, in deep waters relatively far offshore (Figure 3). Even the resident whales in El Hierro perform mesoscale movements. Two Blainville's beaked whales tagged in the same group, three days apart, in the lee area of El Hierro (October 2013) released the tag some 10 nm South and 10 nm North of the island, away from the lee area. This shows that the core resident population in El Hierro does not have a preference for the lee area and that they move to the channels. The fact that they are not observed in the slope of other islands could be interpreted as a sign of territoriality. However, around 50% of both Blainville's and Cuvier's beaked whales identified in El Hierro have been observed only once. They may be part of an oceanic population and it is unknown if they may maintain the genetic connectivity between the island-associated sub-populations.

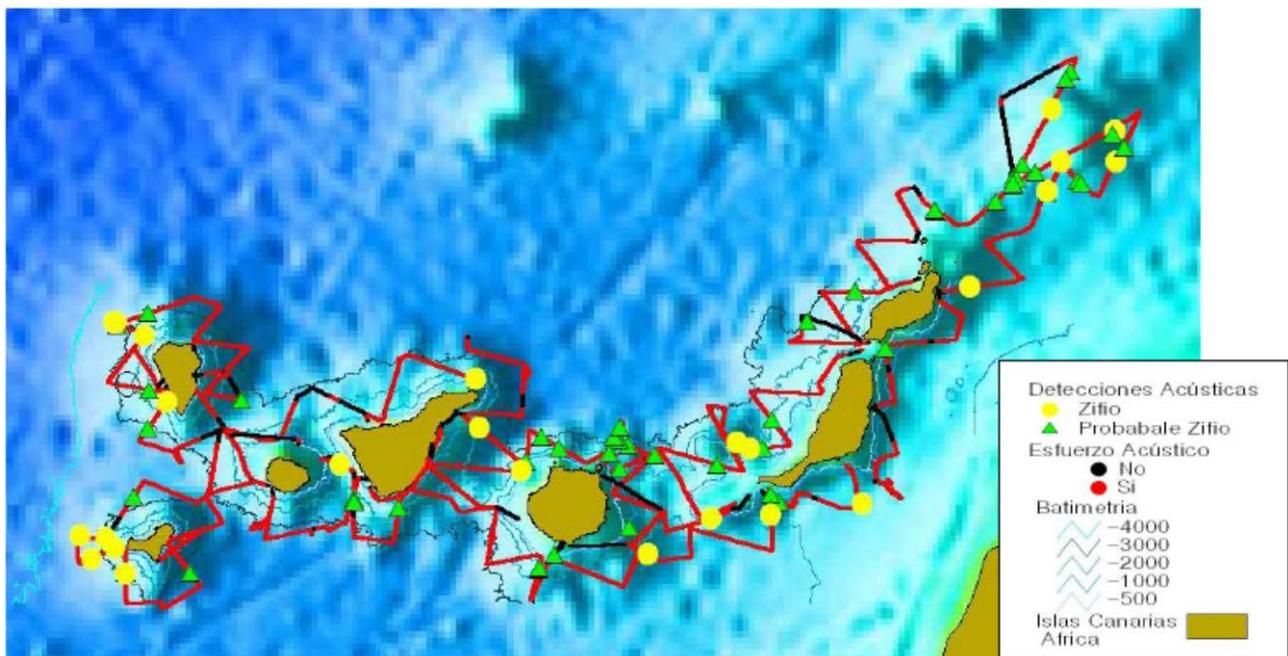


Figure 3. Acoustic detections of beaked whales (*Ziphiidae*) in a survey performed by the University of La Laguna in 2009 (Fais et al. 2010). The distribution of these detections and the large proportion of individual whales observed only once in El Hierro suggest that there is an oceanic population in addition to island-associated sub-populations. It is unknown if the genetic connectivity among different islands is maintained by mixing of the island-associated and oceanic sub-populations.

IMPACTS / APPLICATIONS

National security

This work will provide important baseline data to assess the effects of naval activities, such as tactical sonar, on species protected under the US Marine Mammal Protection Act. To quantify the potential population effects of a given naval activity it is necessary to have knowledge about basic life history parameters of the species likely to be affected by the activity. These basic life history parameters include the size and dynamics of local populations, site fidelity and renewal rates (i.e. breeding rate, age of sexual maturation). Beaked whales are considered by the US Navy as species with enhanced sensitivity to intense acoustic sources, but there is still little or no information about the population dynamics of these species. This project is contributing data with direct applicability to perform modeling of potential population effects of human impacts.

Economic development

Economic development is often related to increasing noise levels in the ocean e.g. from ship traffic or mining activities. An improved understanding of the abundance, habitat use and population dynamics of marine mammals will help to plan human activities and help making economic growth more sustainable.

Quality of life

The project will contribute to the understanding of deep diving cetaceans, their use of the habitat, and their sensitivity to human interactions. The results will facilitate improved regional management with implications on ecosystem health.

Science education and communication

The project produces information that is made available to the general public in www.cetabase.info. Results from the project will base three scientific publications covering abundance estimates, social structure and life history parameters of the study species, including interpretation of results to contribute to PCAD models. Graduate and postgraduate students are involved in all facets of the work.

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