

Understanding the Patterns and Causes of Variability in Distribution, Habitat Use, Abundance, Survival and Reproductive Rates of Three Species of Cetacean in the Alborán Sea, Western Mediterranean

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LONG-TERM GOALS

The question of how environmental variability affects populations of marine top predators is an important one because of their role within ecosystems and their potential to influence community structure and biodiversity (Heithaus *et al.* 2008). An understanding of the patterns of distribution and abundance and particularly the causes of that variation is critical to making informed assessments of the importance of anthropogenic activities to marine mammal populations.

This project will quantify changes in distribution, habitat use, abundance, survival and reproductive rates of three species of cetacean in the Alborán Sea (western Mediterranean) in relation to variation in the physical and biological environment and human activities, based on 18 years of data. The proposed study species, bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*) and long-finned pilot whale (*Globicephala melas*) occupy different oceanographic niches off southern Spain. The Alborán Sea is a highly productive and distinct ecosystem that plays an important role in the oceanography of the Mediterranean basin, and has experienced marked changes in climatic and oceanographic conditions.

We will attempt to relate features of a species' biology to environmental change, particularly climate change, focusing on distribution, abundance and estimated reproductive and survival rates. The two last ones provide information on the mechanisms that cause distribution and abundance to change. Knowledge of these relationships will help us to predict the future impacts of environmental change in a way that studies of distribution and abundance alone cannot.

This project will do this using a two decade dataset on bottlenose and common dolphin and pilot whale in the Alborán Sea and the time series of environmental changes generated by IMEDEA (Mediterranean Institute for Advanced Studies) and by NOAA OceanWatch. Once established, these relationships will be used in conjunction with the simulations of environmental change generated by IMEDEA to predict the effects of further change on these species over the next 40 years. The existing dataset available for these species covers 18 years. Data on human activities (e.g. fisheries, maritime

traffic) are also needed to explore how they interact with the environmental changes and with the species parameters changes.

OBJECTIVES

The primary goals of the research in this Grant are:

- (1) Quantify relationships between measures of cetacean population ecology, dynamics and status (distribution, habitat use, abundance, survival and reproductive rates) and variation in the marine environment (physical and biological oceanography, prey distribution and relative abundance) for the three focal species over the last 18 years in the Alborán Sea;
- (2) Test the hypothesis that environmental changes have had a greater effect on cetacean species that feed at lower trophic levels;
- (3) Explore the relative contribution of environmental variation and anthropogenic activities on cetacean population changes;
- (4) Quantify the effect of moving the Cabo de Gata TSS (the source of major noise pollution) on the distribution and abundance of the three focal species.
- (5) Predict responses of the three focal species to future environmental change under a range of scenarios;
- (6) Assess how well cetaceans can serve as indicators of environmental change in the marine environment and of “ocean health” generally.

APPROACH

To achieve the objectives of this project, the following steps will be taken:

- (1) existing data on the focal cetacean species (line transect sampling and photo-identification), human activities and environmental variables will be compiled and organized into appropriate strata at appropriate resolution and spatial and temporal scales;
- (2) some new data will be collected (summers 2010 and 2011) and, if sample sizes are large enough, they will be organized in the same way as the existing data to complete a 20 year dataset;
- (3) available information on changes in the marine environment over the last two decades (through collaboration with IEO and IMEDEA) will be organized to allow joint analysis with the cetacean and human activities data described above;
- (4) density surface modeling (spatial modeling) of line transect data will be used to relate changes in distribution, habitat use and abundance of the focal species to changes in the environment, including data on oceanography and human activities as explanatory covariates;
- (5) mark-recapture analysis of photo-identification data will be used to relate changes in survival and reproductive rate to changes in the environment again using oceanographic and human activities data as covariates;
- (6) models that are developed that relate changes in cetacean biological/ecological characteristics to changes in the environment will be combined with the output of environmental simulation models developed by IMEDEA to predict impacts up to 40 years into the future (through collaboration with IMEDEA).

WORK COMPLETED

Step 1.

Data on cetaceans - Existing survey data on the focal cetacean species from 1992 to 2010 and *in situ* data on human activities from 1998 to 2009 has been compiled and organized into effort and sightings files, both in the format for Distance sampling analysis (to estimate the detection function) and for spatial modeling.

