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Habitat preference modelling as a conservation tool: proposals for marine protected areas for cetaceans in southern Spanish waters

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ABSTRACT

1. As part of a project to identify marine protected areas (MPAs) in Spanish Mediterranean waters, habitat preference models were developed using 11 years of survey data to provide predictions of relative density for cetacean species occurring off southern Spain.

2. Models for bottlenose, striped and common dolphin described, firstly, probability of occurrence (using GLMs) and, secondly, group size (using linear models) as predicted by habitat type defined by a range of physical and oceanographic covariates. Models for Risso's dolphin, long-finned pilot, sperm and beaked whales used only the first stage because of data limitations.

3. Model results were used to define the boundaries of three proposed Special Areas of Conservation (SAC) (under the EU Habitats Directive) and one proposed Specially Protected Area of Mediterranean Importance (SPAMI) (under the Barcelona Convention).

4. The study illustrates the value of habitat preference modelling as a tool to help identify potential MPAs. The analyses incorporate environmental data in a spatial prediction that is an improvement over simpler descriptions of animal occurrence. Contiguous areas covering a specified proportion of relative abundance can readily be defined. Areas with apparently good habitat but few observations can be identified for future research or monitoring programmes.

5. Models can be refitted as new observations and additional environmental data become available, allowing changes in habitat preference to be investigated and monitoring how well MPAs are likely to be affording protection.

6. The study represents an important contribution to the implementation of the Habitats Directive by the Spanish government by providing a robust scientific basis for the definition of SAC and providing results to inform conservation objectives and management plans for these areas. The results identified areas that are important for a number of cetacean species, thus illustrating the potential for MPAs to improve cetacean conservation generally in the Alboran Sea, a

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region of great importance for supporting biodiversity and ecological processes in the wider Mediterranean Sea.

KEY WORDS: Mediterranean Sea; Alboran Sea; cetaceans; odontocetes; habitat preference models; GLMs; linear models; MPAs; EU Habitats Directive; Barcelona Convention

INTRODUCTION

Effective conservation of wild populations requires an understanding of the relationship between populations and their habitats, preferably with predictive ability. A first step towards this is to determine which habitats are used with higher frequency. This can then be used to help determine those environmental features (abiotic and biotic) that are required to maintain a favourable conservation status.

Despite the difficulties of investigating the marine environment, it is increasingly becoming apparent that human impact on the seas is considerable (e.g. Kelleher, 1999; Roberts and Hawkins, 2000; Salm *et al.*, 2000; Harwood, 2001; Myers and Worm, 2003). Long-term strategies are required for the conservation of populations/habitats in response to human activities that have caused, or may cause, a negative effect on their status. One of the most common approaches to conservation of the marine environment is the establishment of marine protected areas or MPAs (e.g. Gubbay, 1995; Boersma and Parrish, 1999; Schwartz, 1999; Hyrenbach *et al.*, 2000; Hooker and Gerber, 2004). Although their effectiveness is the subject of much debate (e.g. Boersma and Parrish, 1999; Kelleher, 1999), they are currently considered as an important tool for the conservation of biodiversity by many international frameworks (e.g. the Barcelona Convention, 1976; the Bern Convention, 1979; ASCOBANS, 1991; the OSPAR Convention, 1992; ACCOBAMS, 1996; the European Union Habitats Directive, 1992).

This paper describes the results of a study that was undertaken as part of the Spanish Ministry for the Environment's Programme for the Identification of Areas of Special Interest for the Conservation of Cetaceans in the Spanish Mediterranean, which was carried out between 2000 and 2002 (Alnitak — Universidad Autónoma de Madrid, 2002). The aims were to provide and analyse the available scientific data to develop proposals for MPA designation allowing implementation of European marine conservation frameworks concerning cetaceans and the Spanish National Biodiversity Strategy (DGCN, 1998). Some of the species found in this area are catalogued as 'vulnerable' under the Spanish National Endangered Species Act (common bottlenose and short-beaked common dolphins, sperm whales and fin whales) and as 'endangered' (fin whales and Mediterranean short-beaked common dolphin 'subpopulation') by the IUCN (http://www.redlist.org).

The two types of MPA considered in this study are SAC[1] and SPAMI[2]. With respect to cetaceans, SAC are of relevance to common bottlenose dolphins, *Tursiops truncatus*, and harbour porpoises, *Phocoena*

[1] Special Areas of Conservation are required for species listed under Annex II of the EU Habitats Directive. Under Article 1(k) of the EU Habitats Directive, a site of Community importance is defined as a site that contributes significantly to the maintenance or restoration at a favourable conservation status of a natural habitat type in Annex I or of a species in Annex II. Two cetacean species are listed under this latter Annex: the bottlenose dolphin and the harbour porpoise. In Article 1(l) a special area of conservation (SAC) is defined as a site of Community importance where necessary measures are applied to maintain, or restore, to favourable conservation status, the habitats or populations of the species for which the site is designated (European Union Habitats Directive, 1992). To become accepted as part of the European NATURA 2000 Network of protected areas, proposed SACs must be shown to be of particular importance for the conservation of the species.

[2] Specially Protected Areas of Mediterranean Importance under the Barcelona Convention. The general criteria considered for a region to be designated as a SPAMI are described in the technical documents of the Barcelona Convention (SPA Protocol, 1995). They include: (a) exceptional character (hydrology, oceanography, geology, species richness and presence of endangered habitats); (b) representativeness (regarding ecological processes and habitat types); (c) high diversity of flora and fauna; (d) naturalness; (e) presence of habitats of endangered species; (f) scientific, educational and aesthetics interest; and (g) presence of endangered, catalogued or protected species.

phocoena, whereas SPAMI can be applicable for many species and characteristics — an area can be declared as a SPAMI if it is an important and representative area for the whole Mediterranean Sea (SPA Protocol, 1995). The criteria for these types of MPA relevant for cetaceans are discussed later in the paper.

This paper considers the selection process for candidate MPAs for cetaceans in the region of Andalucía, in southern Spain. Since no formal selection process has been specified for SAC or SPAMI, we have largely followed the approach suggested by Salm *et al*. (2000). According to those authors, the initial step is to define conservation objectives for the MPAs. Once these have been agreed, the selection process should include four steps: (1) data collection (including both a literature search and collection of new data with respect to the target species, human activities and threats); (2) data analysis (to determine areas with concentrations of the target species, human activities and threats to the species); (3) data synthesis (to create maps to help to establish priorities for protection and to better understand spatial relationships among the target species, ecological processes and human activities); and (4) application of selection criteria (to ensure objectivity in the choice of the sites, based on the objectives and the legal framework in which they are based).

This paper uses habitat preference modelling as the primary tool for data analysis. The approach uses physical and environmental data to help explain variations in cetacean distribution and predict areas that are important for target species. This is the first time it has been used for cetaceans in the context of MPAs. Current implementation of the MPAs considered here involves the designation of areas with fixed boundaries and no time variation. Therefore we have generally not considered time-varying covariates, even though they may have allowed more of the variability in the data to be accounted for; this will be investigated in future studies.

METHODS

Data collection

Study area

The study area consisted of the waters of the Autonomous Community of Andalucía, in southern Spain. This is a region of high productivity (Rubín *et al*., 1992; Rubín, 1994), of great oceanographic importance for the Mediterranean (the 'hydrological motor' of the Mediterranean Sea; Rodríguez (1982)) and with high cetacean diversity (Cañadas *et al*., 2002). We have divided it into three geographically and oceanographically different areas: the Gulf of Vera, the Alboran Sea, and the Gulf of Cádiz. The Alboran Sea was stratified for some analyses into four sub-areas: southern Almería, Granada, Málaga and Strait of Gibraltar (Figure 1).

Field studies

The fieldwork was carried out with two research vessels. The primary vessel was the *Toftevaag*, an 18-m motor-sailing vessel with two searching platforms (eye height above sea level of 12 m and 2.5 m). She collected data between 1992 and 1999 in the eastern part of the Alboran Sea and the Gulf of Vera, and from 2000 to 2002 in the whole study area. The second vessel, the *Elsa*, is a 9-m motor boat with one observation platform at 4 m above sea level. She operated in 2001 and 2002 in the Strait of Gibraltar and Gulf of Cadiz. Surveys took place from March to April and from June to September, 1992–2002, during November 1999–2001 and during January 2001 (Figure 1). Both ships surveyed at speeds of approximately 5 knots ($9.3\,km\,h^{-1}$). To maintain consistent sighting effort, one trained observer (of a team of five on both ships) occupied each lookout post in 1-h shifts during daylight with visibility of over 3 nmi (5.6 km), assisted by 7×50 binoculars, covering the 180° arc ahead of the vessel. Sighting effort was conducted only under

