Population Parameters of Blainville´s and Cuvier´s Beaked Whales

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LONG-TERM GOALS

Beaked whales are especially 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 assessing the population effects of stranding mortalities. This project continues 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 augments the sparse knowledge of beaked whale population biology, contributing to our understanding of the biological processes influencing population resilience or vulnerability to human impacts. ONR funding has been leveraged by additional Spanish funding to continue field effort and initiate genetic sampling with biopsies in 2015, until February 2016. This is the first step towards gathering a dataset to study genetic diversity and population structure of Cuvier´s and Blainville´s beaked whales in the archipelago. Analyzing PhotoID and genetic data in tandem is a powerful method for close-kin studies of paternity/relatedness and dispersal. Genetic diversity, life history traits, social structure and social cohesion influence the persistence and resilience of cetacean populations. Long-term monitoring of beaked whale populations in El Hierro, a nearly pristine habitat far from areas of sonar testing or marine industry, enables valuable studies of demographic trends and life history dictated mainly by natural parameters. El Hierro is in process of being declared the first fully marine Spanish National Park due to its high natural values and good level of conservation. Beaked whale monitoring will be undertaken by the Park once it starts functioning. This will leverage previous long-term monitoring of beaked whales funded largely by ONR and NOPP since 2003 and enable robust assessment of population trends and patterns of social structure unveiled by this project. Until the Park starts functioning (expected in 2018-2019), it is essential to continue monitoring the populations in El Hierro to obtain an uninterrupted long-term dataset of photoID and genetic data.

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 (*Mesoplodon densirostris* and *Ziphius cavirostris*) in deep waters close to the shore (Aguilar de Soto 2006, Arranz *et al.* 2011, 2013). This allows us to perform low-cost 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. PhotoID studies performed in the area since 2003 have produced one of the largest individual catalogs available for these species, freely accessible on-line at www.cetabase.info. This web-tool is currently being promoted to construct a North Atlantic broad beaked whale photoID catalogue. Co-PIs on the project come from the University of La Laguna (N. Aguilar de Soto) and the University of Saint Andrews (P. Hammond). Researchers contracted to work in this project are A. Schiavi and C. Reyes. ONR funding has been leveraged by other projects of ULL and collaborations with researchers at the University of St. Andrews for biologging (M. Johnson) and genetic studies (E. Carroll).

WORK COMPLETED

Field work
We completed four seasonal field cruises per year to gather photoID data, summing fifteen surveys since 2012. Additional activities during the cruises, leveraged by the on-going field effort, were: i) tagging of two Blainville´s beaked whales with suction-cup attached multi-sensor DTAGs; ii) deployment of drifting recorders in the vicinity of groups with calves; and iii) biopsies of both Cuvier´s and Blainville´s beaked whales for genetic sampling (Table 1).

Table 1: Survey effort. ONR funded photoID cruises from May 2012 to May 2015. This was leveraged to extend field work to February 2012 and August 2015 (current funding extends to February 2016), and to perform biopsies since 2015. In addition, tagging was performed in 2013 in partnership with the University of St. Andrews (UK).

	Total	**2012**	**2013**	**2014**	**2015**
# Cruise days	**165**	39	51	39	36
Days at sea # (% cruise days)	**151 (92%)**	38 (97%)	46 (90%)	37 (95%)	30 (83%)
Days PhotoID of beaked whales # (% days at sea)	**119 (79%)**	27 (71%)	37 (80%)	31 (84%)	24 (80%)
# Sightings from land (beaked whales)	**1822**	399	562	523	338
# DTag deployments	**2**		2		
# Biopsies	**6**				6

Data analysis
All PhotoID data gathered in El Hierro have been processed and uploaded to the online catalogue www.cetabase.info. These data have been used to: i) perform mark-recapture analysis in MARK to obtain estimates of population abundance using standard models, plus on-going Bayesian analysis; ii) study individual associations shaping social structure in SOCPROG; iii) monitor identified female and young to obtain life history parameters such as inter-calf interval and age at sexual maturity (Reyes et al. in prep). In addition, to study the connectivity of ziphiids in the archipelago we obtained beaked whale photos from all other Canary Islands. These photos were contributed at no cost by other research entities and whale-watching companies working in the archipelago. Data have been analyzed to investigate matches of individuals among islands (Schiavi et al. in prep).