Data on environmental variables - Environmental variables, namely sea surface temperature, chlorophyll concentration, sea surface height anomaly and primary productivity have been downloaded from NOAA Ocean Watch (http://las.pfeg.noaa.gov/oceanWatch/oceanwatch_safari.php), in all cases both monthly and 8-day averages for every month of every year. See also **step 3**.

Data on fisheries - Prey distribution and availability is probably the main factor that affects cetacean species distribution. Such kind of data is very difficult to obtain due to economic interests and the variability in the sources. After assessing the potential of different sources of fisheries data the best one found has been the Andalusian fisheries production information system (IDAPES) under the regional administrative agency “Consejería de Agricultura y Pesca “ (Junta de Andalucía”). Thanks to the free public access to the fish catches data download services time series of fish catches for the main fishing ports in Spanish coast of Alboran Sea have been collected from 2000 to the present (data from previous years since 1992 had been collected previously). The dataset contains monthly catches data in Kilograms for each of the 11 main fishing ports of Andalucía including more than 150 fish, shellfish and cephalopods commercial species. The monthly datasets have been downloaded one by one for each fishing port and compiled in order to get the total historical time series of fisheries catches data per fishing port. This process has been very tedious and time consuming because of the download speed and the huge amount of data (approximately 75,000 values).

The catches data for the main prey species for the target cetacean species is being extracted from the global dataset in order to generate graphics on the fish catches evolution for each prey species.

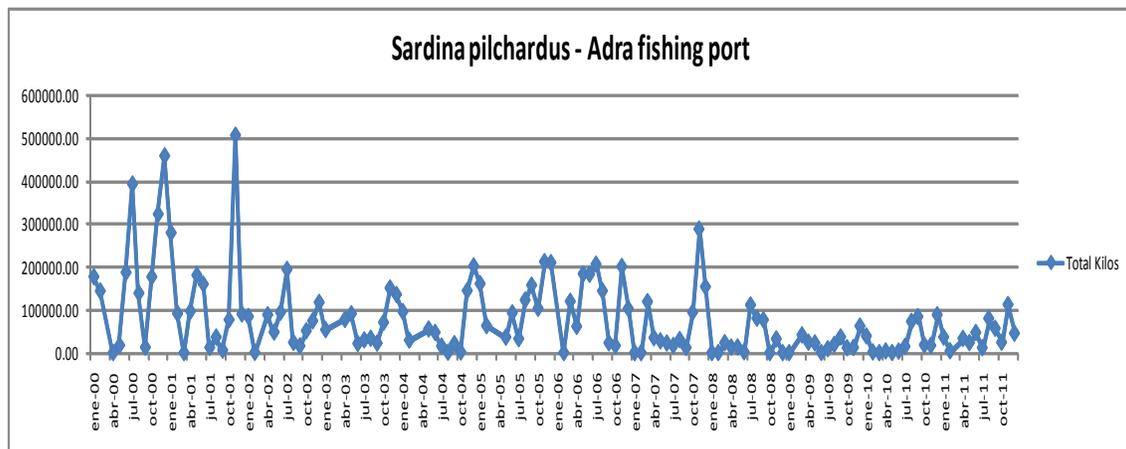


Figure 1. Time series catches for sardine (*Sardina pilchardus*) in Adra fishing port 2000-2011.

The main trouble to use this valuable data set in the spatial modeling analysis is how to transform the fish catches values at a spatial scale, i.e. how to identify the main fishing areas, as not all the catches registered in one fishing port comes from the local fleet, and also for some pelagic species not all years the fishing areas are exactly the same. To achieve this challenge as best as possible, contacts with the Spanish Secretary General of Fisheries have been undertaken to get routes patterns of the main Spanish fleets in Alboran Sea coming from the black boxes installed by law in all fishing boats. The permit to get this data has been already obtained but we are still waiting to receive such data. Additionally, contacts with the Spanish Oceanographic Institute have been undertaken too to try to get georeferenced specific information on the main fishing areas. We have had access to some of them but still are waiting for an official reply from this Spanish institute. If we finally get the authorization it will allow us to get more actual and better defined fishing areas to try to assign catches data.



Figure 2. Fishing areas extracted from the Junta de Andalucía fisheries data set.