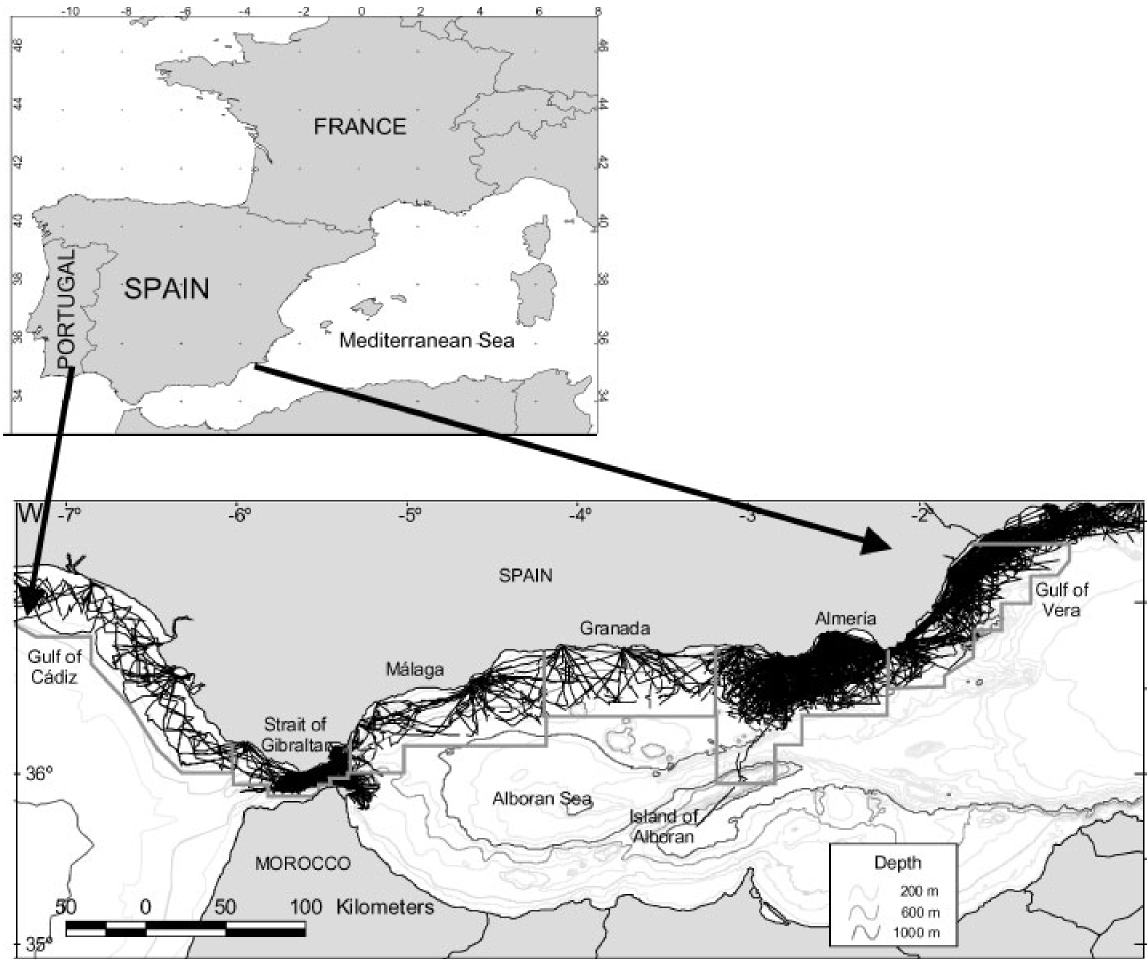

Figure 1. Research area. Depth contours are every 200 m. Survey transects carried out between 1992 and 2002 on effort are shown.

adequate sighting conditions (defined as Douglas sea state 2 or lower, equivalent to Beaufort Sea state 2–3). The position of the vessel was recorded every minute by the ship's computer from a GPS navigation system using the IFAW Data Logging Software, Logger (www.ifaw.org).

Logistical constraints dictated that transects could not follow a systematic design and thus equal coverage probability was not achieved across the area. Instead, cruise tracks were designed as triangles to cross depth contours and to cover as much of the area as possible (Figure 1). Searching effort stopped when animals were encountered (a 'sighting') and recommenced following a return to the previous course. A 'sighting' was defined as a group of animals seen at the same time, showing similar behavioural characteristics and at distances of less than 1000 m from each other (SEC, 1999). Time, species, number of individuals and behaviour were recorded for each sighting. However, it should be noted that determining group size is not always easy. For long-finned pilot whales, the existence of 'super-schools' (NAMMCO, 1997) causes problems with defining groups and their size. The inconspicuous behaviour of Risso's dolphins, *Grampus griseus*, and beaked whales (family *Ziphiidae*) did not allow, in many cases, group size to be estimated properly.

Additional data

A number of potential explanatory variables were considered for the analysis. These were: latitude; longitude; depth (m) or logarithm of depth (logdepth); slope ($\mathrm{m\,km^{-1}}$); sea surface temperature (sst — the difference between the annual average sst for each grid cell with respect to the overall annual average) and temporal variability in sst (measured as the standard deviation of the weekly average sst in a given grid cell over a year).

Data on latitude, longitude, depth and slope were extracted from nautical charts of the Hydrographic Institute of the Spanish Navy. The sst data were extracted from satellite images[3] obtained from the CREPAD service of INTA (Spanish Space Agency). Good sst data were available for the year 2000 and this was used as a 'model' of typical conditions in the research area. Visual inspection of the satellite images from 1997 to 2002 showed no substantial deviation among years. As noted above, the MPAs have to be fixed in time. However, the two covariates describing variability in sea surface temperature were included because the general oceanographic structure captured by them (the anticyclonic gyres and the sst gradient over the whole area) is indicative of the extraordinary productivity and oceanography of this area, which is highly stable in the long-term (Rodríguez, 1982; La Violette, 1986; Millot, 1987; Tintoré *et al*., 1988).

For the spatial analysis, the study area was divided into 2-minute-square grid cells ($n = 3008$). The grid cells were categorized according to the above potential explanatory variables.

Data analysis

Models

No cetaceans were encountered in many of the surveyed grid cells. In addition, for several species (common bottlenose, short-beaked and striped dolphins, and long-finned pilot whales) there were wide ranges in group size. Given the resultant over-dispersed distribution in the number of animals encountered, the probability of occurrence was first modelled, followed by group size (where possible or necessary) conditional on occurrence (Marques, 2001).

'Habitat types' were defined by grouping the grid cells in combinations according to values of the available environmental variables. For each variable, this was achieved by determining a series of equally sized 'bins' via visual inspection of the data. The aim was to specify the minimum number of bins needed for each variable to capture the structure of its relationship with the presence of a given species. This exploratory analysis also provided insights into the shape of the relationship (linear, quadratic, cubic, etc.). For the occurrence models, effort was expressed as the number of times the research ship passed over a grid cell. The response variable was the proportion of positive observations in each habitat type, weighted by the amount of effort.

Generalized linear models (GLMs) were used to model the proportion of positive observations (occurrence) in the different habitat types available weighted by the amount of effort in each habitat type, following the method described by Boyce and McDonald (1999). A binomial distribution was used with the logit link function. The general structure of the model was:

$$E(p_i) = \frac{\exp\left[\beta_0 + \sum_i f_i(z_{ij})\right]}{1 + \exp\left[\beta_0 + \sum_i f_i(z_{ij})\right]} \tag{1}$$

where: p_i is the proportion of positive observations in the ith habitat type, β_0 is a parameter to be estimated and z_{ij} is the value of the jth explanatory variable in the ith habitat type fitted as some unknown function f_i to be estimated.

[3] NOAA Advanced Very High Resolution Radiometer (AVHRR) images with a pixel resolution of $2\,\mathrm{km}^2$.

Given the different physiographic and oceanographic characteristics of each area it had been hoped to be able to fit separate models for each. Owing to sample size considerations, this was only possible for the Alboran Sea and the Gulf of Vera and then only for short-beaked common dolphins, *Delphinus delphis*, striped dolphins, *Stenella coeruleoalba*, and common bottlenose dolphins. In the case of long-finned pilot whales, *Globicephala melas*, the two areas were first analysed separately, but more robust results were obtained from combining them. For the other species, data were pooled over both areas to keep a large enough sample size. The very low number of sightings in the Gulf of Cadiz precluded the development of any models for this region for any species.

The second stage of the modelling exercise was only carried out for short-beaked common, striped and common bottlenose dolphins. For the other species, it was either unnecessary because school size was effectively constant or unwise because the school size estimates were considered unreliable (as discussed above).

To model group sizes, the number of individuals in each sighting was log-transformed, obtaining a normal distribution of the data that allowed the use of a linear model. The general structure of the model was:

$$\ln(n_i) = \beta_0 + \sum_i f_i(z_{ij}) \tag{2}$$

where: n_i is the number of individuals in the ith group, β_0 is a parameter to be estimated and z_{ij} is the value of the jth explanatory variable in the ith group fitted as some unknown function f_i to be estimated.

Where the two models were fitted, the predicted probability of occurrence and group sizes were multiplied to give a prediction of relative density (animals nmi^{-2}) for each grid cell. As these are relative densities they are appropriate only for comparisons between regions for each species. For the other species, the final results were predictions of the probability of occurrence.

Model selection

A stepwise procedure (both forwards and backwards) was applied to select the models that best fitted the data, in conjunction with AIC values (Akaike's Information Criterion; Akaike, 1973). Models with a difference in AIC (delta AIC) smaller than 2 were considered to have equivalent support from the data (Burnham and Anderson, 1998) and in such circumstances the most parsimonious model was chosen. Goodness of fit was investigated using a chi-square test on model deviance and a visual inspection of the residuals.

To examine model robustness, a visual comparison was made of the prediction maps from the best fitting model and those from the models within a delta AIC of 2. If no major differences were observed, the selected model was considered robust.

Model evaluation and significance

To test the significance of the occurrence models, the real data were compared with 1000 matrices of randomly generated data of presence/absence for each grid cell with effort (the proportion present in each randomized matrix being equal to the proportion in the real data). Each matrix was compared with the probability of occurrence predicted by the model for those grid cells using the following likelihood function:

$$L = \sum \log(\hat{p}) + \sum \log(1 - \hat{p}) \tag{3}$$

where $\hat{p}$ is the probability of presence predicted by the model in the grid cells with presence and $(1 - \hat{p})$ is the probability of absence predicted by the model in the grid cells with absence. For a perfect fit, $L = 0$; the closer L is to 0, the better the model prediction fits the data. A frequency distribution was constructed with the L_s values of the randomized matrixes (s = simulated data). The probability (p) of the L_r value (r = real data) in the distribution of L_s was then calculated. From this, a likelihood test was performed with the null hypothesis that the model prediction would fit both the real and simulated data equally well. This allowed evaluation of the statistical significance of the model at a chosen probability level (in this case at $\alpha = 0.01$).

For the four most commonly encountered species (short-beaked common, striped and common bottlenose dolphins, and long-finned pilot whales), an evaluation of the predictive quality of the models was also performed. Data collected during summer 2002 (not used for fitting the models) were used to test the predictive ability of the models built using the data collected between 1992 and spring 2002. A likelihood test similar to equation (3) was used. In this case, the presence or absence of sightings in the grid cells surveyed on effort during 2002 was compared with the probability of occurrence predicted by the model for those grid cells, and 1000 random matrices of presence/absence were generated (with proportion present equal to the actual proportion in 2002). After applying the same likelihood function and test as before, a small p-value would demonstrate the ability of the model to predict the 2002 distribution.