Acoustics and Biologging:
Two Blainville´s beaked whales were tagged in El Hierro in 2013 with DTAGs thanks to a collaborative project with M. Johnson (Univ. St. Andrews, EU Marie Curie funding). This included the first deployment of a DTAG equipped with a Micro Electro Mechanical System gyroscope. Acoustic and sensor data from both tags have been extracted, and data from the gyro-DTAG have been used to develop new methods based on gyroscope, magnetometers and accelerometer sensors in the tag to quantify movements and specific acceleration in tagged whales, as part of the PhD of L. Martín (Univ. St. Andrews) (Martin et al. 2015, Martin et al. submitted). Acoustic recordings from drifting buoys have been analyzed to provide data on acoustic detection function of beaked whales as part of the PhD of K. Gkikopoulou (Univ. St. Andrews) (Gkikopoulou et al. in prep).

Genetics:
First confirmed record of True´s beaked whale (*M. mirus*) in the Canary Islands (most southern cite of this species in the North Atlantic) (Aguilar et al. in prep). To confirm species identification of a beaked whale stranded in El Hierro in 2012 we amplified regions of both the mitochondrial DNA (mtDNA) control region and cytochrome *b* gene. Species identification was made using the DNA surveillance website by the construction of a neighbor joining tree with support through 1000 bootstraps (Ross *et al.* 2003) and through comparison of the sequence to the other True's beaked whale sequences available from GenBank (http://www.ncbi.nlm.nih.gov/genbank/). Genetic analysis was performed by collaborator E. Carroll (Univ. St. Andrews).

Biopsy sampling of beaked whales in El Hierro started in 2015, gathering data of 6 Blainville´s and 4 Cuvier´s beaked whales. Three of the animals were recaptured in later months and photographs of the biopsy wounds showed that recovery was complete. A pilot analysis of these samples and those gathered in the autumn cruise (October 2015) will be performed in winter 2015. This analysis will use restriction associated digest (RAD) tag sequencing to generate high-resolution genomic profiles for Cuvier's and Blainville's beaked whales to assess genetic diversity and population structure in combination with photoID data. However, more samples will be required to reach these targets, relying in the continuation of the surveys in El Hierro.

Meetings
The two IPs of the project met for data analysis in several occasions at the University of St. Andrews. IP N. Aguilar reported the results of the project at the 2014 ONR meeting in Washington.

Publication of results from El Hierro (period 2012-2015)
Data gathered in El Hierro have enabled research by the team working in this project and by international collaborators, as summarized below:

# of PhD: 3 (one completed at ULL, two on-going at Univ. St. Andrews).

Master and other graduate projects: 5 (four at ULL, one at Univ. St. Andrews).

Peer reviewed papers/book chapters: 9 (plus 9 submitted or in preparation, see Annex I)

Conference presentations: 24 (Annex I)

Published articles/book chapters

1. Aguilar de Soto, N., Madsen, P.T., Tyack, P., Arranz, P., Marrero, J., Fais, A., Revelli, E., Johnson, M., 2012. No shallow talk: Cryptic strategy in the vocal communication of Blainville's beaked whales. *Marine Mammal Science* 28, E75–E92. doi:10.1111/j.1748-7692.2011.00495.x
2. Aguilar, N., Johnson, M., Arranz, P., Escanez, A., Reyes, C,Schiavi, A., Madsen, P., Brito, A. 2013. Volcanes, zifios y otros valores naturales de las aguas profundas de El Hierro. Actas VIII SCTB. pp. 81 - 110. Instituto de Estudios Hispánicos de Canarias (book chapter).
3. Arranz, P., Borchers, D.L., Aguilar de Soto, N., Johnson, M.P., Cox, M.J., 2013. A new method to study inshore whale cue distribution from land-based observations. *Marine Mammal Science* n/a–n/a. doi:10.1111/mms.12077
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5. Cox, M.J., Borchers, D.L., Kelly, N., 2013. nupoint: An R package for density estimation from point transects in the presence of nonuniform animal density. *Methods in Ecology and Evolution* 4, 589–594. doi:10.1111/2041-210X.12058 (paper based on the dataset of El Hierro)
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7. Madsen, P.T., de Soto, N.A., Arranz, P., Johnson, M., 2013. Echolocation in Blainville's beaked whales (Mesoplodon densirostris). *Journal of Comparative Physiology A* 199, 451–469. doi:10.1007/s00359-013-0824-8
8. Martín López, L., Miller, P.J.O., Soto, N.A. de, Johnson, M., 2015. Gait switches in deep-diving beaked whales: biomechanical strategies for long-duration dives. *Journal of Experimental Biology* 218, 1325–1338. doi:10.1242/jeb.106013.
9. Tobeña, M.; Escánez, 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