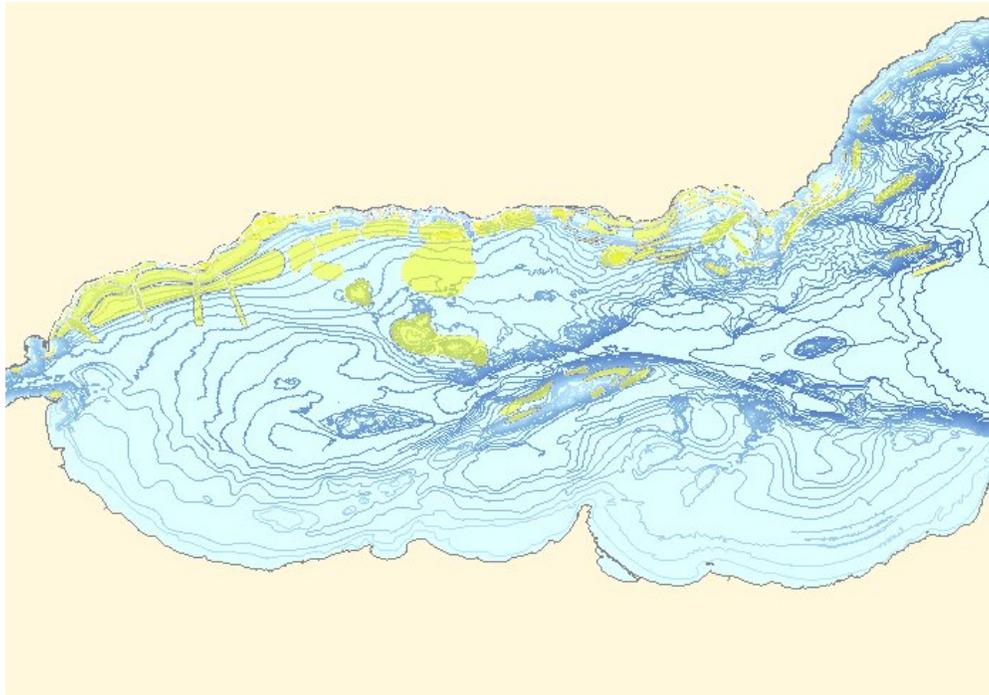


Figure 3. Fishing areas extracted from the IEO data Viewer web service.

Step 2.

Data was collected through line-transect surveys at sea during summers of 2010 and 2011 (under GRANT N00014-09-1-0536), and added to the existing data, yielding a 20 year time series of data for the three focal cetacean species in the Alborán Sea. These surveys in 2010 and 2011 continued using the protocols developed over previous years (Cañadas & Hammond 2006; 2008). Photo-identification data for estimating survival and reproductive rates were collected during the same surveys and similarly added to existing data to create a 20 year dataset.

Step 3.

A video-conference with Dr. Tintoré (IMEDEA) was held at the beginning of 2012 to discuss our collaboration in the framework of this project. He put us in contact with Dr. Navarro, from the Institute for Marine Sciences of Andalucía (ICMAN), who have the oceanographic data in the Alboran Sea in collaboration with IMEDEA.

Communication has been already established and a common interest in collaboration, with Dr. Navarro. Figure 4 (Navarro et al 2011) shows (a) Climatological distribution of CHL (in mg/m³) over the period 1998 to 2009. The black line indicates the 1000 m isobath. WAG is the West Alboran Gyre. (b) Climatological pattern of ADT (in cm) and associated geostrophic currents during the same period. Spatial patterns of (c) CHL#1, (d) ADT#1, (e) CHL#2 and (f) ADT#2 for the first two SVD modes. (g) Time series of expansion coefficients (CHL green line and ADT black line) of the first SVD mode. (h) Time series of expansion coefficients (CHL green line and ADT black line) of the second SVD and SLP (blue line, in mb). (i) Heterogeneous map between the time series of the expansion coefficient of ADT (SVD # 2) and the CHL field over the Alborán Sea. Time series are smoothed by a three-bin running boxcar averaging to dampen high frequency.

This is the data that will be provided by Dr. Navarro for this project.