Data synthesis and application of selection criteria

Specification of SAC boundaries. SAC are only applicable to common bottlenose dolphins and harbour porpoises. Given our data set, only common bottlenose dolphins were considered (but see discussion). Following recommendations for selection criteria for SAC (CTE/CN, 1996), at least 60% of the principal habitats used by common bottlenose dolphins should be covered. To achieve this, the predicted nonzero relative density values were divided into 10 equal intervals and then into three categories: low = 1–3; medium = 4–6; and high = 7–10. Over the surface map of these values, the definition of the sites' emplacement started at the grid cells categorized as high and extended to contiguous grid cells in order to encompass the minimum requirement of 60% grid cells with medium and high relative density.

Specification of SPAMI boundaries. SPAMI are applicable to a wide range of species and oceanographic characteristics. In relation to the specific criteria for cetaceans, the most important points to be considered are: (a) the importance of the area for the feeding and reproduction of several species; (b) its role as a migration path; (c) the inclusion of a high percentage of species' populations at the national or European level; (d) a high density and large diversity of cetaceans; (e) a large proportion of the population(s) is resident; (f) that some human activities are having or may have a negative impact on the cetacean populations inhabiting it; and (g) presence of populations of fragmented species and some degree of genetic isolation.

An extensive study of the literature and unpublished data (not presented here) on human activities in the study area has been undertaken by Alnitak — Universidad Autónoma de Madrid (2002), focusing on use by different stakeholders and on the known and potential threats to the cetacean species in the area. This was used together with the analytical results and a literature review of other biological and oceanographic features of the region to augment justification for the proposed area (SPA Protocol, 1995).

RESULTS

A total of 19 629 nmi (36 352 km) was surveyed on effort (i.e. under adequate sighting conditions) in the research area between 1992 and 2002 (Figure 1, Table 1). During this effort, 2866 sightings of at least 11 species of cetaceans were made. Tables 2–4 give summary information on encounter rates and group sizes for the six most commonly encountered odontocete species and all beaked whale species combined. The variables retained by the final selected model(s) for each species are given in Table 5 (models of occurrence) and 6 (models of group size). In all cases, the comparison of the results from all models with the lowest

Table 1. Effort (nmi steamed under adequate conditions), and surface area (nmi^2) for each sub-area, from 1992 to 2002

Area	Effort	Surface area
Gulf of Cadiz	1160	1642
Strait of Gibraltar	2583	424
Málaga	992	1321
Granada	744	924
Southern Almería	9285	1234
Island of Alboran	32	346
Gulf of Vera	4833	1107
Total	19 629	6998

Table 2. Encounter rates and average group size (SE in brackets) of common bottlenose and short-beaked common dolphins

Area	Common bottlenose dolphin			Short-beaked common dolphin		
	Number of sightings	Encounter rate for sightings	Average group size (SE)	Number of sightings	Encounter rate for sightings	Average group size (SE)
Gulf of Cadiz	6	0.0052	35.5 (9.50)	9	0.0078	43.1 (11.82)
Strait of Gibraltar	60	0.0232	27.7 (3.62)	138	0.0534	35.5 (3.40)
Málaga	7	0.0071	26.3 (7.72)	123	0.1239	45.7 (5.30)
Granada	3	0.0040	10.3 (3.01)	46	0.0618	40.7 (9.45)
Southern Almería	147	0.0158	28.3 (2.53)	363	0.0391	78.4 (5.89)
Island of Alboran	5	0.1587	12.6 (4.16)	0	0.0000	
Gulf of Vera	20	0.0041	11.2 (4.06)	75	0.0155	44.2 (4.72)
Total	248	0.0126	26.5 (1.83)	754	0.0384	58.5 (3.15)

Table 3. Encounter rates and average group size (SE in brackets) of striped dolphins and long-finned pilot whales

Area	Striped dolphin			Long-finned pilot whale		
	Number of sightings	Encounter rate for sightings	Average group size (SE)	Number of sightings	Encounter rate for sightings	Average group size (SE)
Gulf of Cadiz	0	0		0	0	
Strait of Gibraltar	101	0.0398	67.5 (9.87)	56	0.0217	28.5 (4.41)
Málaga	84	0.0846	73.5 (11.39)	4	0.0040	37.8 (7.81)
Granada	46	0.0618	116.2 (15.93)	23	0.0309	26.5 (4.81)
Southern Almería	413	0.0445	50.7 (3.47)	205	0.0221	25.7 (2.55)
Island of Alboran	1	0.0317		0	0.0000	
Gulf of Vera	218	0.0451	44.6 (3.85)	62	0.0128	47.3 (7.58)
Total	863	0.0440	58.0 (2.74)	350	0.0178	30.3 (2.19)

values of AIC (within a value of 2 of the best model) showed that the results were robust to model selection within this range of AIC. The tests of goodness of fit (model deviance) showed that all models fitted adequately. Examination of residuals revealed no unacceptable patterns.

The likelihood tests for the significance of the models showed, for all species, that the probability that the prediction of the models would fit the observed data and the simulated randomized data equally well was extremely low ($p < 0.0001$). To evaluate the ability of the models to predict cetacean distributions in 2002, 21 sightings of common bottlenose dolphins, 89 short-beaked common dolphins, 78 striped dolphins and 28

Table 4. Encounter rates and average group size (SE in brackets) of Risso's dolphins, beaked whales and sperm whales

Area	Risso's dolphin			Beaked whales			Sperm whales		
	Number of sightings	Encounter rate for sightings	Average group size (SE)	Number of sightings	Encounter rate for sightings	Average group size (SE)	Number of sightings	Encounter rate for sightings	Average group size (SE)
Gulf of Cadiz	1	0.0009		0	0.0000		0	0.0000	
Strait of Gibraltar	0	0.0000		0	0.0000		108	0.0418	1.3 (0.08)
Málaga	1	0.0010		0	0.0000		0	0.0000	
Granada	2	0.0027	9.5 (1.50)	1	0.0013		2	0.0027	3.5 (1.67)
Southern Almería	36	0.0039	10.1 (1.29)	37	0.0040	2.3 (0.20)	16	0.0017	1.3 (0.25)
Island of Alboran	1	0.0317		1	0.0317		0	0.0000	
Gulf of Vera	21	0.0043	17.5 (3.32)	3	0.0006	1.3 (0.33)	3	0.0006	1.0 (0.00)
Total	62	0.0032	12.5 (1.41)	42	0.0021	2.2 (0.19)	129	0.0066	1.3 (0.08)

Table 5. Results of the final selected models of occurrence for all species. Variables: lon (longitude), lat (latitude), depth, logd (logarithm of depth), slope, sstdif (difference in sea surface temperature with respect to the overall average) and sstvar (temporal variability in sst). The symbol '*' indicates that the variable was retained by the model. The number in brackets indicates the power of the polynomial function of the variable, if it is not a linear term, and the symbol ':' means an interaction between variables

Species	Variables							
	lon	lat	depth	logd	slope	sstdif	sstvar	interactions
C. bottlenose dolphin								
Alboran Sea	*(4)		*(3)		*	*(2)		lon:depth, lon:sstvar, depth:slope
Gulf of Vera			*(2)					
S-b common dolphin								
Alboran Sea	*(3)			*(2)		*(2)	*	sstdif:logd, sstdif:lon
Gulf of Vera		*	*(2)					sstvar:depth, sstvar:lon
Striped dolphin								
Alboran Sea	*(2)		*(2)			*(3)	*	lon:sstdif, depth:slope, depth:sstvar
Gulf of Vera	*(2)	*		*(2)				lat:logd
Long-finned pilot whale	*(6)		*(2)			*	*	lon:depth
Risso's dolphin	*(2)		*(2)			*	*(2)	
Beaked whale	*(2)		*(2)					lon:depth
Sperm whale	*(5)		*(3)		*		*	lon:depth

long-finned pilot whales were used. The models predicted the distribution of these species in 2002 significantly better than the simulated randomized data ($p < 0.0001$).

It is important to note that our models predict relative density and not abundance. For estimating abundance from a dataset such as this, the probability of detection must be estimated and density modelled as a function of physical and environmental covariates and extrapolated to the whole area using spatial modelling (Hedley *et al*., 1999; Buckland *et al*., 2001). This is the focus of ongoing work.

Species accounts

Common bottlenose dolphin

The common bottlenose dolphin was encountered throughout the whole study area and in all seasons (Figure 2(a)). The highest encounter rates for both groups and individuals occurred around the Island of Alboran followed by the Strait of Gibraltar and the southern waters of Almería (Table 2).

Table 6. Results of the final selected models of group size for common bottlenose, short-beaked common and striped dolphins. Variables: lon (longitude), lat (latitude), depth, logd (logarithm of depth), slope, sstdif (difference in sea surface temperature with respect to the overall average) and sstvar (temporal variability in sst). The symbol '*' indicates that the variable was retained by the model. The number in brackets indicates the power of the polynomial function of the variable, if it is not a linear term, and the symbol ':' means an interaction between variables

Species	Variables							
	lon	lat	depth	logd	slope	sstdif	sstvar	interactions
C. bottlenose dolphin								
Alboran Sea				*(2)				
Gulf of Vera		*(2)	*(2)					
S-b common dolphin								
Alboran Sea	*(2)			*(2)		*(2)		lon:logd
Gulf of Vera	*(2)	*		*(2)	*			
Striped dolphin								
Alboran Sea				*(2)				lon:logd, lon:sstdif
Gulf of Vera	*			*(3)				lon:logd

Highest density was predicted in the southern section of the Strait of Gibraltar, the areas south of Almería (especially the region of the Seco de los Olivos seamount) and the island of Alboran (Figure 2(b)). In the Alboran Sea, the model of occurrence retained longitude as a polynomial function up to the fourth order, reflecting a bimodal distribution. The first peak corresponds to the Strait of Gibraltar, and the second to the island of Alboran and south of Almería (at the longitude of the Seco de los Olivos).

