Beaked Whales and Pilot Whales in the Alboran Sea (SW Mediterranean): Research Towards Improved Science-Based Mitigation Strategies for Risks from Man-Made Sound

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LONG-TERM GOALS

There has been growing recognition that atypical mass strandings of beaked whales may coincide with naval exercises that use mid-frequency sonar, but the causal chain of events from sound exposure to stranding has not been elucidated. Even less is known about potential risks for other species of odontocete or for other signals. The primary genus proposed for study here, the pilot whale, has been documented to mass strand coincident with a sonar exercise, but the evidence linking strandings of delphinid odontocetes with sonar is weaker than that for ziphiid beaked whales. Preliminary studies indicate that the responses of delphinids to sonar and predators may differ from responses of beaked whales to the same stimuli, suggesting differential risk. The proposed research is part of a collaborative research program that will compare responses of beaked whales vs other odontocetes to playbacks of mid-frequency sonar sounds vs other sounds. The primary applied goal of the proposed research is to gain a better understanding of risks presented by sonar and other sounds to these species, to define safe exposures, and to improve science-based mitigation strategies.

OBJECTIVES

The primary goals of the research proposed here are:

1. To assist with a cruise to tag, observe baseline behavior, and conduct playback experiments with beaked whales and blackfish in the Mediterranean during 2009. This includes, in terms of my participation:
    a. Organizing a meeting with Spanish authorities.
    b. Organizing a scientific meeting at a Mediterranean level.
    c. Participation in MED09 on board the Alliance.

2. To contribute to further work tagging, observing baseline behavior, and conducting playback experiments with pilot whales during the summers of 2010 and 2011. This includes achieving the following objectives:

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a. To estimate the proportion of time the animals spend underwater, and therefore estimate g(0) to be able to obtain an absolute estimate of abundance for the population.
b. To understand their feeding behavior.
c. To understand their acoustic behavior, both under "normal" circumstances (e.g. when resting, feeding, travelling) and how they behave and react under different circumstances, such as presence of other species, different sources of potential stress (e.g. playbacks, maritime traffic).
d. To gain insight into their social structure and dynamics, both under "normal" circumstances and under different circumstances, such as presence of other species, different sources of potential stress (e.g. playbacks, maritime traffic).

APPROACH

Goal 1 (2009) was addressed through the organization of meetings (objectives a and b) and participation of myself and a group of trained Spanish researchers onboard the *Alliance* during the MED09 survey (see report for 2009).

Goal 2 (2010-2011) was addressed in 2010 through ship-based surveys in the Alboran sea on board the Alnitak research vessel *Toftevaag*, in search of long-finned pilot whales, beaked whales, and other species of cetaceans.

WORK COMPLETED

Ship-based surveys in 2010 onboard the research vessel *Toftevaag*.
Alnitak provided the research ship Toftevaag for the survey in 2010, and Ana Cañadas participated as PI for the visual data collection in the field trip.

As PI of this project Ana Cañadas was in charge of the protocol for visual data collection during the survey mode of this cruise. I was also in charge of the validation and organization of the visual data during the survey, on a daily basis, in preparation for its further analysis. This included cleaning the data (sightings, effort and environmental) checking for errors, filling in missing but recoverable fields, assigning effort status to each sighting, and compiling and organizing all the data in an excel spreadsheet in a format more easily usable for analysis.

Tagging of pilot whales.
The cruise was very successful, with 16 pilot whales tagged, all with multiple animals tagged within a social group. We also conducted focal follows on two *Ziphius cavirostris* in sea conditions suitable for tagging, but were not able to tag this difficult species.

Preliminary analysis of Sirena08 and Med09 survey data in the Alboran Sea.
The survey data from Sirena08 and Med09 has been organized in the appropriate format to be analyzed to estimate abundance of several species and to provide information on distribution patterns through spatial modeling. Data has been analyzed first with software DISTANCE to estimate the probability of detection in order to correct the survey data. In a second step, the corrected data has been analyzed with spatial modeling using software R, providing maps of predicted density and habitat patterns.

To increase sample size, Alnitak´s data from 2008 and 2009 has also been added to the dataset for the spatial modeling. These data were collected thanks to the funding provided by **Fundación**

Biodiversidad from Spain. The detection functions created for each species include also all Alnitak data.

RESULTS

Ship-based surveys in 2010 onboard the research vessel *Toftevaag*.
A total of 444 km were surveyed on effort between 18th August and 6th September 2010, producing 37 sightings of several species: short-beaked common dolphins, *Delphinus delphis* (n=3); long-finned pilot whale, *Globicephala melas* (n=7); striped dolphin, *Stenella coeruleoalba* (n=7); common bottlenose dolphin, *Tursiops truncatus* (n=4): Cuvier´s beaked whale, *Ziphus cavirostris* (n=4) and unidentified dolphins (n=2). Additionally, 6 more sightings were made while off effort or as secondary sightings while working on a focal follow: common dolphins (n=1), pilot whales (n=2), bottlenose dolphins (n=2) and Cuvier´s beaked whales (n=1). Figure 1 shows the tracks and sightings during this period.

Photo-identification work was carried out during the sightings of pilot whales and Cuvier´s beaked whales to contribute to the existing catalogues.

The analysis of all this data plus the data of the 2011 survey will be carried out at the end of 2011, after the field trip.

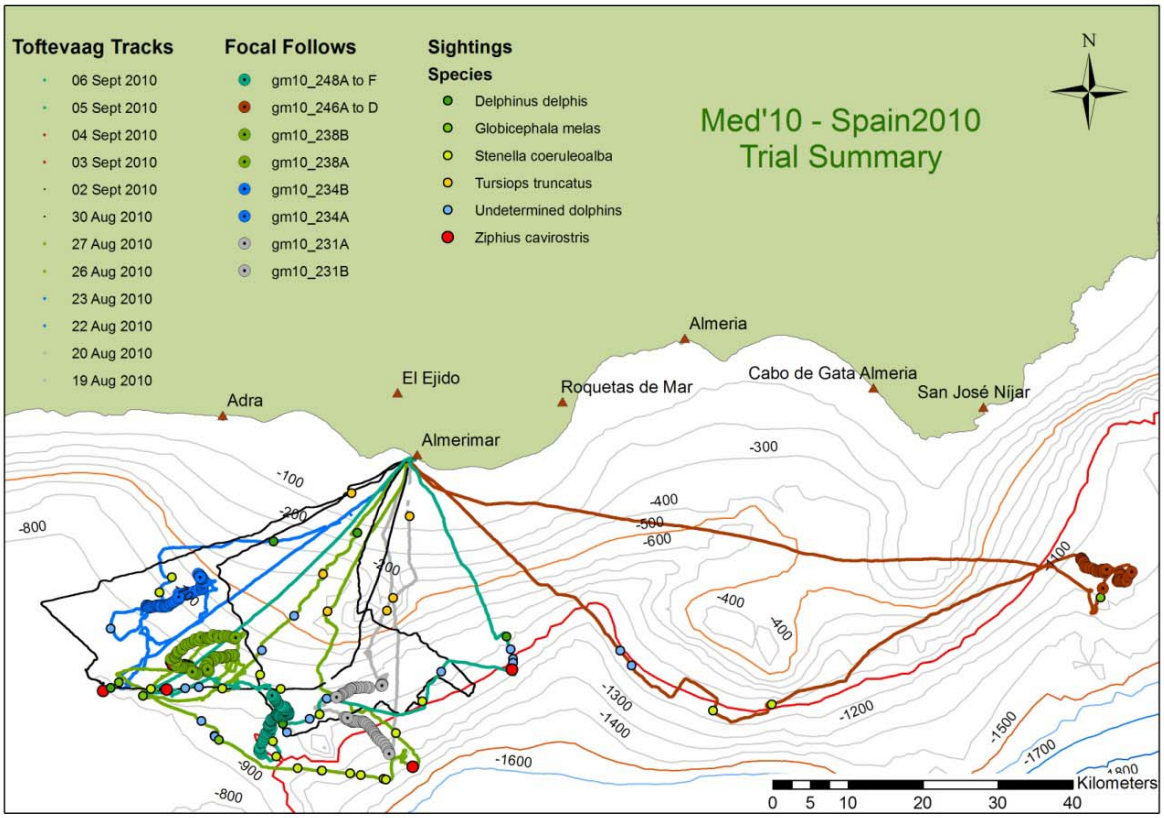


Figure 1. Tracks and sightings on effort during the 2010 field work

Photo-identification during the 2010 cruise.

Long-finned pilot whales

Long-finned pilot whales were encountered and photographed on 5 different occasions during Med10. Photographs of the dorsal fin and other distinguishing features (for example, pigmentation patterns and scars) of individual pilot whales were usually taken by 5 or 6 different photographers (Table 1 in Annex I), both from RV Toftevaag and from the tag boat. A total of 7773 photos of long-finned pilot whales were taken during the cruise. These will be analyzed and recognizable individuals entered into a catalogue. Recognizable individuals will be cross-referenced with an existing catalogue of pilot whales to determine whether they have previously been photographed in the Alborán Sea.

Cuvier's beaked whales

Cuvier's beaked whales were encountered and photographed on 5 different occasions during Med10. Photographs of the dorsal fin, body coloration and scars were taken (Table 1 in Annex I) and will be analyzed. Good quality photographs will be cross-referenced with, and where necessary added to, an existing catalogue of recognizable individuals from the Alborán Sea. A total of 731 photographs were taken of Cuvier's beaked whales.

Deployment of D-Tags on long-finned pilot whales in the Alboran Sea.

Table 2 in Annex I lists the pilot whales tagged during the field effort. The time indicates the duration of the focal follow. Individual whales were tagged for shorter periods of time within the follow (see report from project N000140910528).

Preliminary analysis of Sirena08 and Med09 survey data in the Alboran Sea.

Detection functions:

A detection function to estimate the probability of detection was fitted to Alnitak's data from 1992 to 2009 and Alliance data from 2008 and 2009. Only sightings realized when surveying at speeds of 11kts or less were considered to avoid bias created by data collected at very different speeds. Covariates considered for inclusion in the detection functions for the different species were of two types: effort related covariates (ship, observation platform height, position of observer, speed of vessel, sea state, swell height, sightability conditions) and animals related (cue, group size, logarithm of group sizes). Table 3 in Annex I shows a summary of the best models selected for the detection functions for all species.