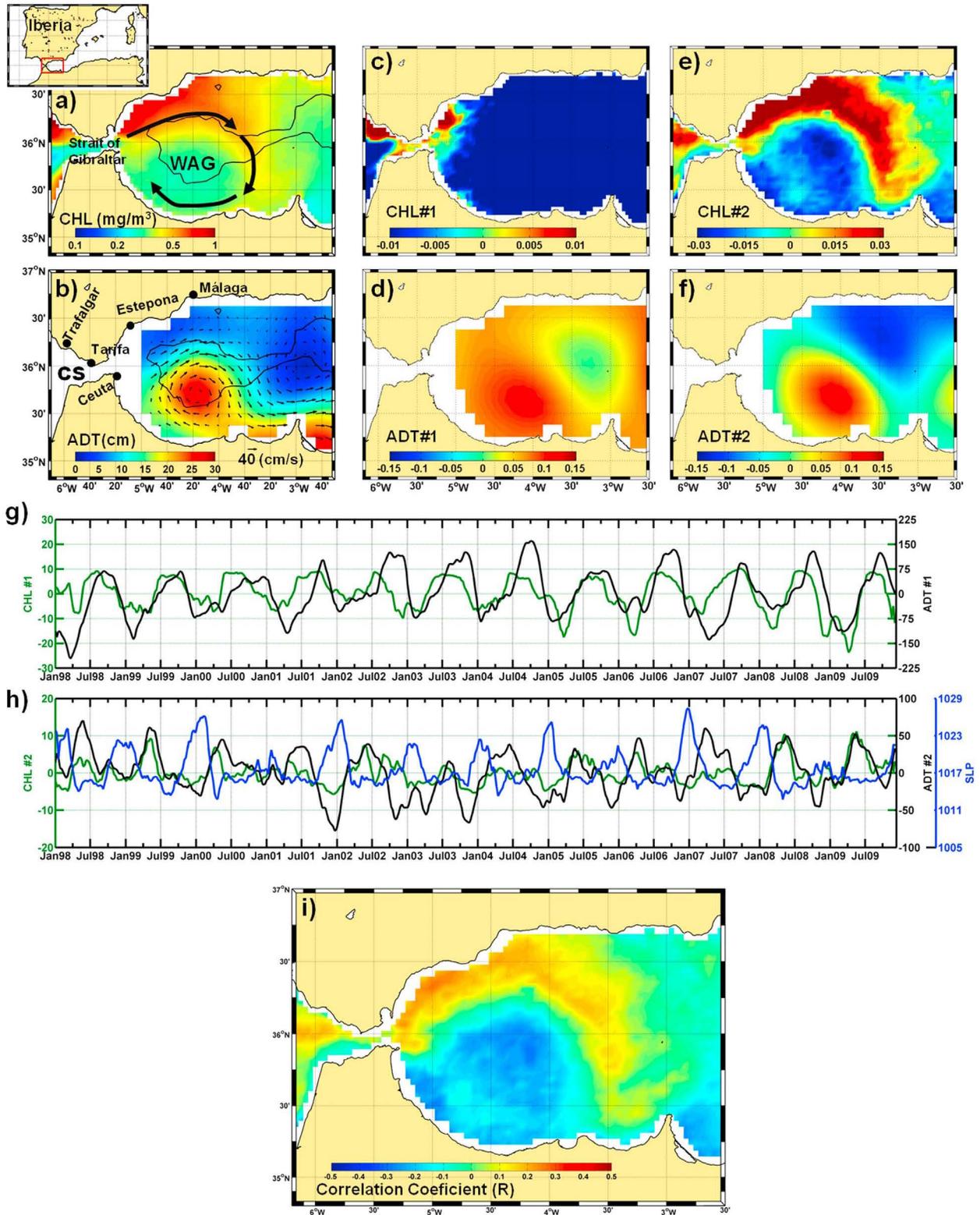


Figure 4. Oceanographic data for the Alboran Sea.

Step 5.

Bottlenose dolphins - The photo-identification catalogue of bottlenose dolphins for the years 1992 to 2010 has been finished in a database in Access 2010, with a matching process including more than 11,000 photographs resulting in 823 individuals in this catalogue with 2,529 images included in it. The cumulative plot of individuals identified is shown in Figure 5. The asymptote has not yet been reached, indicating that not all marked animals in the population have been yet identified.