RESULTS

El Hierro as part of a breeding area with higher site fidelity for females. Low abundance.
Beaked whales observed in El Hierro can be divided in: i) a core group with a pattern of residence in the coastal waters of the island, where these whales have been observed up to 10 of the 13 years of study (20013-2015); ii) animals observed in only one of the study years (Table 2). The number of animals with good and regular marks is similar in both groups for both study species. The yearly time-lag between sightings of whales of the core group averages 2 years, this may be due to the difficulties inherent to photographing beaked whales or reflect temporary emigrations, not dictated by seasonal patterns. The division of core/resident and transient groups is supported by a Goodness of Fit test performed in program U-CARE (Choquet et al. 2009) (TEST3.SR $p<<0.01$ for Blainville´s and $p<0.05$ for Cuvier´s beaked whales).

Table 2: Data for abundance estimation. Whales classified as indeterminate are subadults without teeth (i.e. not adult ♂) which have never been observed associated with calves (i.e. not adult ♀). Best estimates of abundance are given with 5-95% confidence intervals. *=preliminary data using closed full likelihood models. Abundance estimations are corrected for % unmarked whales.

	Blainville´s (*M.densirostris*)	Cuvier´s (Z. *cavirostris*)
Period 2003-2015		
# PhotoID whales	117	99
Core resident whales	45% of recognizable whales best estimate: 37* (37-37)	50% of recognizable whales best estimate: 44* (44-44)
Time-lag in years between sightings of core whales	Median:1 5-95 percentiles: 1-4	Median:1 5-95 percentiles: 1-4
Period 2012-2015		
# Individuals photoID	56 (17 ♂ / 7 ♀ /22 indet /10 young)	58 (11 ♂ / 5 ♀ /36 indet /6 young)
# New individuals	36	31
# females with calves	7 (all from the core group)	5 (4 recognizable: from core group)
best estimate: 2012-2013	40 (40-40)	39 (39-39)
best estimate: 2014-2015	43 (43-43)	29 (29-29)
best estimate: 2012-2015	69 (63-86)*	59 (53-79)*
POPAN	NA	65(41-85)
Jolly Seber	42 (35-50)	55 (44-71)

The incorporation of new whales to the marked population may be explained by the acquisition of recognizable marks by individuals previously observed as unmarked juveniles, and now classified as indeterminate. New animals include many more adult males than females, i.e. there is a higher diversity of males than females of this species visiting the coastal waters of El Hierro. Most recognizable adult females found in El Hierro (and all females identified during this project) belong to the core group. In the case of Blainville´s beaked whales, most of these females have been observed with 3-4 offspring in the study area. These results suggest that the coastal waters of El Hierro are part of a breeding area inhabited by females with high site fidelity, and visited by adult males, which probably compete to gain access to the area for reproduction (Reyes et al. in prep).

Software MARK was used for abundance estimations based on mark-recapture models. The low sample size of marked whales did not allow using standard open population models such as POPAN or Jolly-Seber, nor advanced methods such as Robust Analysis, to analyze the full dataset. This analysis is on-going, applying Bayesian statistics as used by Claridge (2013) (Reyes et al. in prep).

Here we provide a rough estimate of the number of whales in the core population by removing the transients and applying full likelihood models for closed population; model selection was performed according to the lowest Akaike Information Criterium and Deviance. The same was applied to estimate total numbers of whales in pairs of years during this project (2012-2015). Open population models (POPAN, Jolly Seber) were used for this subset of data also, although for Blainville´s, POPAN does not converge with the data in this period either. POPAN provide an estimate of the total number of animals that have ever been in the area during the duration of the

study period and thus POPAN estimates are always larger than the estimates using Jolly Seber (Reyes et al. in prep).