Spatial modeling:

The methods used were those described in Cañadas and Hammond (2006; 2008). Table 4 in Annex I shows the covariates retained by each step of the model and the smoothed functions. Table 5 in Annex I shows the final predicted estimate of abundance and density for each species for the Alboran Sea and their measures of uncertainty. In summary: density of 1.094 for common dolphin, 0.580 for striped dolphin, 0.180 for bottlenose dolphin, 0.028 for Risso's dolphin, 0.118 for long-finned pilot whales and 0.029 for beaked whales.

These estimates are uncorrected for availability and perception bias, the two components of the g(0), or probability of detecting the animals at distance zero from the transect line. If unknown, it is assumed g(0)=1, which invariably leads to an underestimation of abundance of unknown magnitude as it is known that some animals on the transect line are missed, either because they are not available to the observer (e.g. diving) - availability bias-, or because being available they are missed by the observer - perception bias-.

There are methods to estimate the g(0), either during the surveys (using double platform configuration to do a mark-recapture analysis) or, less desirable, during analysis when double platform observation was not realized. Double platform was not used during the present surveys. In the cases of common, striped and bottlenose dolphins and for pilot whales, there are estimates of g(0) for surveys from large vessels in the NE Atlantic (e.g. CODA, SCANS-II) which in these four species is around 0.5 to 0.55. A correction made with this g(0) would yield an abundance estimate more or less double of what is presented here. Nevertheless, even if it could be assumed that sightings from the Alliance could have a similar g(0) than from those surveys in the NE Atlantic due to similarities in the vessel size and height and the use of BigEyes binoculars in both, many of the sightings used in these analysis were made from the much smaller Alnitak´s vessels, where we cannot assume a similar g(0). Therefore, a correction cannot be made in this way.

Another way of minimizing the bias produced by animals missed on the trackline is by estimating the availability bias from information on diving times, speed of the vessel and height of the observation platform. This calculation has been made for Cuvier´s beaked whales based on data from a single D-Tag deployed on a Cuvier´s beaked whale in the Alboran Sea during Sirena08 (Oedekoven 2009), yielding a g(0) of 0.306, in agreement with other g(0) values estimated for beaked whales elsewhere (Barlow et al. 2006). Correcting the estimated abundance of 1,519 by this g(0) yields an estimate of 4,964 (density of 0.096 animals per km^2, much higher than that reported in other places of the world; Barlow et al. 2006). Nevertheless, I would advise taking this value with caution as it is based on one single D-Tag deployed. However, it is beyond doubt that the Alboran Sea presents, at least, one of the highest densities of beaked whales in the world (if not the highest). But more work is needed to confirm this, i.e. through more systematic surveys in the whole area and with more information on diving times and behavior of this population.

In the case of long-finned pilot whales, this correction will be possible to make thanks to all the information from the several D-tags deployed within this project on these animals. This estimates will be done after the data from the 2011 field work is also available. For other species of dolphins which are not deep divers, an estimate of availability bias will be done for all ships providing data for this project at the end of the 2011 field work.

Data from the field work from 2010 and 2011 will be added to these datasets to improve the abundance estimates and, hopefully, extend the prediction area a bit more to the East.

Figure 2 in Annex I shows the total survey effort realized in 2008 and 2009 with Alnitak's vessels and the Alliance research vessel. Figures 3 to 8 in Annex I show the sightings of the different species during 2008 and 2009 from all vessels: short-beaked common dolphins, Risso's dolphins, long-finned pilot whales, striped dolphins, common bottlenose dolphins and beaked whales respectively.

Figures 9 to 14 in Annex I show the **preliminary** predictions of abundance of the different species: short-beaked common dolphins, Risso's dolphins, long-finned pilot whales, striped dolphins, common bottlenose dolphins and beaked whales respectively.
It is important to highlight here that effort in the area during 2008 and 2009 was very heterogeneous and there was a big area in the center of the western half of the Alboran Sea which was not surveyed at all. Therefore, all predictions produced by the models into this area should be taken with extreme caution and be considered as an exploratory exercise. Therefore, these results should be considered as a very useful preliminary exploration of the Alboran Sea, which should be confirmed more soundly after

proper systematic surveys are realized in the area, ensuring equal coverage probability or at least a more homogeneous coverage of the area.

IMPACT/APPLICATIONS

The main impact of this phase (2010) of the project is:

First abundance estimate and habitat modeling of Cuvier´s beaked in the Alboran Sea.
An abundance estimate of beaked whales has been obtained for the Alboran Sea, an area which has proven to be a hot spot for this species. This is of great importance to (a) put potential threats into context (impact of a given amount of deaths -mass strandings, entanglements, etc- on the population) and (b) highlight the most important areas for this species, susceptible for protection for the conservation of the species.

Valuable information on long-finned pilot whales diving and foraging behavior.
This cruise developed and tested methods to measure social behavior and communication in pilot whales, and collected significant amounts of baseline data for pilot whales, including extremely interesting data on synchronized behavior.

RELATED PROJECTS

INDEMARES (LIFE07NAT/E/00732). This European Commission LIFE+ Nature project deals with the identification of marine areas of special interest for the conservation of biodiversity. In the context of this project, coordinated by *Fundación Biodiversidad* and with the partnership of the Environment Ministry General secretariat for the Sea (SGM), the National Scientific Council (CSIC) the Spanish Oceanographic Institute (IEO) and the NGOs SEO Birdlife, WWF Adena, OCEANA, SECAC, CEMMA and ALNITAK, the latter coordinates action A14 (MITIGA LAB) in the Alboran Sea dealing with the development of technological measures for mitigating risk for cetacean populations deriving from the sectors of transport, energy, tourism, fishing and defense. With regards to the defense sector, MITIGA LAB creates a bridge between this project and the Spanish administration as well as other key stakeholders.

GTCAT (Alborán, un caso práctico para la aplicación de la Estrategia Marina Europea).
This project has been funded by Fundación Biodiversidad in Spain, focusing on the creation of a platform for the promotion and coordination of international and intersectorial cooperation for the Working Group on Cetaceans, sea turtles and seabirds of the "Initiative for the sustainable development of the Alboran Sea". Through this platform research, management, capacity building and outreach actions have been developed actively prompting international cooperation. This project was envisaged as a pilot experience for the development of innovative and exportable tools to face the logistic and economic challenge of the conservation of the marine biodiversity. As with the previous project, GTCAT creates a bridge between this project and the Spanish administration as well as other key stakeholders. Data collected in both projects are complementary to give a wider context to such data and the results of their analysis.

ONR: Tagging and Playback Studies to Toothed Whales. Grant Number: N00014-09-1-0528 to Peter Tyack.

REFERENCES

Barlow, J., Ferguson, M.C., Perrin, W.F., Ballance, L., Gerrodette, T., Joyce, G., Macleod, C.D., Mullin, K., Palka, D.L. and Waring, G. 2005/06. Abundance and densities of beaked and bottlenose whales (family Ziphiidae). J. Cetacean Res. Manage. 7(3): 263-270

Cañadas, A. and Hammond, P. 2006. Model-based abundance estimate of bottlenose dolphins off Southern Spain: implications for conservation and management. Journal of Cetacean Research and Management, 8(1): 13-27.

Cañadas, A. and Hammond, P.S. 2008. Abundance and habitat preferences of the short-beaked common dolphin (*Delphinus delphis*) in the South-western Mediterranean: implications for conservation. Endangered Species Research 4: 309-331.

Oedekoven, C., Cañadas, A. and Hammond, P.S. 2009. Estimating beaked whale abundances in the northern Alboran Sea using spatial habitat models. Poster presented at the 18th Biennial Conference on the Biology of Marine Mammals. Society for Marine Mamalogy, Quebec, Canada.

Annex I

Table 1: Photographers, cameras used and number of photographs taken during pilot whale and Cuvier's beaked whale encounters.

Photographer	Camera used	Number of photographs taken	
		Long-finned pilot whales	Cuvier's beaked whales
Ana Cañadas	Canon EOS 30D	915	41
Rebecca Jewell	Canon EOS 40D	2429	298
Eletta Revelli	Canon EOS 30D	808	197
Leigh Hickmott	Nikon D300	1182	114
Frants Jensen	Canon EOS 300D	537	42
Nicholas MacFarlane	Nikon D300s	1902	39
TOTAL		**7773**	**731**

Table 2. Pilot whales tagged, and beaked whale tagging attempts for Med10 cruise in the Alboran Sea.

Date	Species	Animal ID*	Group size	Time (start-end)
19-Aug-10	*Globicephala melas*	A	36	local 10.10-19.40
19-Aug-10	*Globicephala melas*	B	36	local 10.10-19.40
22-Aug-10	*Globicephala melas*	A	49	local 12.31-21.00
22-Aug-10	*Globicephala melas*	B	49	local 12.31-21.00
26-Aug-10	*Globicephala melas*	A	21	local 12.10-21.00
26-Aug-10	*Globicephala melas*	B	21	local 12.10-21.00
02-sept-10	*Ziphius cavirostris*	Unknown	4	local 14.43-17.22
03-sept-10	*Globicephala melas*	A	11	local 15.40-20.30
03-sept-10	*Globicephala melas*	B	11	local 15.40-20.30
03-sept-10	*Globicephala melas*	C	11	local 15.40-20.30
03-sept-10	*Globicephala melas*	D	11	local 15.40-20.30
05-sept-10	*Ziphius cavirostris*	Unknown	3	local 10.10-11.00
05-sept-10	*Globicephala melas*	A	14	local 14.25-20.30
05-sept-10	*Globicephala melas*	B	14	local 14.25-20.30
05-sept-10	*Globicephala melas*	C	14	local 14.25-20.30
05-sept-10	*Globicephala melas*	D	14	local 14.25-20.30
05-sept-10	*Globicephala melas*	E	14	local 14.25-20.30
05-sept-10	*Globicephala melas*	F	14	local 14.25-20.30

Table 3. Best models selected for the detection functions for all species

Species	Covariates	Average probability of detection (CV)	Truncation distance (m)	Number of observations within truncation distance
Delphinus delphis	Position observer, cue, log of cluster size, sea state, ship	0.22 (0.028)	3,000	1,214
Stenella coeruleoalba	Platform height, cue, cluster size, sea state	0.19 (0.025)	3,500	1,705
Tursiops truncatus	Position observer, cue, log of cluster size, sea state	0.30 (0.047)	2,000	438
Grampus griseus	Platform height, cue, log of cluster size	0.27 (0.091)	3,000	157
Globicephala melas	Platform height, sea state	0.19 (0.049)	4,000	605
Physeter macrocephalus	Platform height	0.32 (0.148)	7,000	53
Beaked whales	Position observer, log of cluster size, sea state	0.20 (0.088)	7,000	162