The prediction of relative density was higher for areas of intermediate depths (mainly between 200 and 600 m) and steep slope. Relative density declined northwards from Cabo de Gata, but increased again approaching the border with the region of Murcia (Figure 2(b)).

Short-beaked common dolphin

The short-beaked common dolphin was also found throughout the whole research area and in all seasons (Figure 3(a)). The highest encounter rates for both groups and individuals occurred in the Alboran Sea (especially off Málaga) and the Strait of Gibraltar. These are much higher than the rates obtained in either the Gulf of Cádiz or the Gulf of Vera (Table 2). However, the largest group sizes (mean around 78) were observed in southern Almería; almost double those in the other areas.

The model predicted a preference for areas with a lower temporal variability in average sst and cooler waters than the overall average. The area with the highest prediction of occurrence included the Bays of Málaga and Estepona, especially off Punta Calaburras, coinciding with the northern branch of the western anticyclonic gyre of the Alboran Sea (Gascard and Richez, 1985; Parrilla and Kinder, 1987; Figure 3(b)). However, larger numbers of dolphins were predicted in southern Almería, where the average group size was much larger than in the other areas (Table 2). Combining the results from both models (i.e. occurrence and school size), these two areas were predicted to have the highest relative density, especially at depths between 100 and 400 m.

The results also highlighted the importance of the Strait of Gibraltar, especially the more coastal areas, including the Bay of Algeciras. Predicted relative densities were lower in the Gulf of Vera. However, within this area they were higher in the south (specifically to the south-east of Cabo de Gata), where the productive 'Almería–Orán' thermohaline front often forms (Tintoré *et al*., 1988). To the north, the areas with higher predicted relative density were in deeper waters than in the Alboran Sea.

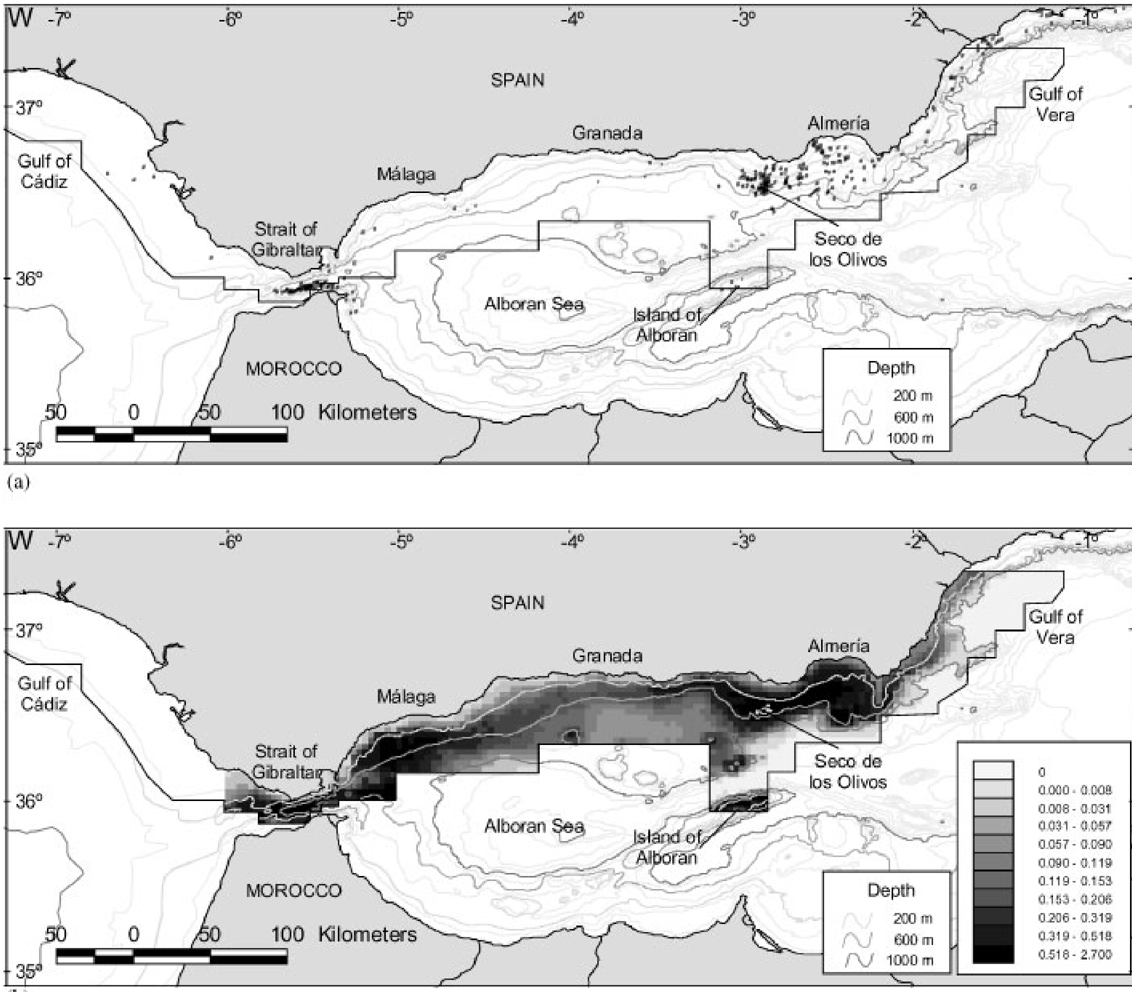

Figure 2. (a) Sightings of common bottlenose dolphins. (b) Prediction of relative density of common bottlenose dolphin in the research area.

Striped dolphin

The striped dolphin was encountered in all seasons and in all areas except the Gulf of Cádiz (Figure 4(a)). The encounter rates were the highest of any species. The highest striped dolphin encounter rates for both groups and individuals, and the highest group sizes (mean around 116) occurred off Málaga and Granada (Table 3).

The areas with highest predicted relative density were the deep waters of the Alboran Sea, followed by the Strait of Gibraltar and then the deep areas of the Gulf of Vera (Figure 4(b)). The encounter rates for groups and individuals followed the same pattern. The model predicted a preference for warmer waters than the short-beaked common dolphin, with low variability. However, in the Gulf of Vera, neither of the sst covariates were retained, possibly because the whole area had a higher sea surface temperature than the overall average for the entire survey area. In the Strait of Gibraltar, the preferred area predicted for striped dolphins was narrower than that for the short-beaked common dolphins, and closer to the central channel (Figures 4(a) and 4(b)).

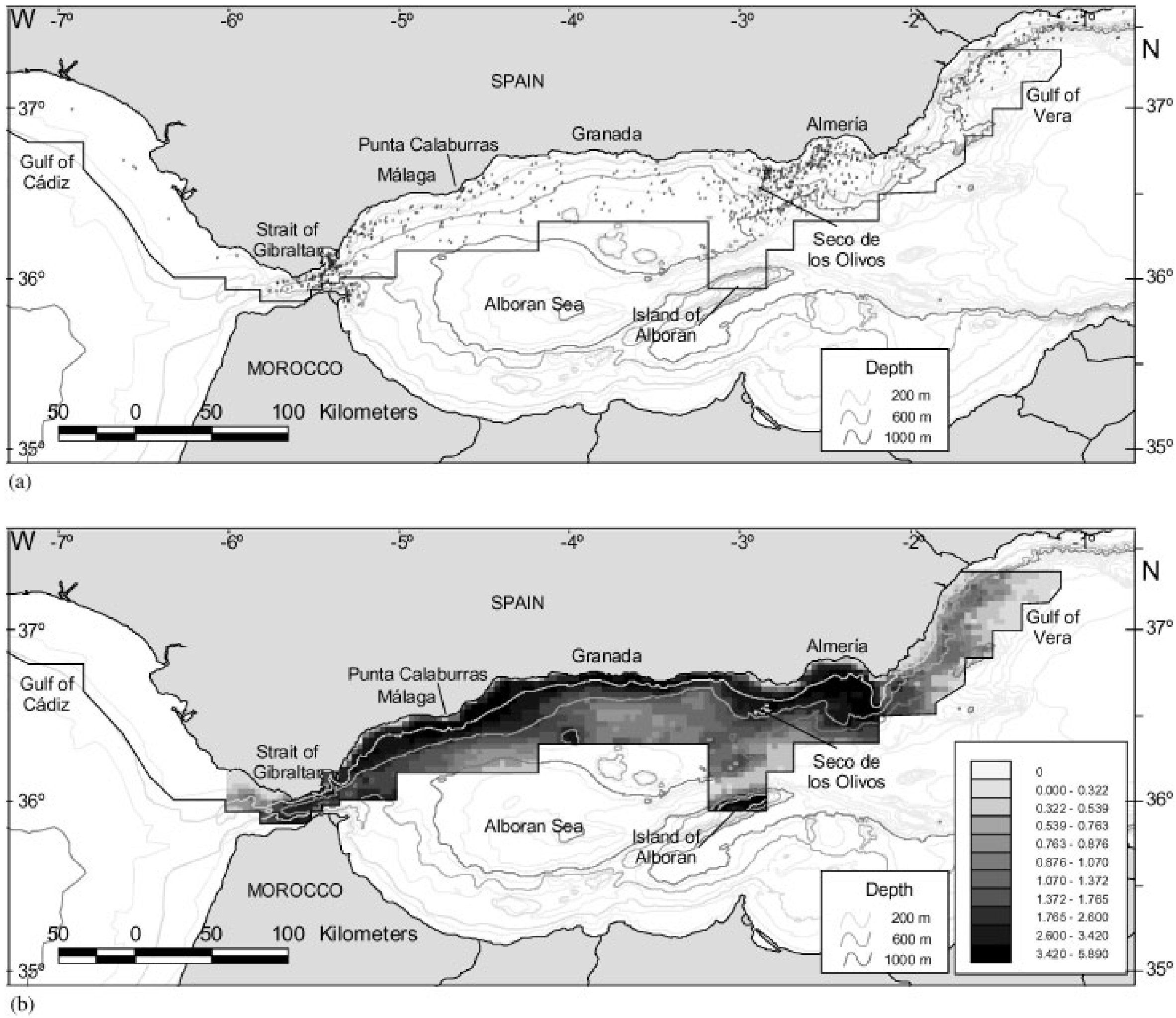

Figure 3. (a) Sightings of short-beaked common dolphins. (b) Prediction of relative density of short-beaked common dolphin in the research area.