No apparent connectivity in the archipelago
This analysis is in preparation for publication and has been presented in a conference as: Schiavi, A., Aguilar de Soto, N, Reyes, C., Martín V. (2014) Inter-island movements of Blainville's and Cuvier's beaked whales the Canary Islands. Int. Conf. Marine Sciences. Gran Canaria. Spain

Beaked whales are found in all the Canary Islands and could 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 unknown genetic interchange. Each option has different demographic and management implications. The analysis of photoID data gathered in El Hierro and other islands (Table 3) separated from 60 km to 400 km from El Hierro, has shown no matches among these areas. In contrast, re-sightings of individual beaked whales are common within each island and can be recorded up to 6 years apart.

Table 3. Number of individuals used to study connectivity. PhotoID data were contributed by whale watch operators and by Vidal Martín (SECAC, Society for the study of cetaceans in the Canary Islands). SECAC provided the data for the western islands.

# of well marked whales	Eastern Islands*	Western Islands	El Hierro
Blainville's beaked whale	34	39	81
Cuvier's beaked whale	60	9	66

Although the sample size is relatively small (154 Blainville´s and 135 Cuvier´s beaked whales) the results of a previous study show that 20% of 313 bottlenose dolphins photo-identified in the central and western Canary Islands can been observed in two or more islands (Tobeña et al. 2014). This suggests that we would have observed movements among islands for beaked whales if movements are frequent. Our results indicate that a large part of the beaked whales observed in the Canary Islands has strong site-fidelity for areas around the slope of different islands, and thus these areas should be considered separated beaked whale management units.

The lack of connectivity among islands within the same archipelago has been observed before in Cuvier´s and Blainville´s beaked whales in the Bahamas (Claridge 2013). This is in spite of satellite data from Hawaii and California showing that these species are able of travelling large distances (Schoor et al. 2009). Even whales with a resident pattern 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 away from the lee area, some 10 nm South and 10 nm North of the island, respectively, within a day of tag deployment. Around 65% and 50% of Blainville´s and Cuvier´s beaked whales identified in El Hierro have been observed only once and may be part of an oceanic population. It is unknown if they maintain genetic connectivity between the island-associated sub-populations. Further analysis combining photoID and genetics will help clarifying population structure in the archipelago.

Life history
Blainville´s beaked whale - We monitored 44 young and 21 adult females since 2003. Of these, the history of recaptures of seven females with more than one calf during the study period provided estimates of inter-calf interval and age of weaning, and two females were monitored from young to first reproduction. These data supports the following best estimates of life history parameters for Blainville´s beaked whales in El Hierro: i) age of sexual maturity and first birth for females: ≈9-10

and 10-11 years, respectively; ii) inter-calf interval: ≈**3** years and as low as two years in one case where the first calf was missing (dead?); iii) weaning age: 2-3 years; iv) a male observed from calve to subadult has not yet formed a harem, with an estimated age of 7 yrs. These results are consistent with the observations of Claridge (2013) on the Bahamas population of the same species.

Cuvier´s beaked whales - Sample size is smaller for this species, with only 12 young and 9 adult females observed in the area. Three of these had more than one calf, supporting 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.

Long-term female associations. Unknown paternity
The composition of the groups of beaked whales changes with time, resembling a fission- fussion society. However, some individuals seem to have preferred companions and the factors influencing the degree of inter-individual association are still unknown. Blainville´s beaked whales in El Hierro often form harem social groups containing generally two or three females with their offspring and an adult male, as observed in Bahamas (Claridge 2013). The association remains while females are associated with their offspring (some 3 years) and then individuals may disperse and join with other females to form a new breeding-group. While females may remain associated for at least another consecutive reproductive period, males accompanying females during consecutive calves are different. Moreover, males in a harem with young were not observed with the females forming his harem the year before, when females were expected to get pregnant assuming a one year-long pregnancy. These observations raise questions requiring further data gathering and a combined genetic and photoID analysis of social structure: i) a potential role of inter-female kin relationship in the composition of the harems; 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.

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. The results are essential to improve models such as New et al. (2013) and feed transfer functions for PCAD models of population-level impact of acoustic sources.

IMPACTS / APPLICATIONS

National security
This project provides 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 especially sensitive to intense acoustic sources, but there is still little information about the population dynamics of these species. This project contributes data directly applicability to models of 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 helps planning human activities and contributes to make economic growth more sustainable.