Table 4. Best models selected for the spatial modeling for all species. Covariates into brackets mean an interaction

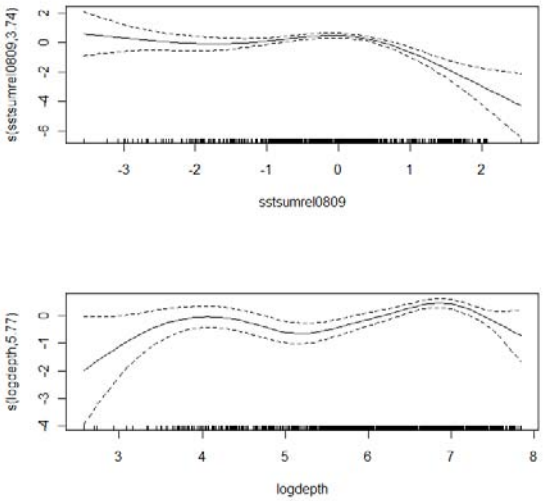
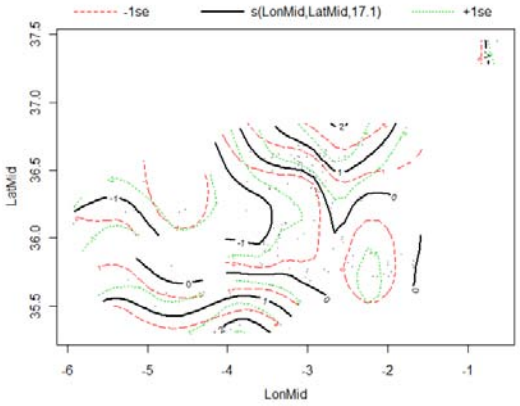
Species	Model	Covariates (degrees of freedom)	Smoothed functions
Delphinus delphis	Groups	- Sst (3.74) - Logdepth (5.77)	
	Group sizes	- (Latitude, Longitude) (4.85) - Distance from coast (1)	

Table 4 (cont.). Best models selected for the spatial modeling for all species. Covariates into brackets mean an interaction

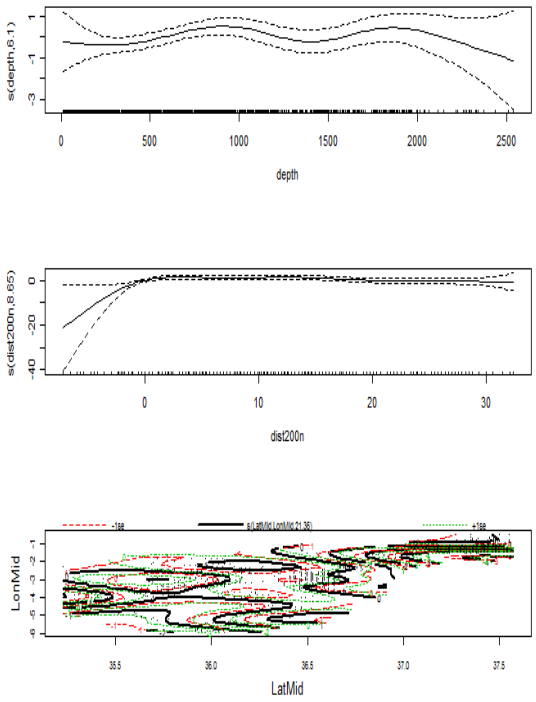
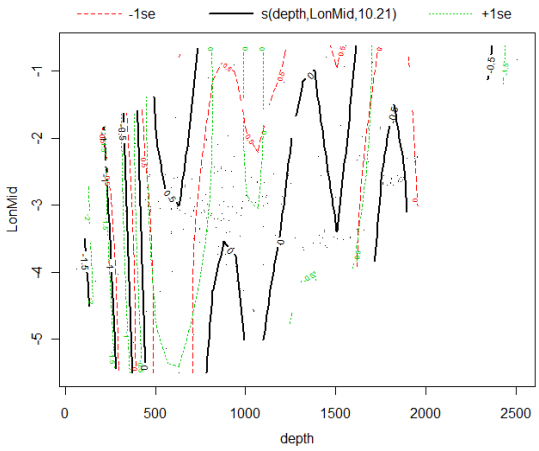
Species	Model	Covariates (degrees of freedom)	Smoothed functions
Stenella coeruleoalba	Groups	- Depth (6.10) - Distance from 200m depth contour (8.65) - (Latitude, Longitude) (21.36)	
	Group sizes	- (Depth, Longitude) (10.21)	

Table 4 (cont.). Best models selected for the spatial modeling for all species. Covariates into brackets mean an interaction

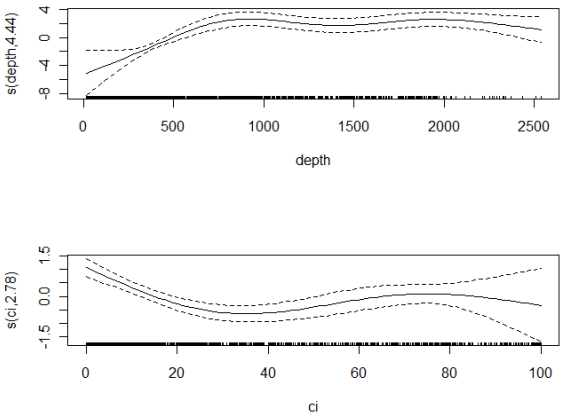
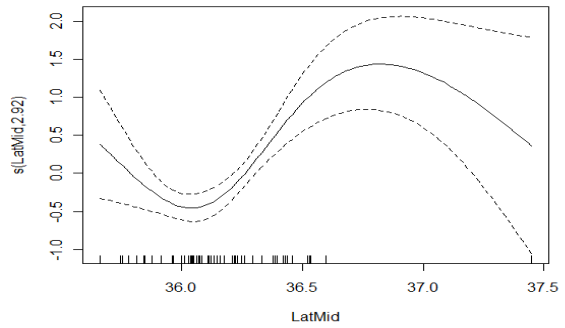
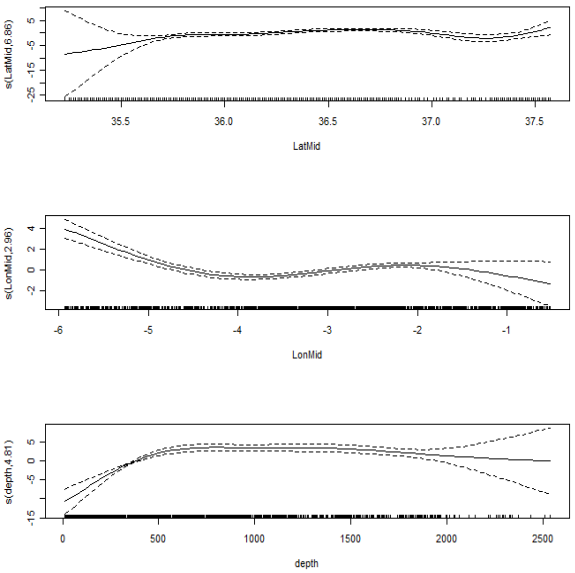
Species	Model	Covariates (degrees of freedom)	Smoothed functions
Grampus griseus	Groups	- Depth (4.44) - Contour index (2.78)	
	Group sizes	- Latitude (2.92)	
Globicephala melas	Groups	- Latitude (6.86) - Longitude (2.96) - Depth (4.81)	

Table 4 (cont.). Best models selected for the spatial modeling for all species. Covariates into brackets mean an interaction

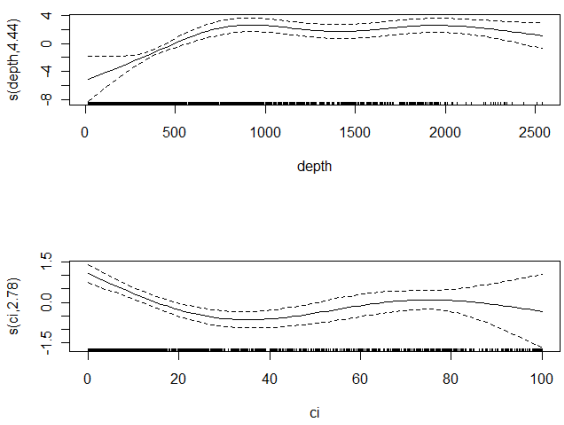
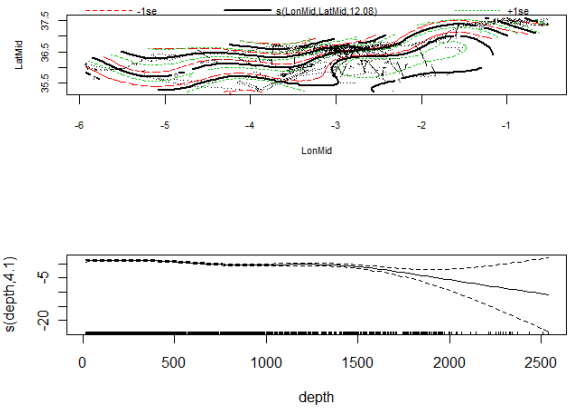
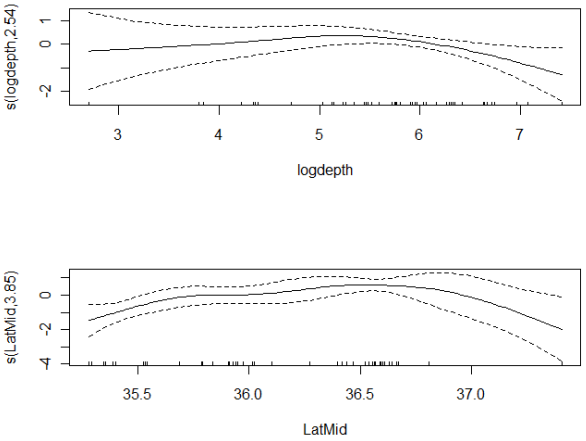
Species	Model	Covariates (degrees of freedom)	Smoothed functions
Beaked whales	Animals	- Depth (4.44) - Contour index (2.78)	
Tursiops truncatus	Groups	- (Latitude, Longitude) (12.08) - Depth (4.10)	
	Group sizes	- Latitude (3.85) - Log of depth (2.54)	