Long-finned pilot whale

The long-finned pilot whale, like the striped dolphin, was encountered in all seasons and everywhere except the Gulf of Cádiz (Figure 5(a)). The highest encounter rates for both groups and individuals occurred in Granada, Almería and the Strait of Gibraltar, followed by the Gulf of Vera (Table 3). The mean group size was highest in the Gulf of Vera (mean around 47).

Predicted probability of occurrence was highest in three areas: the Strait of Gibraltar; the area off Almería and Granada; and south-east of Cabo de Gata. The last may be considered a continuation of the Almería–Granada area towards the north-east (Figure 5(b)). The polynomial function of longitude retained in the model reflects this trimodal distribution. In all cases, the model predicted a preference for waters deeper than 500 m.

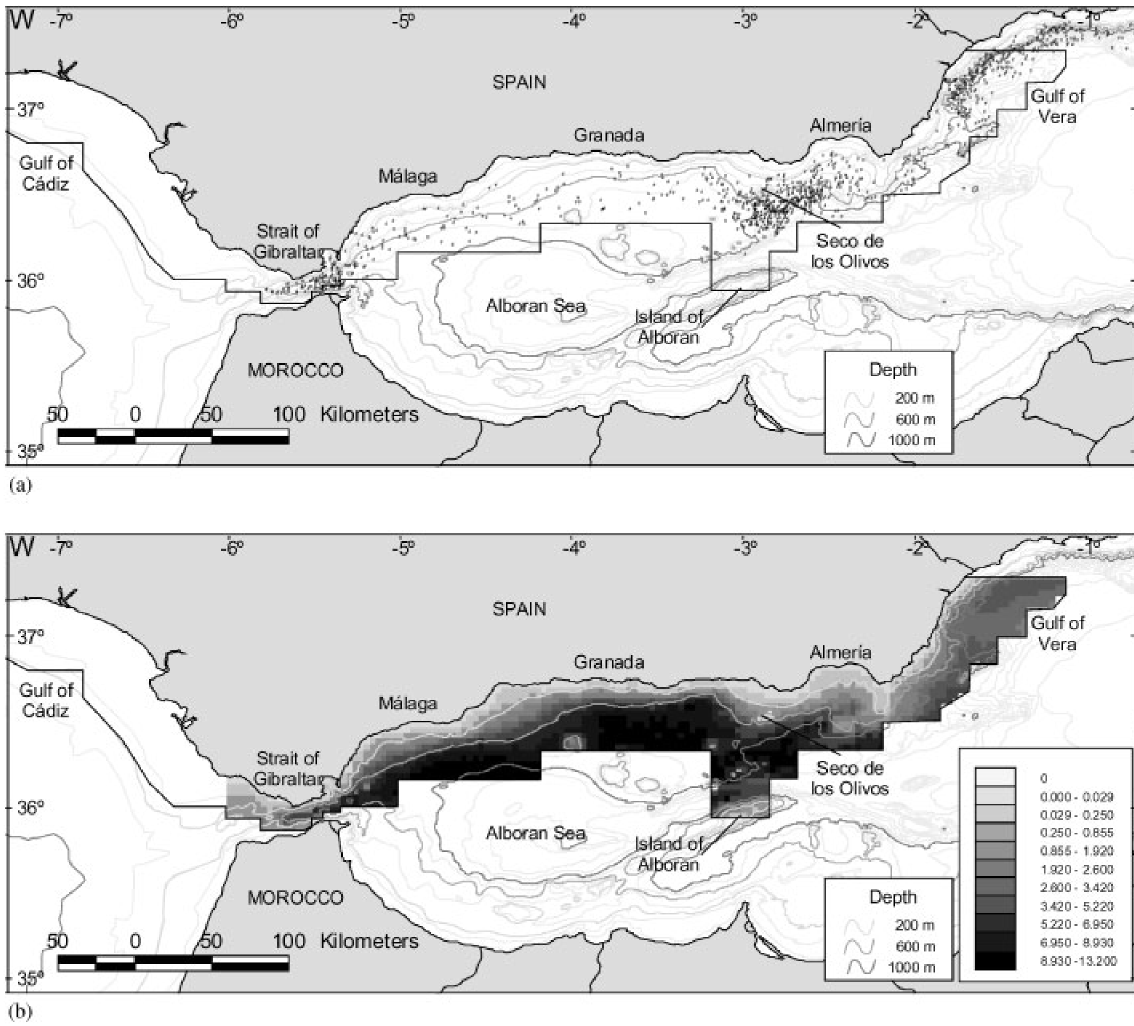

Figure 4. (a) Sightings of striped dolphins. (b) Prediction of relative density of striped dolphin in the research area.

Risso's dolphin

The Risso's dolphin was mainly confined to the eastern half of the Alboran Sea and the Gulf of Vera, where it was encountered in all seasons (Figure 6(a)). Encounter rates and group sizes increased from west to east, the exception being around the Island of Alboran where the high sighting rate was due to a single sighting being combined with low effort (Table 4). Its distribution was similar to that of the long-finned pilot whale (with the exception of the Strait of Gibraltar, where it was absent), but with a slightly more restricted area and in deeper waters. The predicted areas were the deep waters off southern Almería, greater than 600 m depth (especially greater than 800 m) and the deep waters of the Gulf of Vera (Figure 6(b)).

Beaked whales

Most beaked whale sightings were classified as 'unidentified species of beaked whale' ($n=25$). All sightings identified to species were of Cuvier's beaked whale, *Ziphius cavirostris* ($n=13$), or northern bottlenose

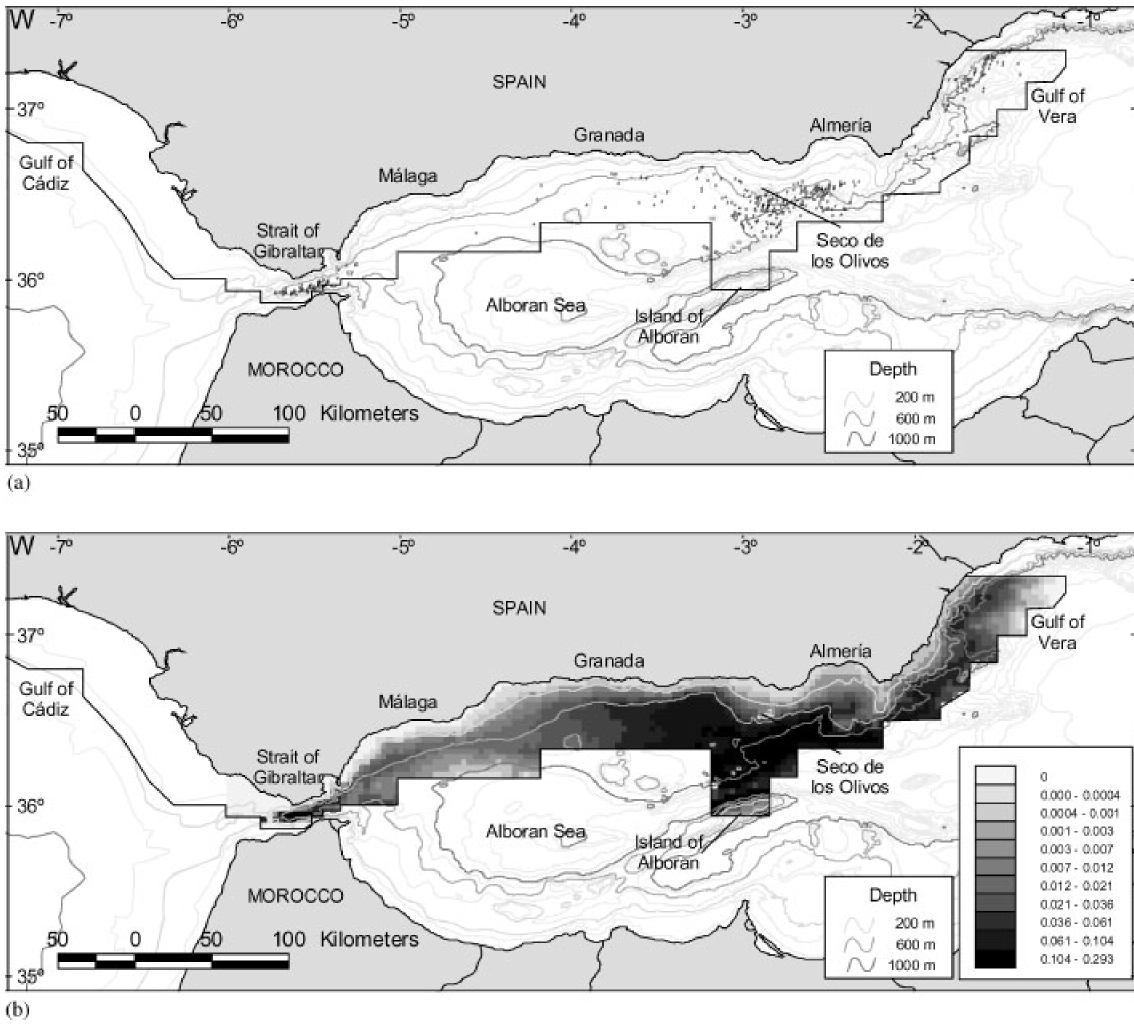

Figure 5. (a) Sightings of long-finned pilot whales. (b) Prediction of probability of occurrence of long-finned pilot whale in the research area.

whale, *Hyperoodon ampullatus* ($n = 4$). The beaked whales had the most restricted distribution of all species and they were mainly confined to the deep waters off southern Almería, with a few sightings in the Gulf of Vera (Figure 7(a)). The highest encounter rates were obtained for Almería and around the Island of Alboran (Table 4). In the latter case this was due to a single sighting and low effort. The area with the highest predicted occurrence was around the 1000 m isobath off southern Almería and the deep waters north of the Island of Alboran (Figure 7(b)).