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

Science education and communication
The project produces information that is made available for educational purposes to the general public in www.cetabase.info. There is an increasing trend both in number of hits/visitors (summing more than 300,000 and 16,000 since 2012) and in number of nationalities (48 in 2015) accessing the web. A recent initiative (summer 2015) of the cetacean conservation coalition World Cetacean Alliance is promoting the use of Cetabase. WCA is proposing to its more than 40 international partners to add data to CETABASE in order to create a broad beaked whale photoID catalogue in the North Atlantic. This is expected to increase significantly the reach of CETABASE and its use for both scientific and educational purposes.

REFERENCES (see also list of publications of this project)

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New, L.F., etal. 2013. Using energetic models to investigate the survival and reproduction of beaked whales (family Ziphiidae). PLoS ONE 8, e68725

Schorr et al. (2009). Movements of satellite-tagged Blainville's beaked whales off the island of Hawai'i. *Endangered Species Research*, *10*, 203–213. doi:10.3354/esr00229

PUBLICATIONS

Submitted and in preparation

1. Aguilar de Soto, N., Madsen, P., Tyack, P., Johnson, M. Click together stick together: social cohesion in deep diving beaked whales (in prep).
2. Aguilar de Soto, N., Reyes, C., Schiavi, A. We shall not be moved: site fidelity of beaked whales overcomes volcanic eruptions (in prep).
3. Aguilar de Soto, N.: Killer whale predation and the cryptic acoustic behavior hypothesis of beaked whales (in prep).
4. Aguilar de Soto, N., Roland, R., Reyes, C., Schiavi, A, Carroll, E. The True´s beaked whale in the Makaronesia (in prep).
5. Gkikopoulou K.C., Aguilar de Soto N., Gillespie D.M., Tyack P. and Johnson M., Filed measurements of the detection function of Blainville's beaked whale (*Mesoplodon densirostris*) using passive acoustic sensing (in prep).
6. Johnson, M., Shearer, J., Aguilar Soto, N, Jensen, F., Wisniewska, D., Tyack, P., Madsen, P. Morfotype predicts biosonar emission patterns and ecology in cetaceans (in prep).

7. Martín López, L. M., Miller, P. J. O., Aguilar de Soto, N. and Johnson, M. "Tracking the kinematics of swimming: a comparison of two on-animal sensing methods". Submitted to the Journal of Experimental Biology.
8. Reyes, C., Schiavi, A., Hammond, P., Aguilar de Soto, N. Abundance and social structure of beaked whales off El Hierro, Canary Islands (in prep).
9. Schiavi, A., Aguilar de Soto, N., Reyes, C., Martín, V. Connectivity of beaked whales in the Canary Islands (in prep).

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. Strasbourgh, France. 2014.
2. Aguilar de Soto, N. Cheetash, elephants and camels of the deep sea. Oral presentation at the V National Congress of Biodiversity. Tenerife, Spain. 2015.
3. Aguilar de Soto, N. Proposal of inclusion in Annex I CMS: Mediterranean subpopulation of Cuvier´s beaked whale *Ziphius cavirostris*. Invited talk at the meeting of the Scientific Committee of ACCOBAMS (Monaco). 2012.
4. Aguilar de Soto, N. Foraging ecology of marine mammals. International University Menendez Pelayo. Valencia. Spain. 2014.
5. 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. 2014.
6. Aguilar de Soto, N. et al. Areas of Special Concern for Beaked Whales. 3rd Conference on the Effects of Noise on Marine Fauna. Budapest, Hungary. 2013.
7. Aguilar de Soto, N. et al. Areas of Special Concern for Beaked Whales in the Mediterranean. Invited talk. Workshop on Cetaceans and Marine Protected Areas at the 27th Conference of the European Cetacean Society, Setubal, Portugal. 2013.
8. Aguilar de Soto, N. Ecology studies of deep diving cetaceans in the Canary Islands. Oral presentation at the Spanish Cetacean Society. Tarifa, Spain. 2014.
9. Arranz, P. Aguilar de Soto, N. Modelling hábitat selection by beaked whales from land-based sighting data with a modified point simple method. 26th Conference of the European Cetacean Society. Galway, Ireland. 2012.
10. Arranz, P., Aguilar de Soto, N., Johnson, M. Use of drifting broadband autonomous recorders to study beaked whale distribution. 6th International Workshop on Detection, Classification, Localization and Density Estimation of Marine Mammals using Passive Acoustics. St Andrews, Scotland. 2013.
11. Gkikopoulou, K., Aguilar de Soto, N. and Johnson, M. Field evaluation of acoustic detectors and detection functions for Blainville's beaked whales *Mesoplodon densirostris.* 6th International Workshop on Detection, Classification, Localization and Density Estimation of Marine Mammals using Passive Acoustics. St Andrews, Scotland. 2013.
12. Gkikopoulou, K., Aguilar de Soto, N. and Johnson, M. Field evaluation of acoustic detectors and detection functions for Blainville's beaked whales *Mesoplodon densirostris.* Oral presentation at the 20th Biennial conference of the Society of Marine Mammals, Dunedin, New Zealand. 2013.