Table 5. Uncorrected estimates (for availability and perception bias) of abundance from spatial modeling and measures of uncertainty

Species	Density (animals / km^2)	Uncorrected estimate of abundance	Coefficient of Variation	95% Confidence Interval
Delphinus delphis	1.094	56,739	0.276	38,898 - 100,613
Stenella coeruleoalba	0.580	30,068	0.176	28,228 - 53,680
Tursiops truncatus	0.180	9,356	0.436	5,412 - 19,488
Grampus griseus	0.028	1,451	0.235	754 - 1,901
Globicephala melas	0.118	6,144	0.184	4,071 - 7,841
Beaked whales	0.029	1,519	0.207	965 - 1,932

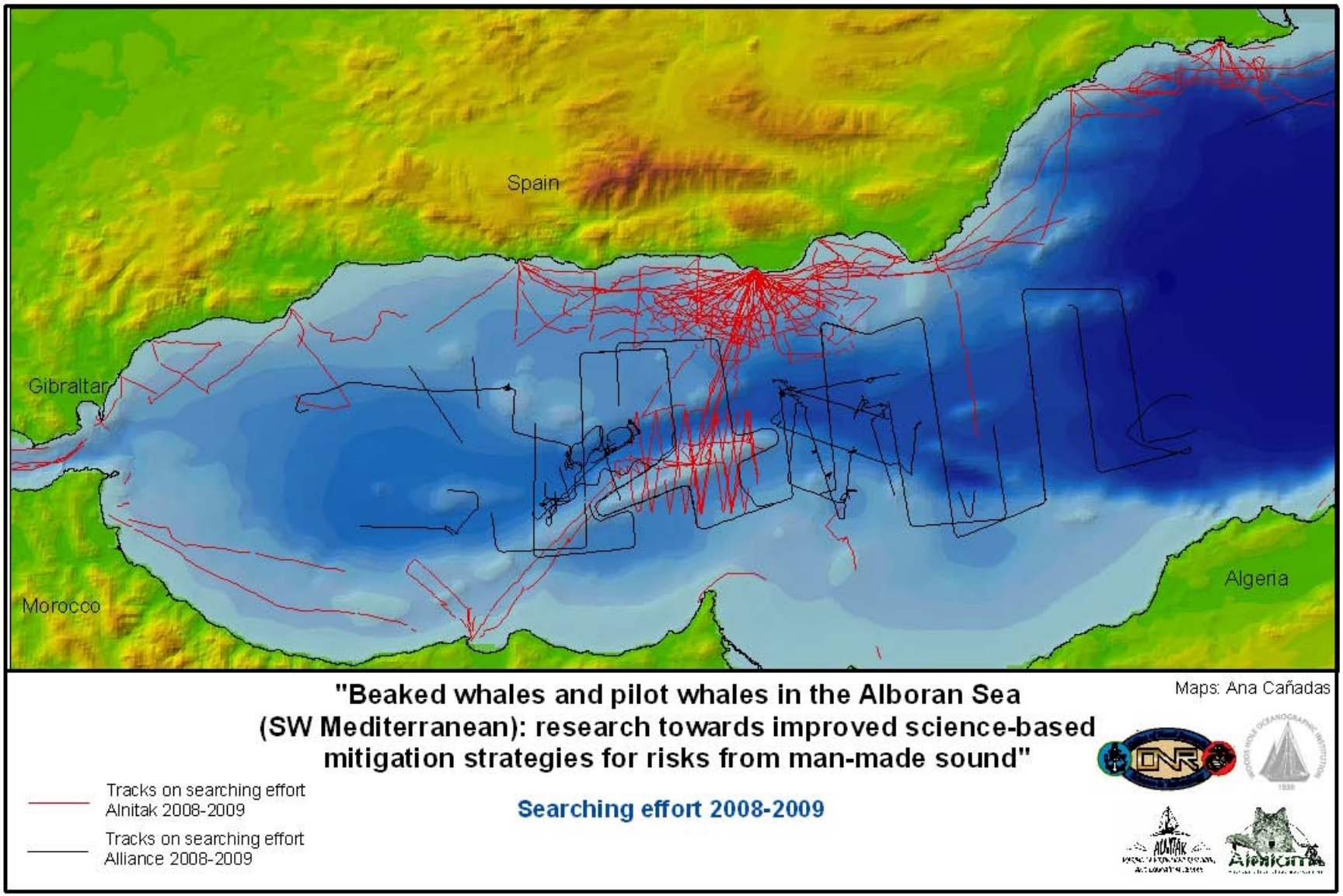


Figure 2. Searching effort in 2008 and 2009 by Alnitak's ships and the Alliance.

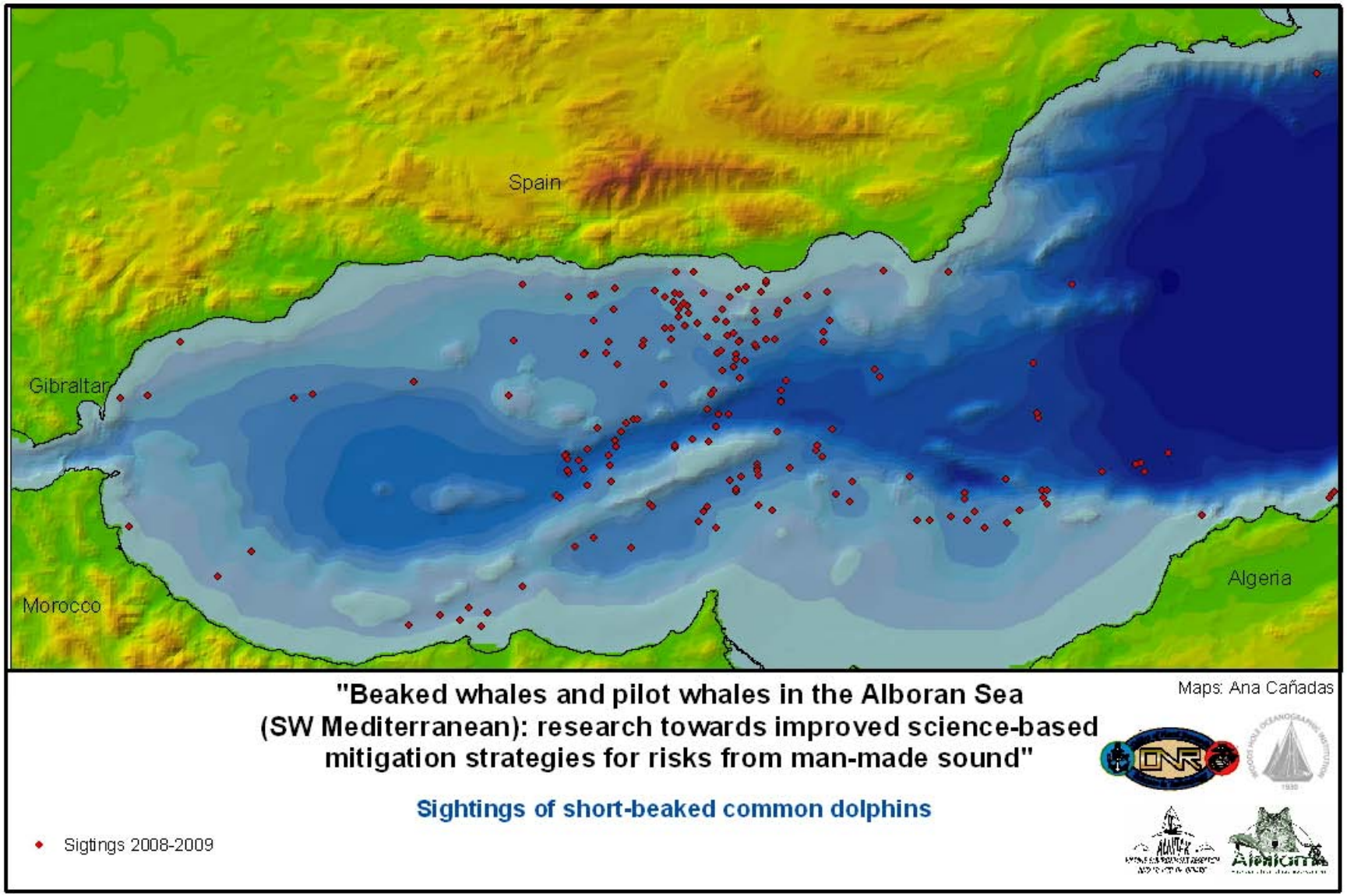


Figure 3. Sightings of short-beaked common dolphins in 2008 and 2009 by Alnitak's ships and the Alliance.