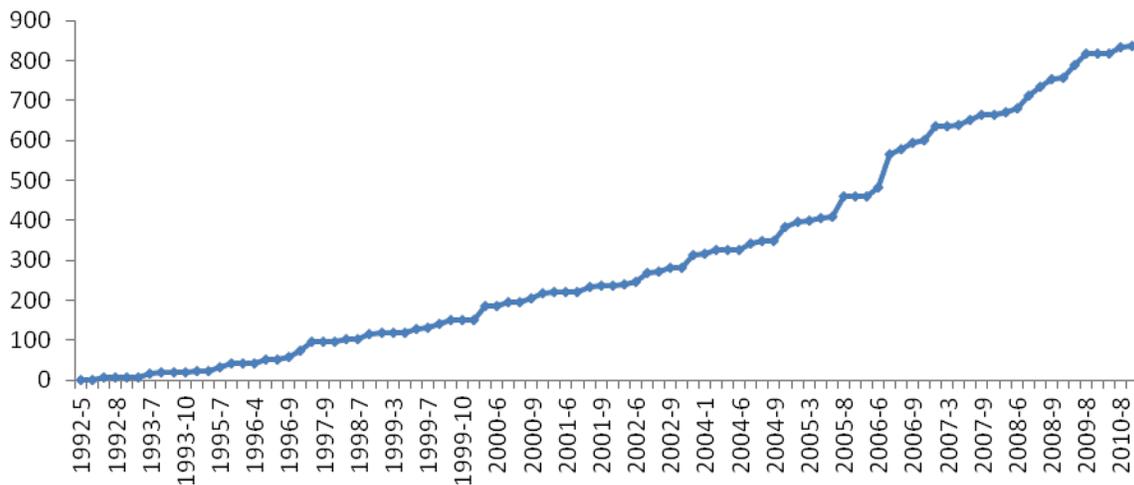


Figure 5. Cumulative plot of identified animals. The Y axis shows the number of animals, and the X axis shows the months of survey from 1992 to 2010.

Most of the animals have been seen only once, but 291 individuals have been identified in more than one month and there have been animals identified in up to 15 different months over these years. 272 individuals have been identified in more than one year and some up to in 9 different years. This preliminary summary includes all images (all quality and distinctiveness grades), and further filters will be done to discard poor quality images and fins from the analyses.

Annex 1 shows this preliminary catalogue, pending of further revision and filtering.

Long-finned pilot whales - In view of the results obtained over the last years, mainly through satellite tagging of pilot whales and the study of their spatial distribution with predictive models, and data from other sources with which a collaboration has been established, it has been decided to create a joint coordinated catalogue for long-finned pilot whales including our study area (Alboran Sea) and the adjacent areas (Strait of Gibraltar to the West provided by CIRCE, and Murcia to the North-East provided by ANSE, two collaborating ngos), but keeping the three sub-catalogues in an independent way also.

In Annex 2 a summary of the individuals identified up to now in the three sub-catalogues can be seen. These three sub-catalogues, together with the results from spatial prediction will help running mark-recapture models through multi-site, multi-state or multi-event models, which will help estimating

survival rates for our study area every year, taking into account the rest of survival rates in the region, and especially, will help to calibrate the models due to the morbillivirus epizootic that affected the population between 2006 and 2008.

The amount of pictures to analyze is huge, but good progress is done in the three sub-catalogues. Up to now, more than 200,000 photographs have been analyzed in total. In total, 1,415 individuals have been identified from 1992 to 2007, including 510 in the Strait of Gibraltar, 699 in the Alboran Sea (our study area) and 206 in Murcia. Initial comparison of the sub-catalogues have shown no recaptures between the Strait of Gibraltar and the other two areas, but 22 animals have been found both in the Alboran Sea and Murcia.

The catalogues will be finished by the beginning of 2013, when the full analysis will start.

Common dolphins - A total of 17,836 photographs are being processed. Of these, 9,169 images of fins have been obtained from 1991 to 2011. The distribution of fins processed by year up to now are:

Year	Fins obtained
1991	12
1992	633
1993	
1994	
1995	
1996	248
1997	
1998	4
1999	1,748
2000	905
2001	
2002	
2003	1,199
2004	1,874
2005	1,386
2006	
2007	
2008	
2009	1,090
2010	28
2011	42
TOTAL	9,169

The processing of the images will be finished before the end of 2012, and then the building of the catalogue will start in order to do the proper analysis.

RESULTS

During this fiscal year all the work has concentrated in the collation, processing and organization of data. Analysis will be conducted during the next fiscal year and results will be reported in the next report.

Given that the project was scheduled to start in April 2011, but it actually started in September 2011 due to delays in the review and decision making process by ONR, a request for at least 6 months of no-funds extension is foreseen, at the end of the next fiscal year, in order to finish all the analysis and reports.

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