13. 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. Strasbourgh, France. 2014.
14. Johnson, M., Aguilar de Soto, N., Arranz, P., Madsen, P. How to escape a charging beaked whale: using echolocation to visualise deep-sea predator-prey interactions Oral presentation at the 20th Biennial conference of the Society of Marine Mammals, Dunedin, New Zealand. 2013.
15. 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. Strasbourgh, France. 2014.
16. Martín López, L. M., Miller, P. J. O., Aguilar de Soto, N. and Johnson, M. "Gait switches and fast twitches: biomechanical strategies for long diving in beaked whales." Society of Marine Mammals 20th Biennial conference, Dunedin, New Zealand. 2013.
17. Martín López, L. M., Miller, P. J. O., Thompson, D. and Johnson, M "Gait changes in deep-diving Blainville´s beaked whales" European Cetacean Society 26th Annual conference, Galway, Ireland.
18. Martín López, L. M., Miller, P. J. O., Aguilar de Soto, N. and Johnson, M. "Inferences of energy expenditure in marine mammals: a detail insight into the biomechanical and foraging strategies and body condition of beaked whales". Postgraduate Conference at the University of St Andrews. 2014.
19. Martín López, L. M., Miller, P. J. O., Aguilar de Soto, N. and Johnson, M. "Gait switches and fast twitches: biomechanical strategies for long diving in beaked whales." Diving Physiology Workshop at Aarhus University, Denmark. 2014.
20. Martín López, L. M., Miller, P. J. O., and Johnson, M "New method to identify and quantify fluking rotations using magnetometer data. Case study: Gait switches and fast twitches: biomechaical strategies for long diving in beaked whales." UK Regional Student Chapter of the Society for Marine Mammals, at Oban, Scotland. 2013.
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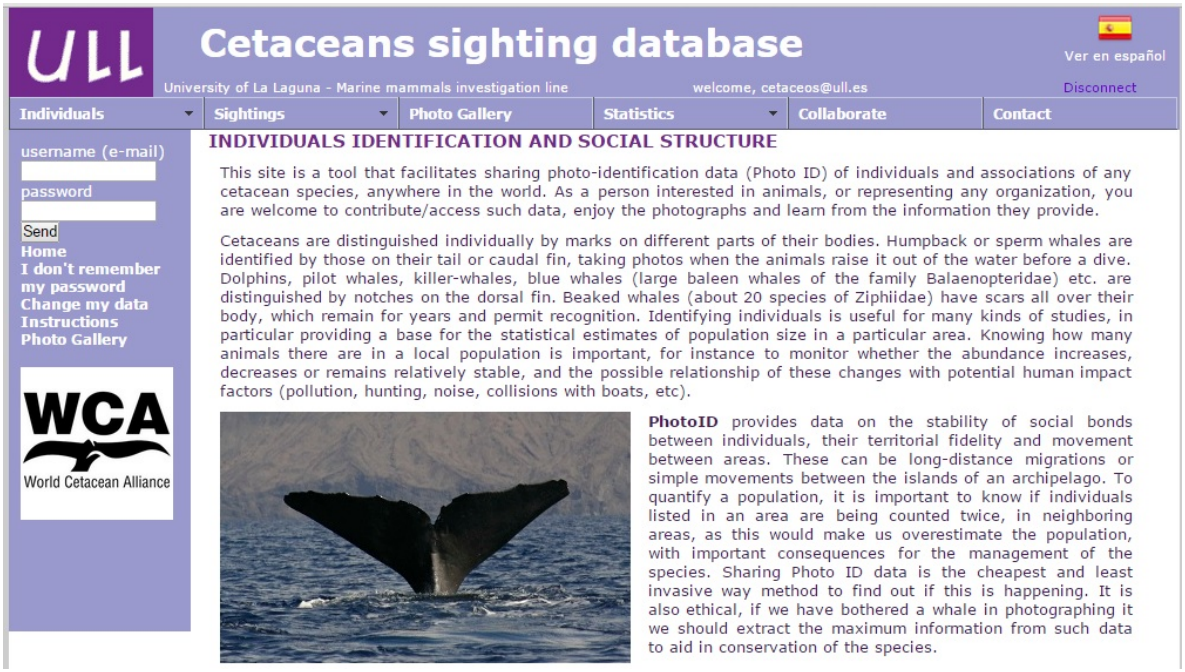