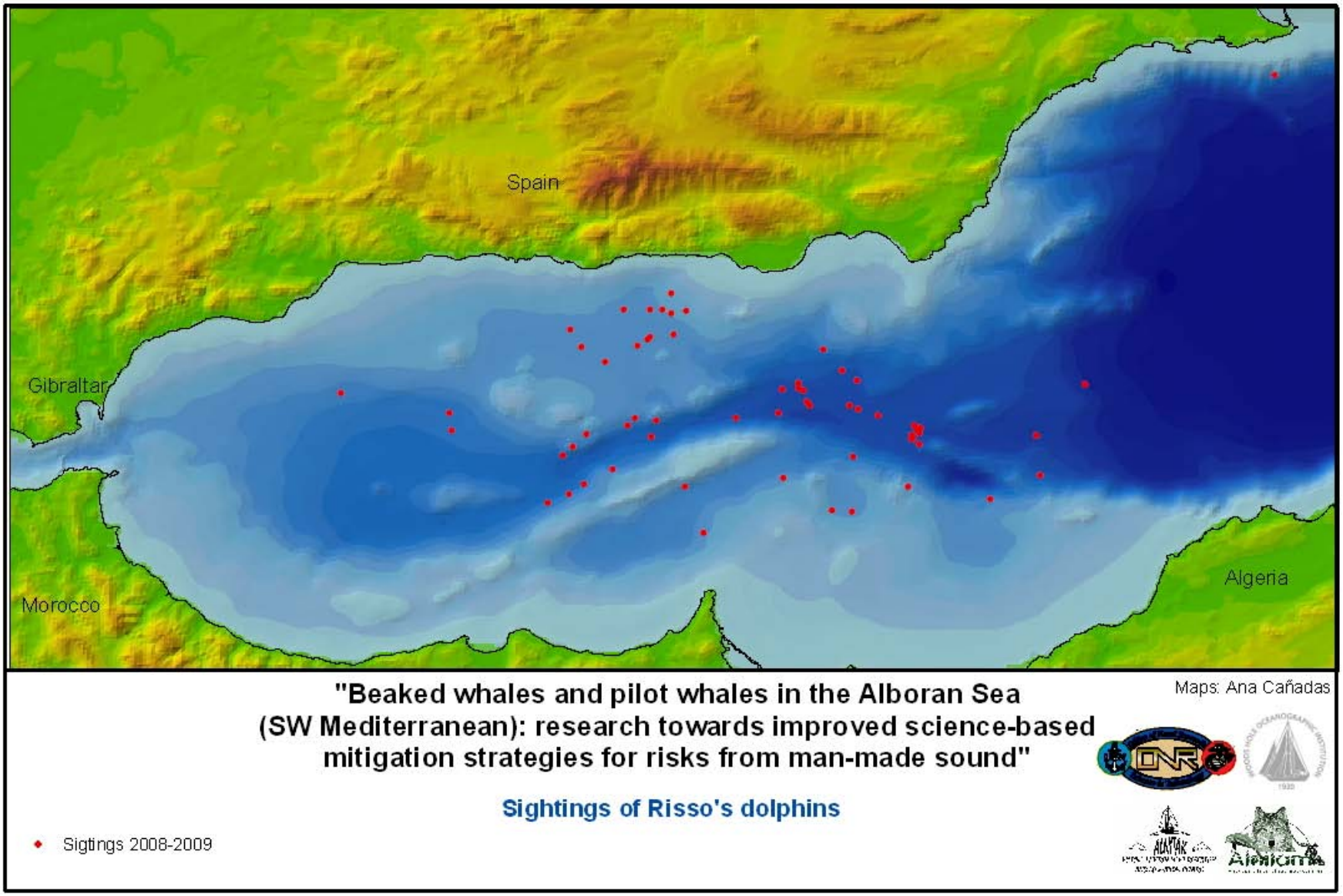


Figure 4. Sightings of Risso's dolphins in 2008 and 2009 by Alnitak's ships and the Alliance.

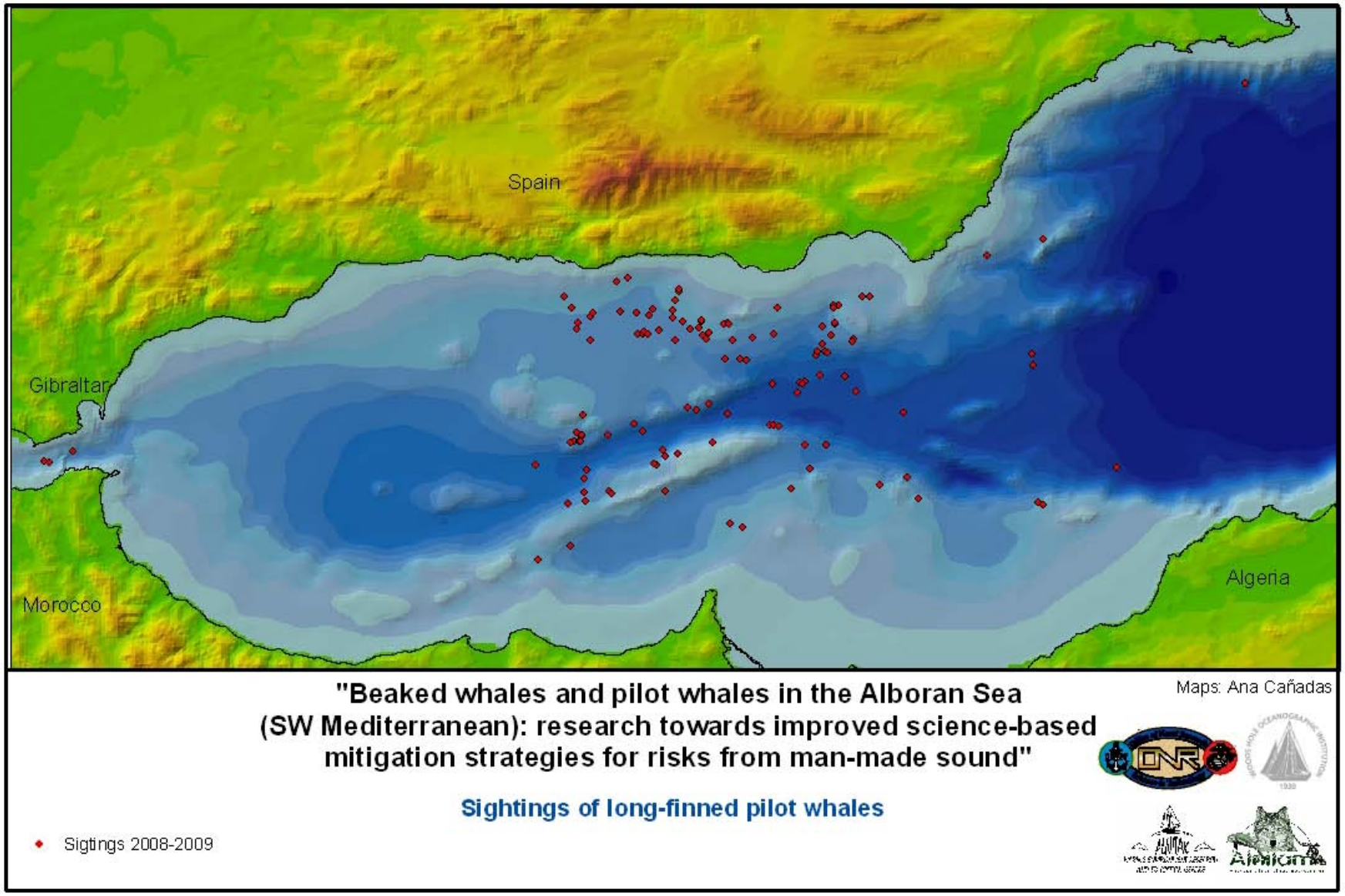


Figure 5. Sightings of long-finned pilot whales in 2008 and 2009 by Alnitak's ships and the Alliance.

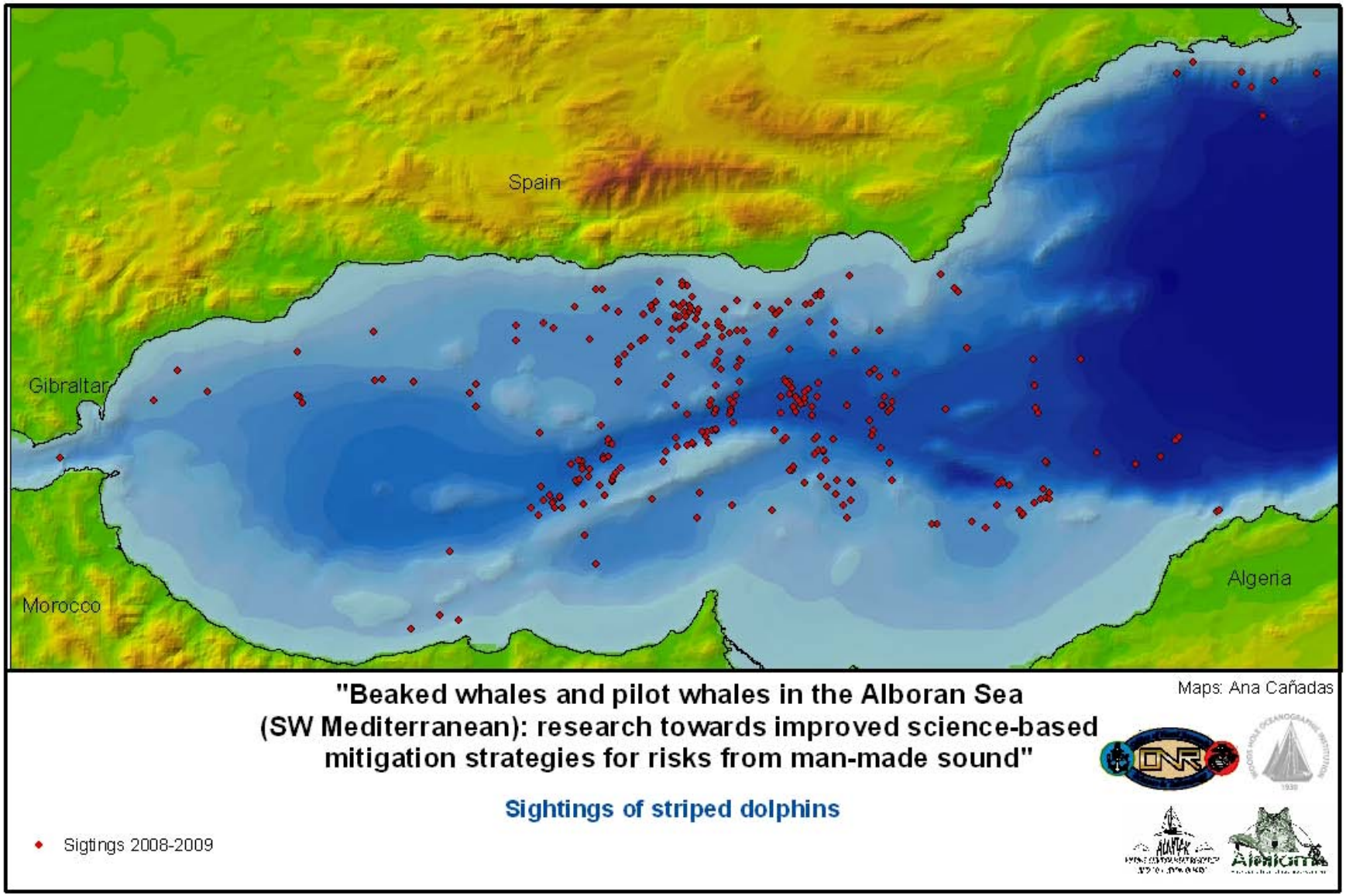


Figure 6. Sightings of striped dolphins in 2008 and 2009 by Alnitak's ships and the Alliance.