Sperm whales

The sperm whale showed a wider distribution than the beaked whales. The highest encounter rate was found in the Strait of Gibraltar (Figure 8(a), Table 4). This species showed two areas of high predicted

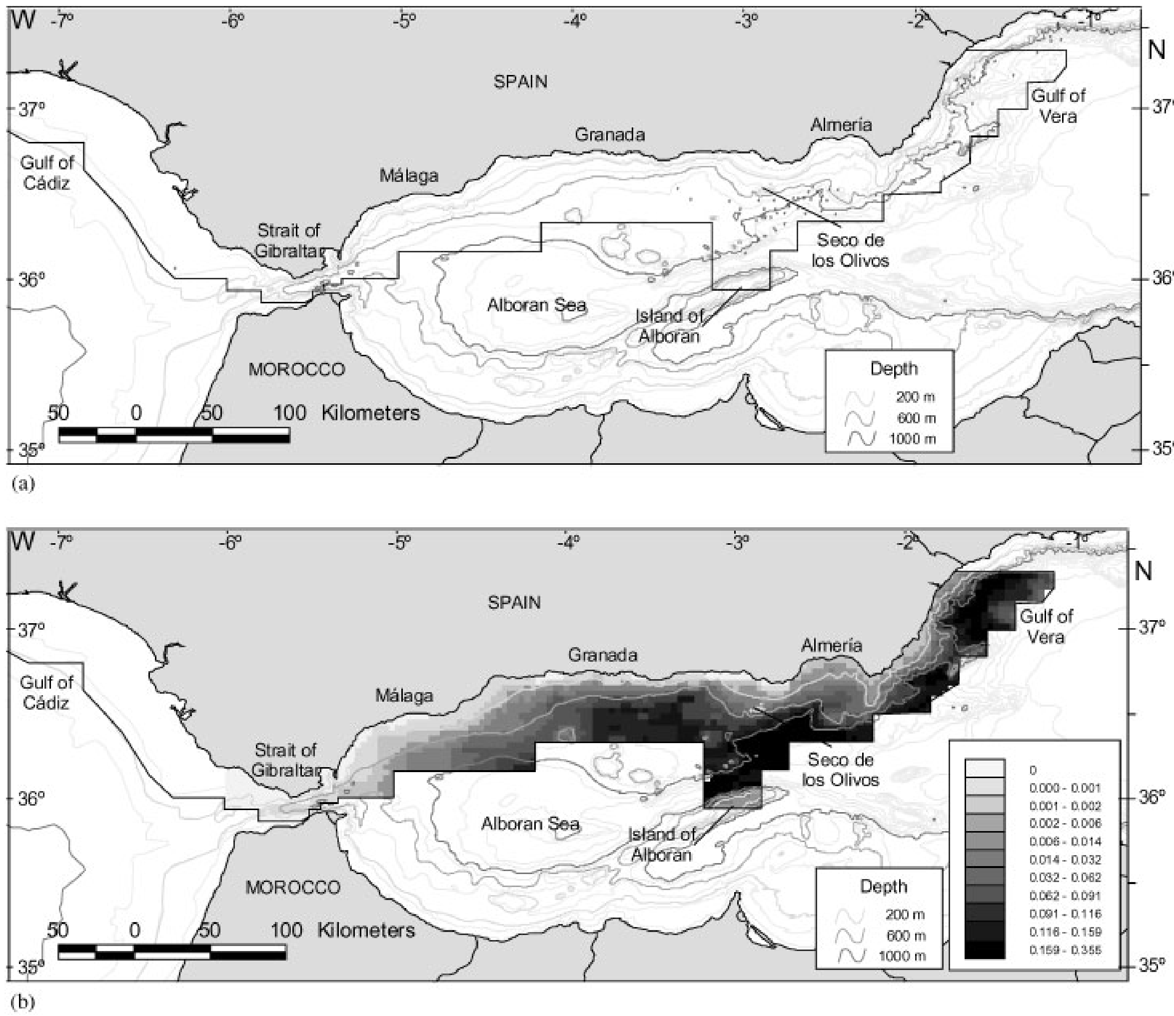

Figure 6. (a) Sightings of Risso's dolphins. (b) Prediction of probability of occurrence of Risso's dolphin in the research area.

relative density, the most important being the Strait of Gibraltar followed by the deep waters south of Almería (Figure 8(b)).

Proposed marine protected areas

The results obtained from the habitat preference modelling identified those areas of higher relative density of each cetacean species and, therefore, by implication more important for their conservation.

Special Areas of Conservation

Three areas were identified as candidates for SAC on the basis of their importance for common bottlenose dolphins (Figure 9), as inferred from three nuclei of high predicted relative density: in the Strait of Gibraltar; around the Seco de los Olivos seamount; and around the Island of Alboran. We have proposed areas that extend from the coast to the limit of territorial waters, to facilitate the implementation of future

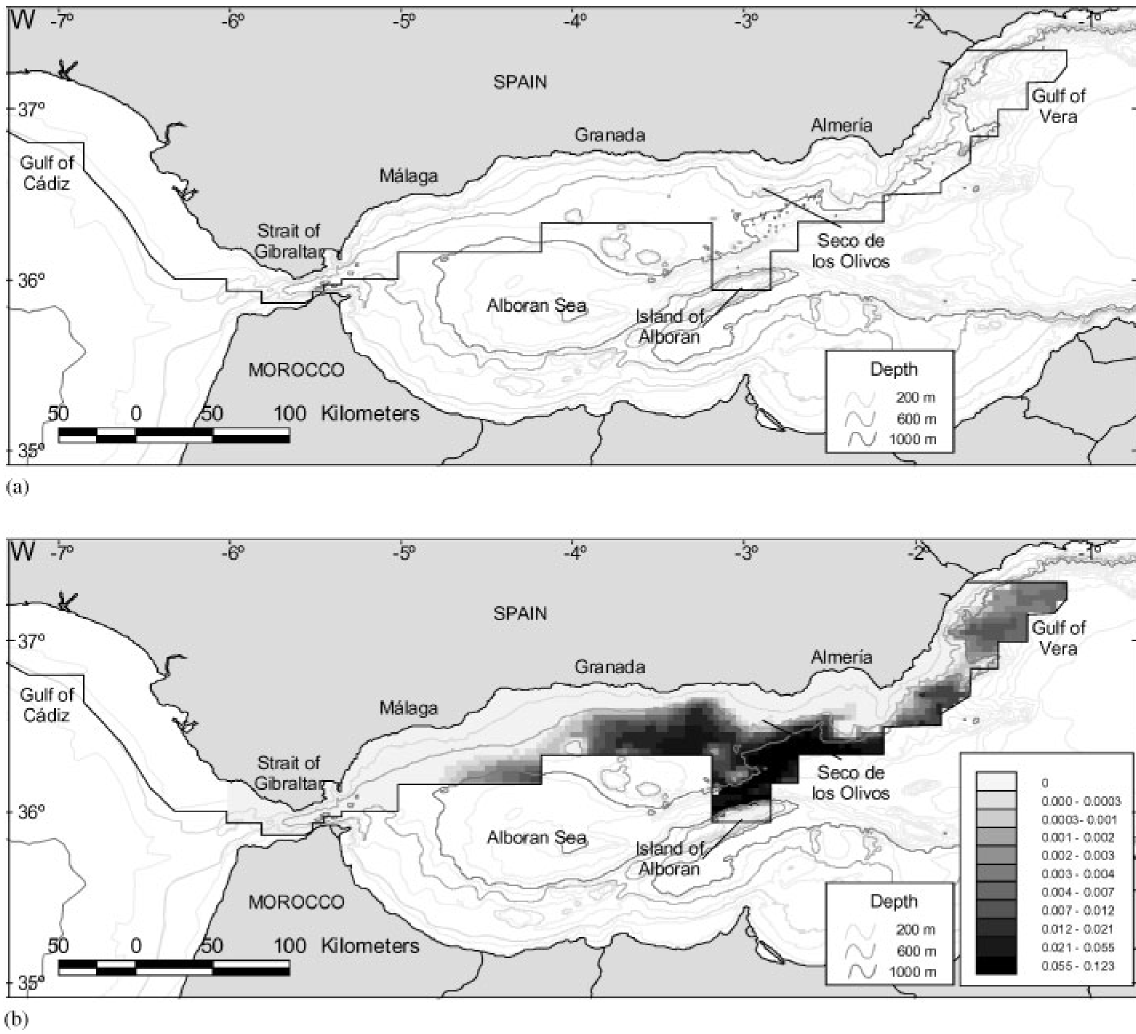

Figure 7. (a) Sightings of beaked whales. (b) Prediction of probability of occurrence of beaked whales in the research area.

management plans by national agencies (except in the Strait of Gibraltar where the boundary was defined slightly to the south of this limit to include the grid cells with higher density). In accordance with the guidance that at least 60% of the principal habitats are covered (CTE/CN, 1996), the sites proposed cover 82% of the grid cells with predicted medium or high relative density. Some 86.5% of the groups and 93.2% of the individuals were sighted within these areas, despite only 54.9% of the total searching effort being conducted there. The average encounter rates within these areas ($0.54\,\mathrm{nmi}^{-1}$) were an order of magnitude greater than outside them ($0.05\,\mathrm{nmi}^{-1}$), and the average value of estimated relative density was five times greater inside than outside the areas.