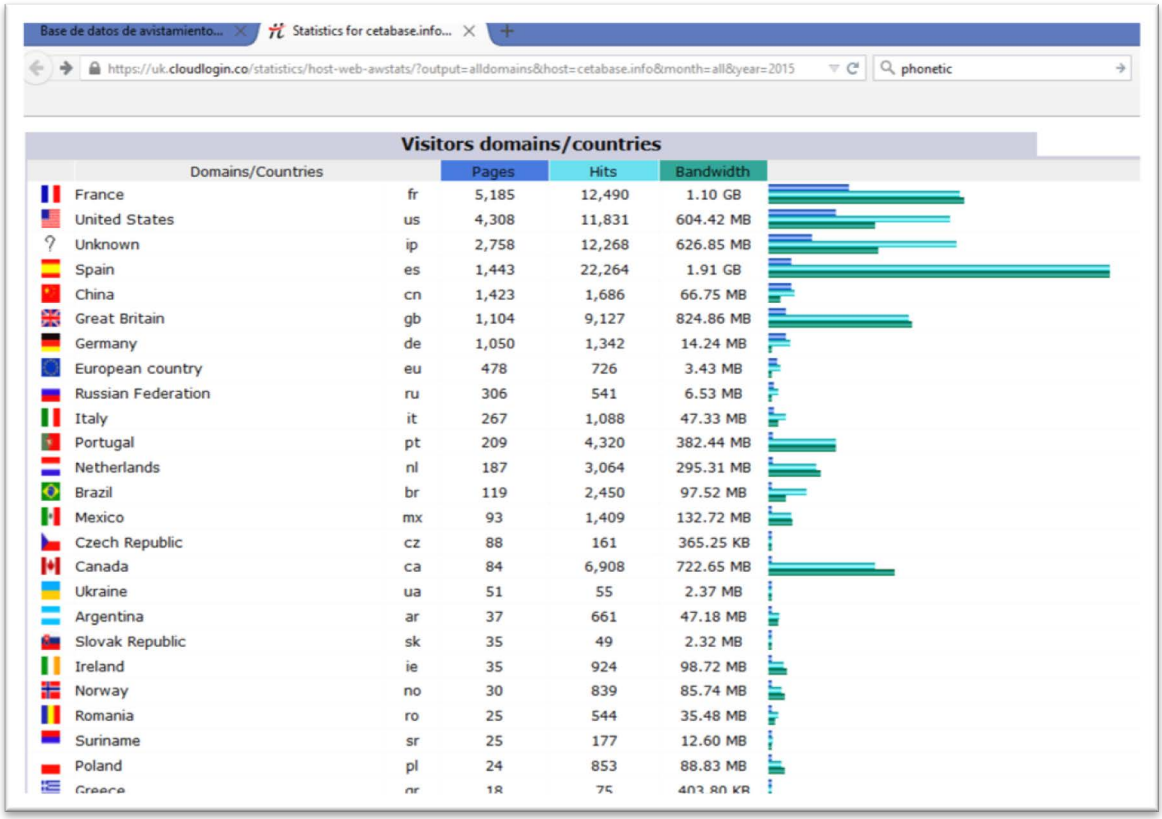

Figure 1. CETABASE www.cetabase.info is both a scientific and an educational tool. It receives thousands of hits per year. In 2015, visitors were from 48 nationalities (24 of these shown above). CETABASE is a bilingual open-access virtual catalogue of photoID data. It has analytical tools for mark-recapture population analysis. It is designed to allow data sharing of marine mammals often performing inter-boundary movements, while maintaining data ownership.

Figure 2. Monitoring of biopsied whales shows good recovery. Here, a subadult Blainville´s beaked whale shows the mark of the dart and the scar three months later.