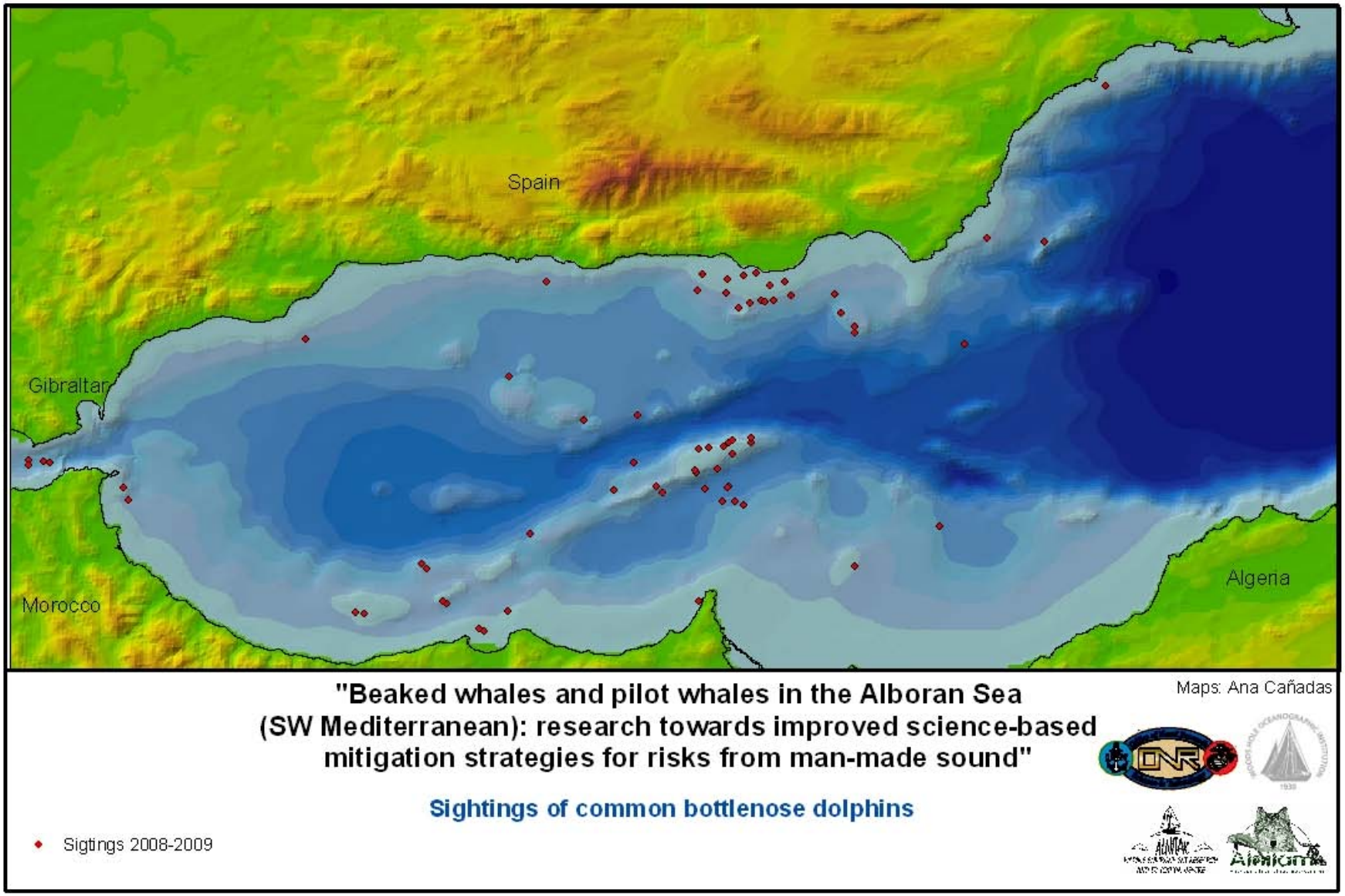


Figure 7. Sightings of common bottlenose dolphins in 2008 and 2009 by Alnitak's ships and the Alliance.

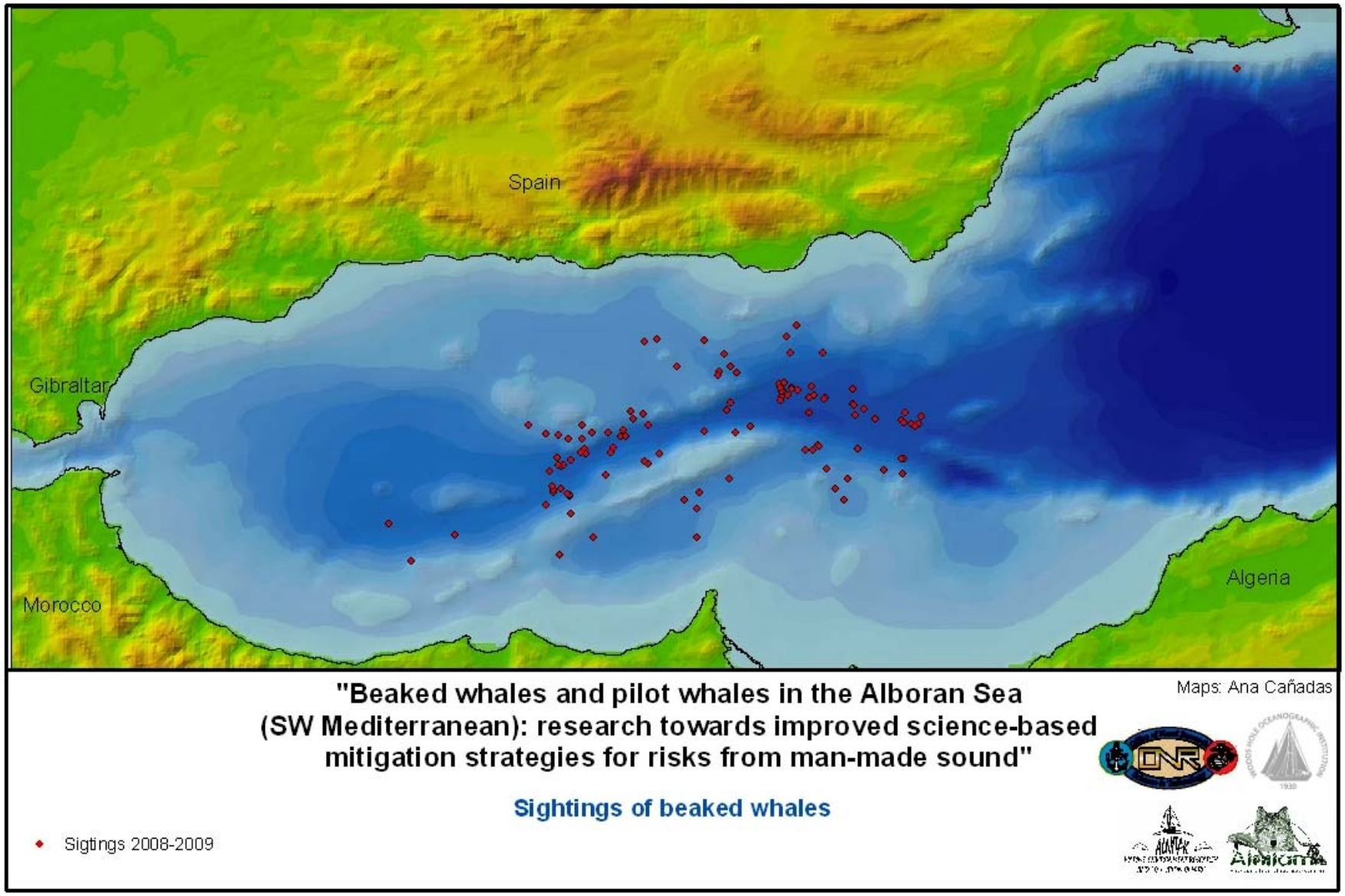


Figure 8. Sightings of beaked whales in 2008 and 2009 by Alnitak's ships and the Alliance.

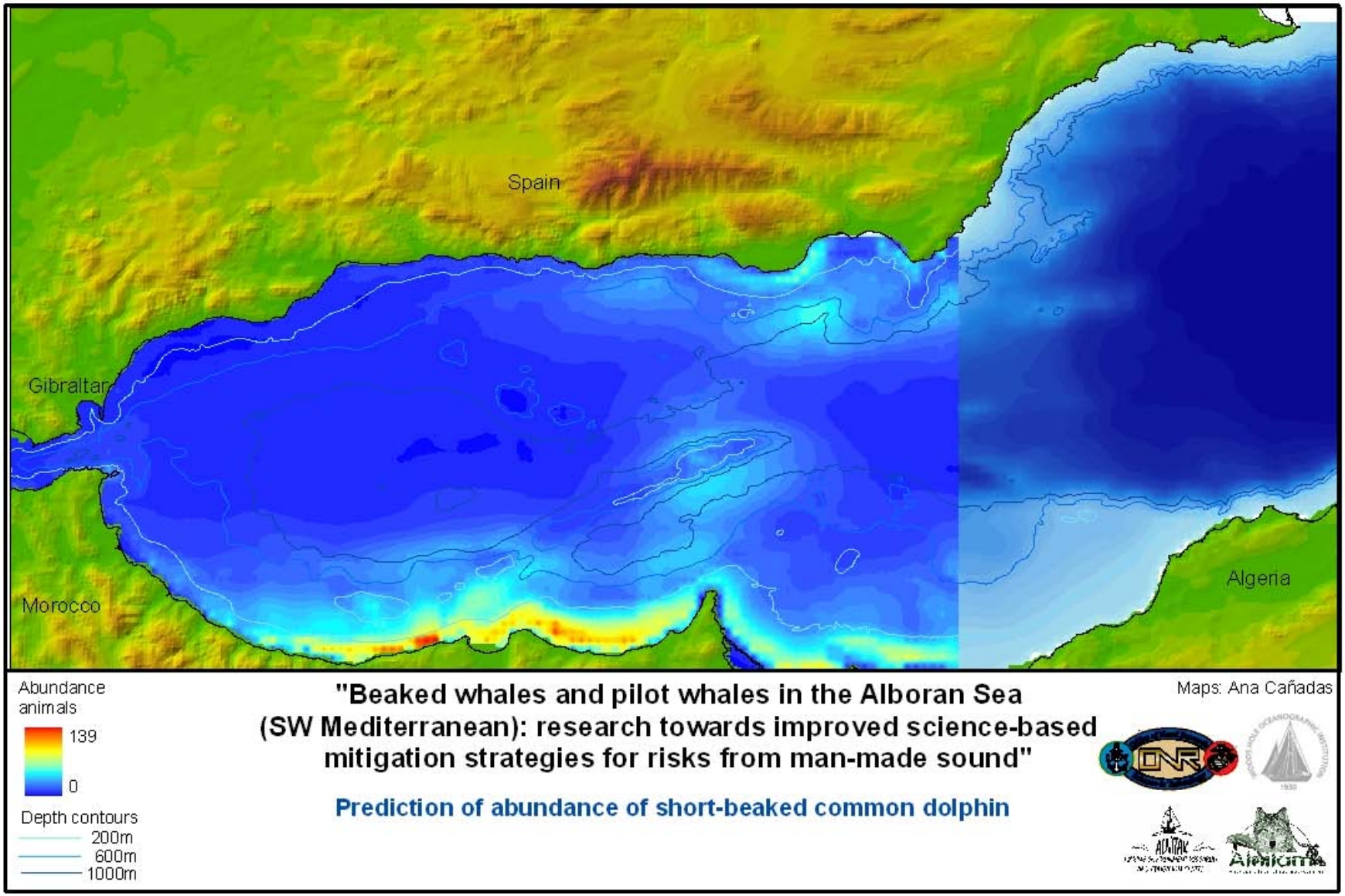


Figure 9. Prediction of abundance of short-beaked common dolphin.