Specially Protected Areas of Mediterranean Importance

Based on the predicted high and medium density areas for the species analysed, as well as an evaluation of the criteria for cetaceans (a) to (g) listed in the methods section, a SPAMI covering the northern half of the

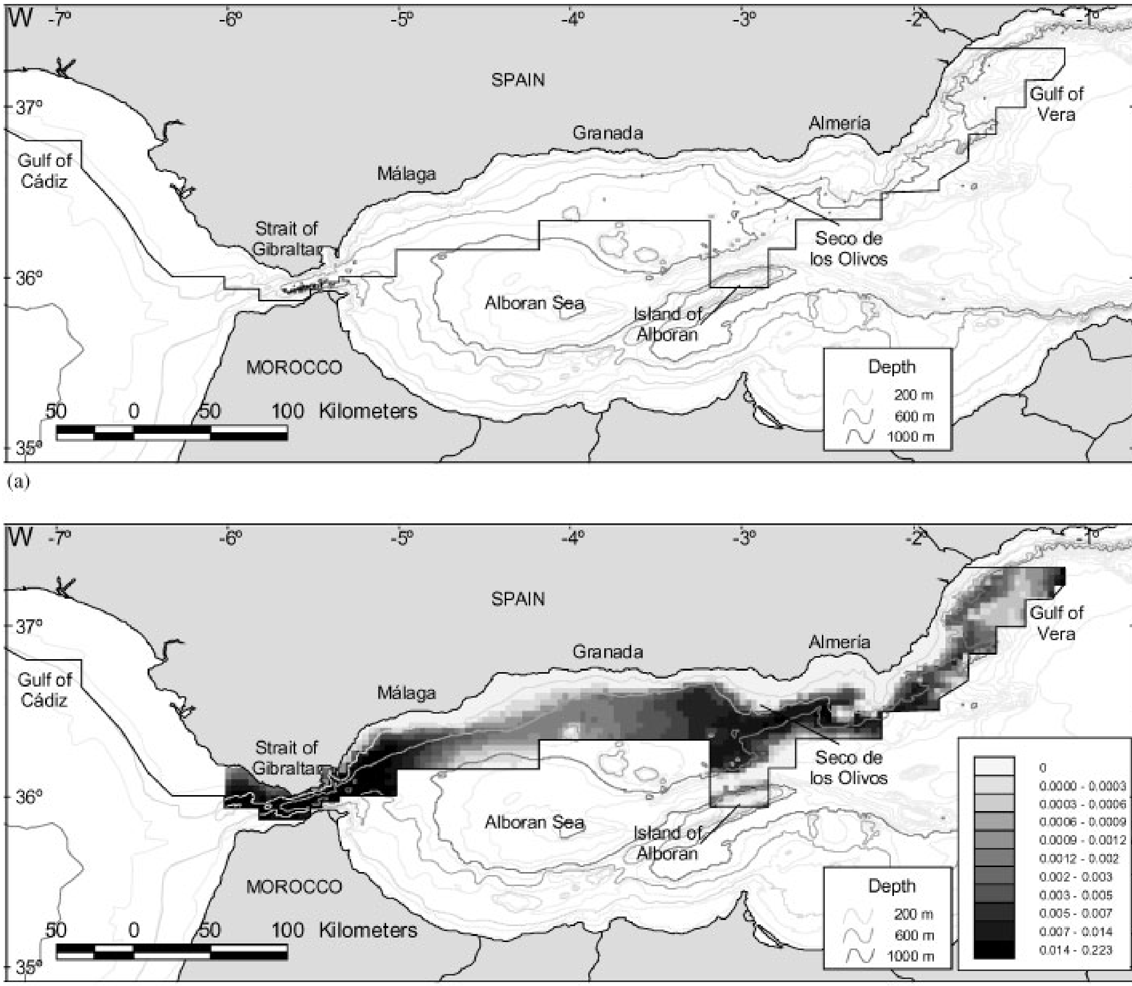

Figure 8. (a) Sightings of sperm whales. (b) Prediction of probability of occurrence of sperm whale in the research area.

Alboran Sea and the whole Gulf of Vera (Economic Exclusion Zone of Spain) is proposed for the conservation of all cetacean species present in the area.

DISCUSSION

Assumptions of the models

For the models used here the most important assumptions are: (a) correct species identification; (b) unbiased estimated group size; (c) equal probability of success in finding animals for all units of effort (sampling units); (d) no change in the distributions of the variables that characterize the different habitats during the timeframe of the study; (e) correct identification of places available to the animals and equal access to all available habitats; (f) correctly identified variables that influence habitat preference; and (g) correctly classified (i.e. used or not used) habitats (Alldredge *et al*., 1998; Boyce and McDonald, 1999). How well these assumptions were met is discussed below.

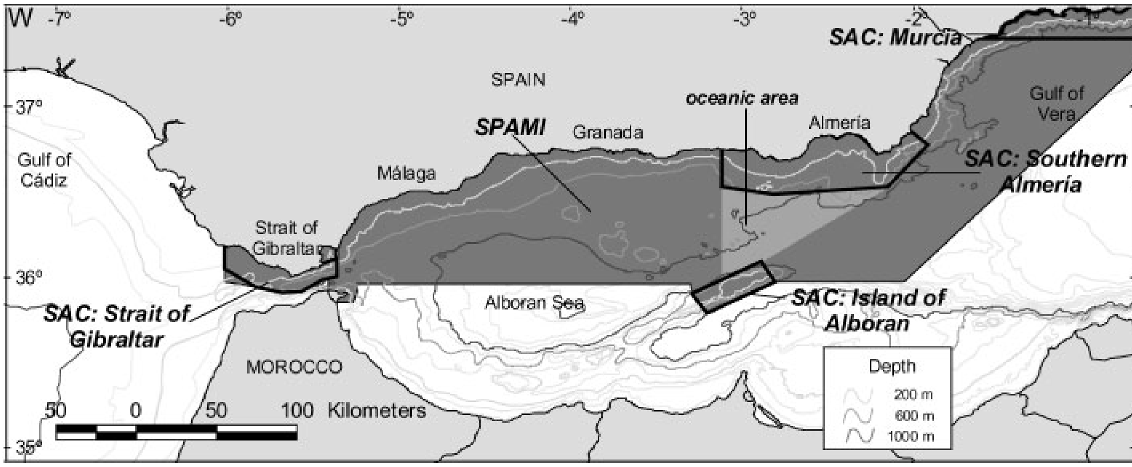

Figure 9. Proposed marine protected areas: SPAMI (dark grey area) and the three SAC: Strait of Gibraltar, Island of Alborán and Southern Almería. In the north-eastern section of the map the existing SAC for bottlenose dolphins in the contiguous area of Murcia is shown. The important oceanic area of the deep waters off Southern Almería within the SPAMI is highlighted (light grey).

We are confident that assumption (a) was met for most species — if species identification was uncertain, the sighting was recorded as 'unidentified' and was not used in the analysis (apart from the aggregated beaked whale sightings where it was sure that all were beaked whales although they could not be identified to species). With respect to assumption (b), for those species for which school size was modelled, sightings with uncertain group sizes were not used in the analysis and a visual inspection of the data was sufficient to confirm that this did not result in any bias in the analysis.

Although assumption (c), that there was an equal probability of finding animals for each unit of effort, was formally violated (effort segments ranged in length from the minimum threshold value of 0.2 nmi (0.4 km) to the maximum grid cell diagonal distance of 2.5 nmi), we do not believe that this is serious in practice for two reasons. Firstly, the relatively small size of the grid cells (1.6 by 2 nmi: 3 by 3.7 km) combined with the fact that groups were detected at an average distance of 0.7 nmi (1.3 km) from the survey vessel, meant that even a short passage over a grid cell would allow a large proportion of it to be visually covered. Notwithstanding this, given that correlation between segment length and an explanatory variable could lead to bias, a visual inspection of the scattergrams showed no such correlations for any of the variables. Secondly, although the assumption could also be violated if there was an heterogeneous distribution of variables affecting sighting conditions (and thus detection) per unit of effort, visual inspection of the data showed no trends in the sighting conditions for any of the variables, except a slight one in the case of depth (better conditions in deep waters). Although this might lead to a slightly higher probability of detecting cetaceans in deeper waters, the fact that some species had a higher preference for shallower waters suggests that the possibility that the results were much affected is small.

With respect to assumption (d), the only variable used that changed during the study period was sea surface temperature (sst). However, although the absolute values may vary annually, the general oceanographic features captured by the sst variables remain similar every year (Rodríguez, 1982; La Violette, 1986; Millot, 1987; Tintoré *et al.*, 1988). As noted above, given the fixed temporal nature of the MPAs, interannual and seasonal variation were not intended to be captured in our model predictions. There is no violation of assumption (e) that all habitats are equally available.

Assumption (f) is difficult to meet in any study. When attempting to determine important habitat features to explain species' habitat preferences, one can only use the available data to describe habitats even if that does not completely categorize them from the perspective of the target species; clearly there may be other unmeasured variables with the potential to explain variability in the data. Nevertheless, even an incomplete description is valuable both to improve understanding of how at least some factors affect distribution and to inform the selection of the best areas for MPAs. As more information becomes available, the models can be rerun and adjustments made to recommendations, as appropriate.

Whether or not assumption (g) is fulfilled, depends on how 'used' is defined. Our models were not intended to predict areas by behavioural category (e.g., feeding, resting, travelling) but rather to predict areas that the animals prefer, regardless of their activity.

A further potential problem to consider is the possible spatial autocorrelation of sightings collected along continuous transects due to clumping of observations, for reasons unrelated to habitat preference, e.g. social behaviour. If this occurs and is not taken into account, habitat preference models might generate false relationships and thus erroneously identify those features of the environment that most influence distribution. This appears unlikely in this analysis because the data were collected from multiple independent transects over many years. In order to examine whether there was any variability in the data unexplained by the models that could be explained spatially, we visually inspected semivariograms of the residuals of the model fits as a function of distance. Spatial autocorrelation would result in a higher semivariance at shorter distances but in all cases the variograms were flat. Thus, we conclude that there was no spatial autocorrelation.

Proposed marine protected areas

From a cetacean perspective, it should be noted that the Habitats Directive only allows the creation of protected areas for common bottlenose dolphins and harbour porpoises. It thus is not a useful direct management tool for the conservation of other cetacean species, even if they are equally or even more threatened. At least for the Mediterranean, therefore, the SPAMI instrument represents a potentially important complementary measure for the adequate conservation and management of cetacean populations and their habitats in the Mediterranean Sea.

SAC for the Habitats Directive

At present, one SAC for common bottlenose dolphins in the region of Murcia has been accepted by the Spanish Government in 2000 (ES6200048 Medio Marino) as a result of a proposal by SEC, the Spanish Cetacean Society.