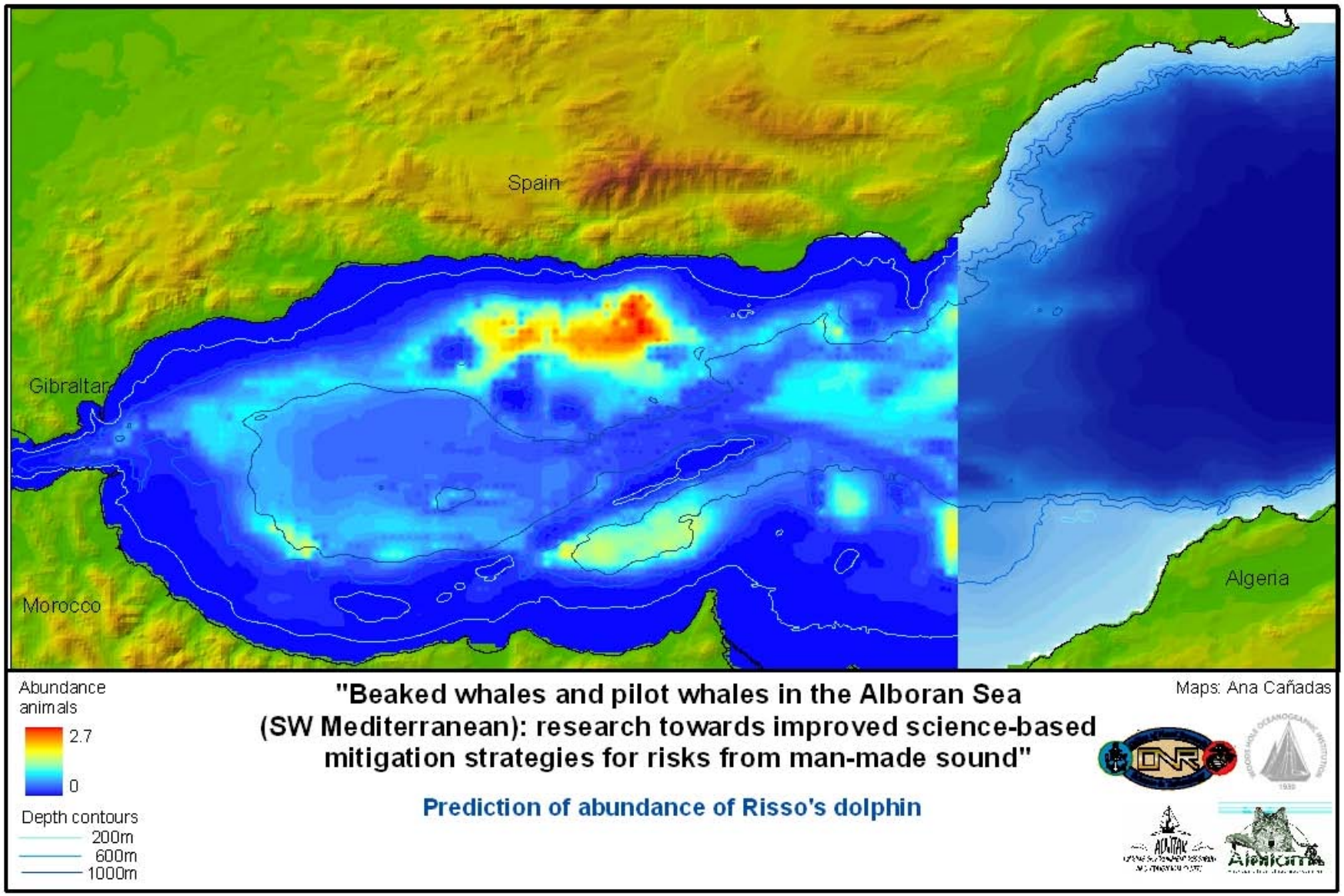


Figure 10. Prediction of abundance of Risso´s dolphin.

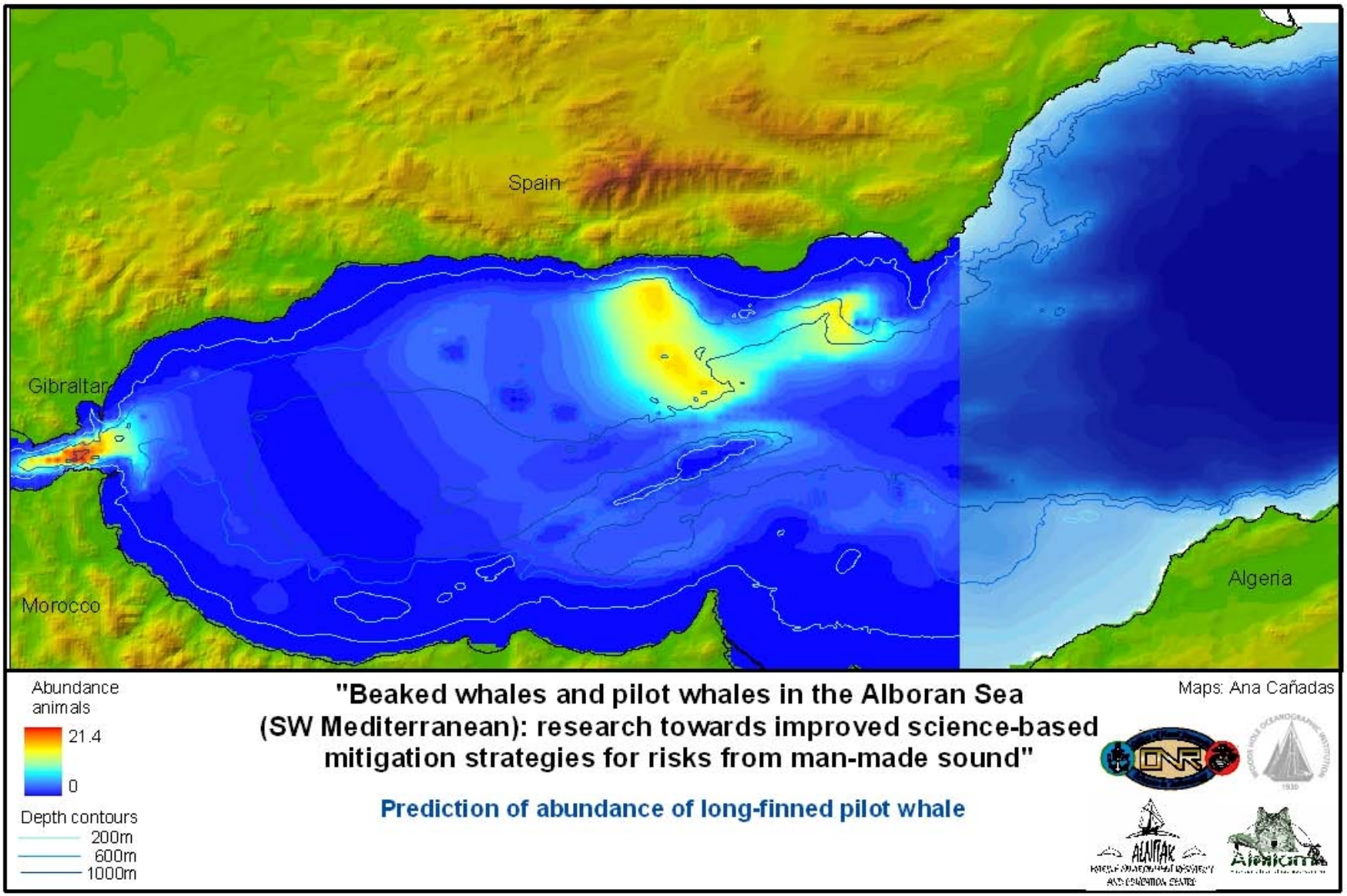


Figure 11. Prediction of abundance of long-finned pilot whale.

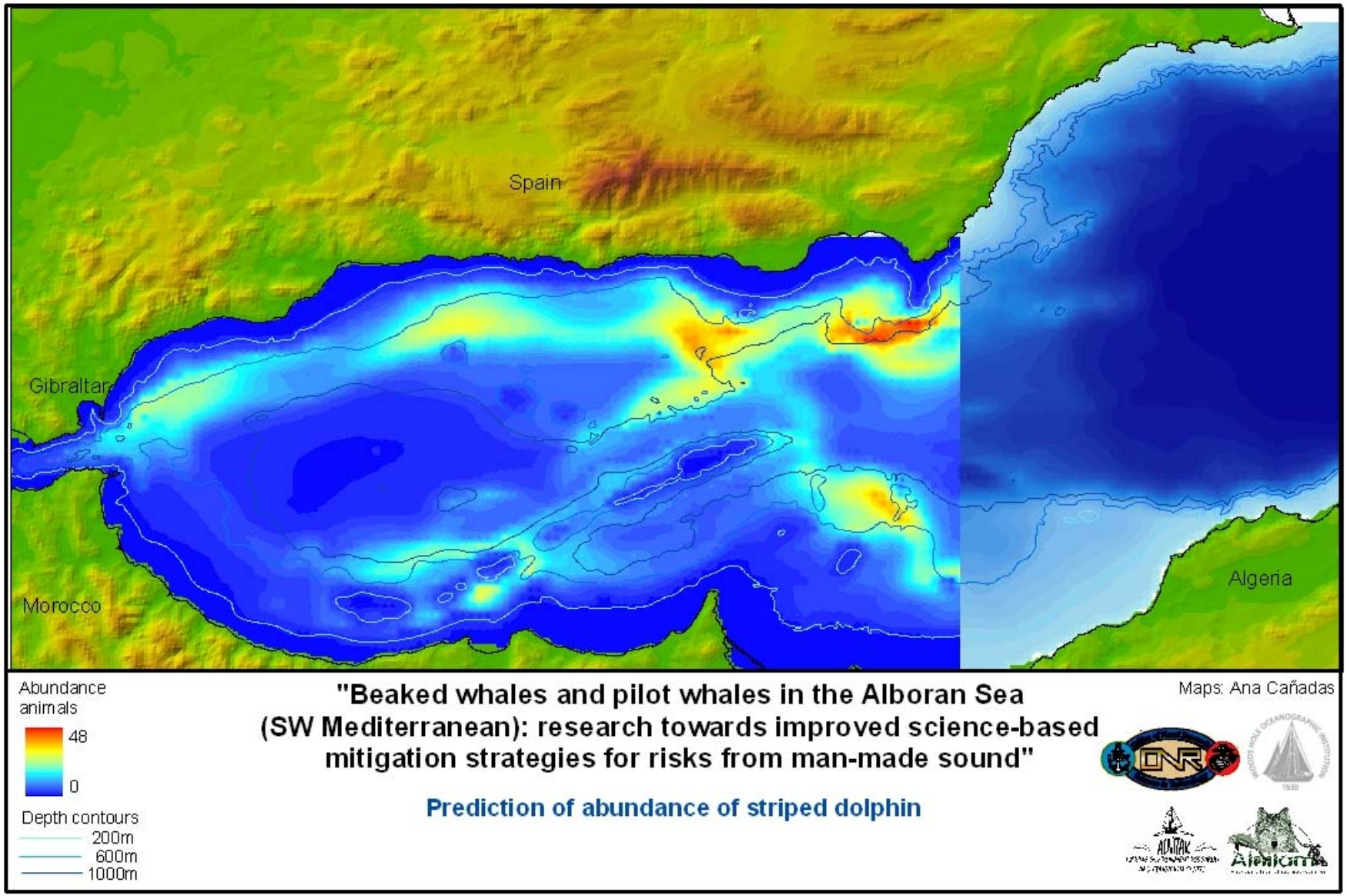


Figure 12. Prediction of abundance of striped dolphin.

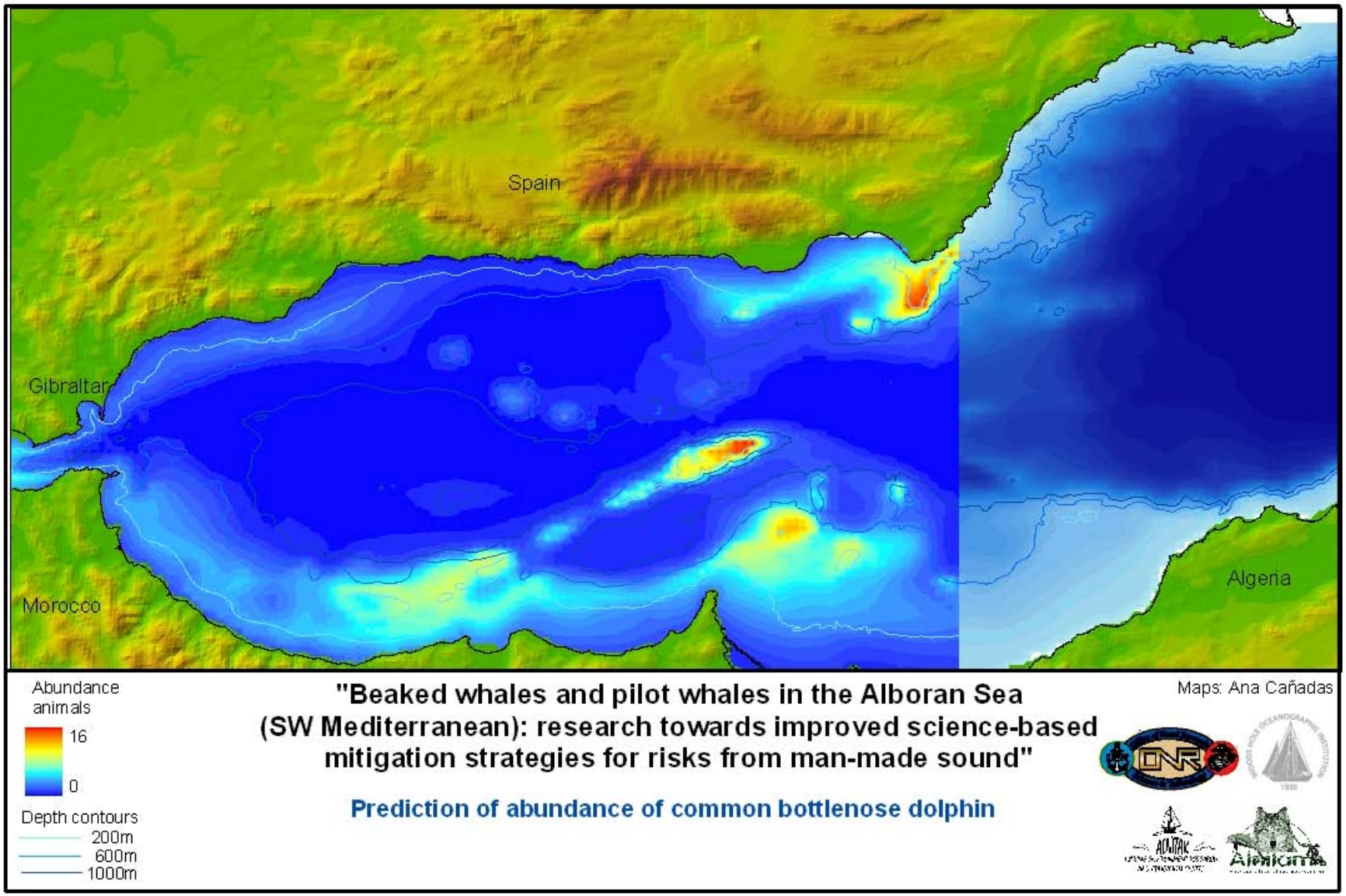


Figure 13. Prediction of abundance of common bottlenose dolphin.

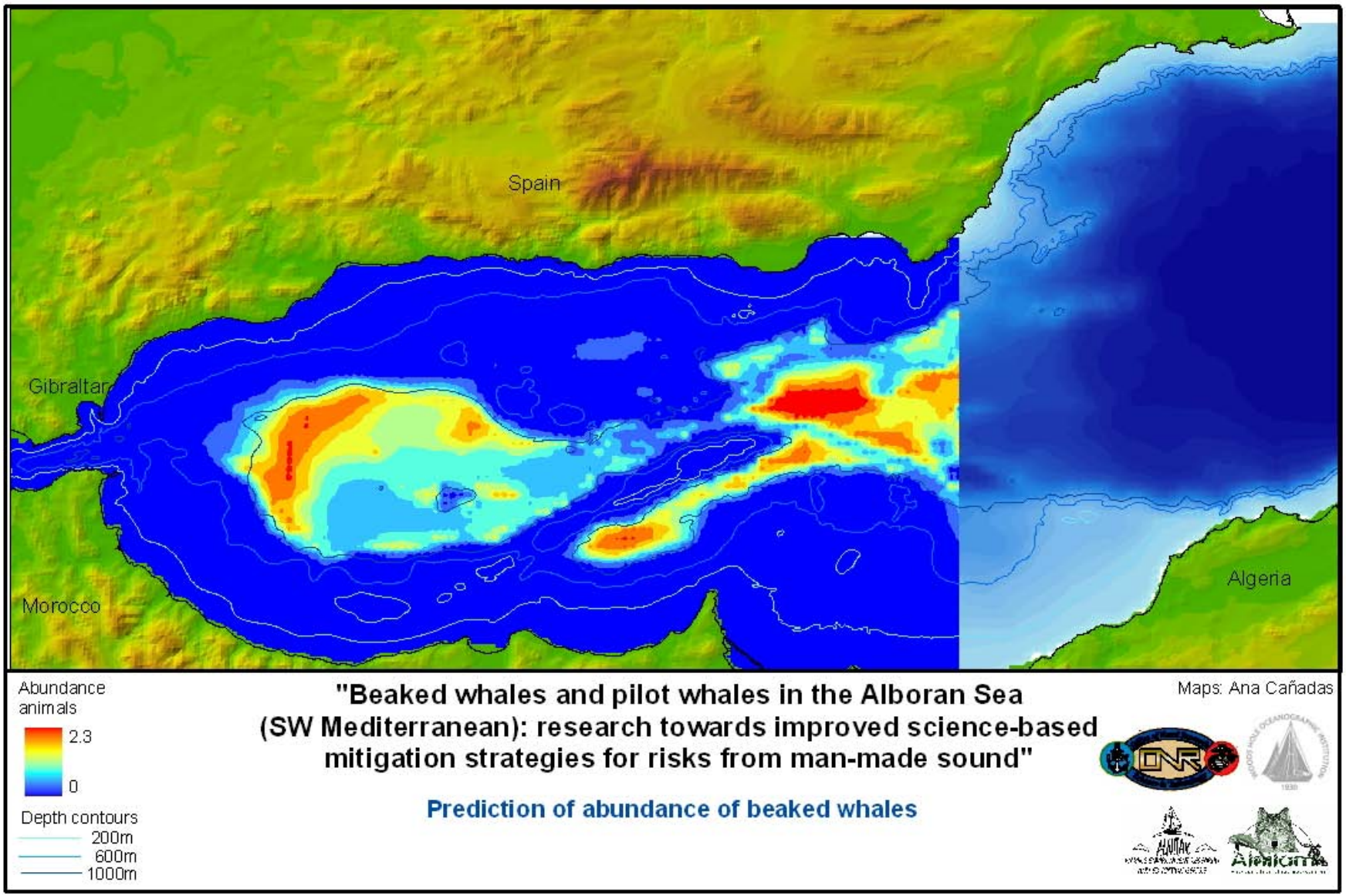


Figure 14. Prediction of abundance of beaked whales