The following three proposed SAC are currently being evaluated by the local government of Andalucía and the Spanish Ministry for the Environment. Although SAC are only directly relevant to the common bottlenose dolphin and harbour porpoise, many of the actual and potential threats to them are also shared by other cetacean species. Indirectly, therefore, conservation plans developed for SAC may benefit other cetaceans occupying the same areas; such threats are also identified in the discussion below.

SAC 1: Strait of Gibraltar

The proposed SAC for the Strait of Gibraltar (1120 km^2) has been extended slightly to the north-west from the area derived from the model results to include the only region where harbour porpoises are now seen in the western Mediterranean (observations by the authors; M. Morcillo pers. comm.). The harbour porpoise is also found in the Aegean Sea (in the far eastern Mediterranean) but is apparently absent in the rest of the Mediterranean basin (Frantzis *et al.*, 2001).

The proposed SAC represents preferred habitat for several other species, especially short-beaked common dolphins, striped dolphins, long-finned pilot whales and sperm whales; fin whales (*Balaenoptera physalus*) and killer whales (*Orcinus orca*) are also found there regularly. Whaling data suggest that this was an important area for sperm whales and some baleen whales in the past (Aloncle, 1964; Aguilar and Lens, 1981; Bayed and Beaubrun, 1987; Sanpera and Aguilar, 1992). The Strait also represents the primary route of movement (and gene flow) between the Alboran Sea and north-eastern Atlantic populations of some species such as the short-beaked common dolphin (Natoli *et al.*, 2001).

A conservation plan to address the main anthropogenic threats for common bottlenose dolphins in the area must address: chemical and other physical pollution in the form of contaminants, plastic debris and sewage from Gibraltar and Algeciras; oil from ships crossing the Strait and the shipyards and harbours of the area; bilge-cleaning, particularly from the large number of tankers around the port of Algeciras and the oil refinery; acoustic pollution and ship strikes due to intense maritime traffic; and whale-watching operations, which are growing rapidly in the area (Alnitak — Universidad Autónoma de Madrid, 2002). Such a plan would also benefit other cetaceans, within both Spanish waters and the western Mediterranean Sea.

SAC 2: Southern Almería

The area south of Almería (2534 km^2) was also identified as an area of importance for the common bottlenose dolphin (and see Cañadas *et al.*, 2002). It includes the Seco de los Olivos seamount, which had the second highest encounter rate of this species (3.4 nmi^{-1}; 1.8 km^{-1}) within the research area and the highest predicted relative density. Preliminary results of photo-identification studies (that allow individuals to be recognized) have shown that the groups in the area of Almería are resident (year round and over several years) and also occur in the region of Murcia, in the northern part of the Gulf of Vera (S. García-Tiscar, pers. comm.). The latitudinal trend in predicted relative density in the Gulf of Vera coincides well with observations made during previous years and the proposed SAC would link well with the existing Murcian SAC (Figure 9).

With respect to other cetacean species, our modelling predicts that the area is important for striped and Risso's dolphins, long-finned pilot, beaked and sperm whales and particularly short-beaked common dolphins. The area has one of the highest concentrations of small pelagic fish in the Alboran Sea (Rodríguez, 1990; Gil, 1992; Rubin *et al.*, 1992; Rubín, 1994; Giráldez and Abad, 2000), which are the main prey for short-beaked common dolphins elsewhere (Young and Cockcroft, 1994; Kenney *et al.*, 1995; Cordeiro, 1996; Santos *et al.*, 1996).

A conservation plan to address the main anthropogenic threats for common bottlenose dolphins in the area must address: over-exploitation of fish resources (this area supports intense fishing activity, both commercial and for sport); mechanical destruction of the sea bottom caused by the large number of trawlers operating in the area; chemical pollution from the intense agriculture in greenhouses which uses large amounts of plastics, pesticides and chemical fertilizers; non-treated sewage from coastal towns; and oil spills produced by the intense maritime traffic in the area (Alnitak — Universidad Autónoma de Madrid, 2002).

SAC 3: Island of Alborán

The Island of Alboran and its surroundings have attracted increasing interest by competent authorities in marine conservation (Pinilla, 2001). This area already contains a Fisheries Reserve, a Natural Site and an SAC proposed by the local government of Andalucía (ES6110015 Isla de Alborán) because of the high ecological value of the area and the need to protect some of the most valuable coastal and marine habitats of the Mediterranean (Pinilla, 2001). Our study predicted that this was an area of high importance for the common bottlenose dolphin, hence we propose an increase in the size of the existing SAC to include all territorial waters around the island (774 km^2).

A conservation plan to address the main anthropogenic threats for common bottlenose dolphins in the area must address the most important threats (Alnitak — Universidad Autónoma de Madrid, 2002), all of which are related to fishing: overfishing; the mechanical destruction of the sea bottom by trawlers from

Spain and other countries; and the use of driftnets, which are illegal in Spanish waters but still commonly used by Moroccan fleets (Tudela *et al*., 2003). To a lesser extent, the uncontrolled increase in diving activities also creates perturbation and destruction of the sea floor.

SPAMI (Barcelona Convention)

The proposed SPAMI includes both inshore and offshore areas (including the three proposed SAC). It contains preferred habitats for several cetacean species and meets all the important specific SPAMI criteria for cetaceans.

The proposed SPAMI has the highest encounter rate for long-finned pilot whales within the whole Mediterranean basin (Cañadas and Sagarminaga, 2000) and will link the population nuclei of this species in the Strait of Gibraltar and the Almería–Gulf of Vera area.

The short-beaked common dolphin is believed to have suffered a steep decline in the Mediterranean in recent years and the Alboran Sea is at present the most important remaining habitat for this species in the basin (Bearzi *et al*., 2003). Predicted areas of importance for the short-beaked common dolphin not covered by the proposed SAC include the coastal waters off Málaga and Granada (Figure 3(b)).

In general, offshore areas of importance to cetaceans have received little conservation attention, although a few precedents exist in the north-west Atlantic (e.g. Ward, 1995; Hooker *et al*., 1999) and the Ligurian Sea Pelagos Cetacean Sanctuary in the Mediterranean (www.cetaceansanctuary.com). Thus, in this context, it is important to highlight the oceanic area south of Almería.

In the deep waters south of Almería, there is a high diversity of cetaceans and the habitat preference models clearly showed its importance for the oceanic species, which are mainly teutophagous (beaked whales, Risso's dolphin, long-finned pilot whale, sperm whale and striped dolphin) as well as for short-beaked common and common bottlenose dolphins.

The importance of this proposed SPAMI for cetaceans reflects the richness and diversity of this region; the wider (non-cetacean) criteria for the selection of SPAMIs (see footnote 2) also support the proposed area. This region is the only natural passage connecting the Mediterranean Sea with the Atlantic Ocean and is considered the 'hydrological motor' of the western Mediterranean basin (Rodríguez, 1982). Its complex oceanography also makes it one of the most productive regions of the Mediterranean (Rodríguez, 1982; MOPU, 1991; Rubín *et al*., 1992) with great diversity of fauna and flora (Templado *et al*., 1993; EEA, 1999; Pinilla, 2001). It contains endangered habitats (e.g. *Cystoseira* and *Dictyopteris membranacea* forests, coral reefs; Pinilla, 2001) and habitats important for other endangered or protected species of fauna and flora, such as the loggerhead turtle (*Caretta caretta*, included in Annex II of the EU Habitats Directive), and several species of fish, marine invertebrates and algae (UNEP, 1996; Pinilla, 2001). In addition, large portions (i.e. the oceanic waters and large coastal sectors) of the proposed area remain largely pristine. The ecological processes (e.g. the anticyclonic gyres, the Almería-Oran front; Gascard and Richez, 1985; Parrilla and Kinder, 1987; Tintoré *et al*., 1988) and habitat types (e.g. *Posidonia oceanica* and *Cystoseira* sp. prairies; Pinilla, 2001) are particularly representative and important for the Mediterranean Sea. The region thus has high scientific research value (oceanography, geology, marine biology, ornithology and marine mammalogy) and represents an important potential site for educational and public awareness purposes. Thus, from a number of perspectives, the designation of this region as a SPAMI, and the consequent development of a management strategy, would constitute an important step in the implementation of the Barcelona Convention.

From the perspective of cetacean conservation, a large-scale MPA such as this proposed SPAMI better matches the large spatial requirements of the cetacean populations that are at present being fragmented in the Mediterranean region (Notarbartolo di Sciara *et al*., 1993; Bearzi *et al*., 2003). It can also play an important role by connecting the proposed SAC for common bottlenose dolphins as well as connecting with the existing SAC in Murcia. In fact, an integrated management strategy applied to the whole area would probably be more significant for the conservation of cetacean species than the development of specific management plans for relatively small MPAs such as the SAC. Even if management plans are successfully developed and implemented for small MPAs, without some connectivity amongst them, their conservation objectives might not be fully achieved.

However, it is essential that any SPAMI has a clear set of conservation and management objectives and a specified plan to achieve these by addressing actual or potential threats to the species in the whole area. This includes dealing with existing problems as well as taking action to continue to preserve areas that at present are relatively pristine. Issues to be addressed include those listed above for the SAC (e.g. stricter enforcement of existing fisheries legislation including the driftnet ban, overfishing) and measures to ensure minimal impact of development activities (e.g. those related to oil exploration, chemical and noise pollution). A particular problem recently identified involves the use of high-powered acoustic devices (both military and scientific). This is especially important for beaked whales, which are vulnerable to certain military activities (Frantzis 1998; IWC 2001; Fernández *et al.* in press). These species have the most restricted distribution in our research area, and overall their distribution is mainly confined to the oceanic area south of Almería. An initial management action has been taken already by the Hydrographic Office of the Spanish Navy, which has agreed not to use active sonar in the deep waters south of Almería (C. Gamundi[4], pers. comm.).

Habitat preference modelling as a conservation tool

The present study has illustrated the value of habitat preference modelling as a tool to help identify potential MPAs. The analyses incorporate data on the environment to generate a spatial prediction of relative density based on the preference for habitats defined by combinations of environmental covariates. The areas identified for the candidate MPAs thus provide the best description of distribution available, as informed by features of the habitat that are shown to be important. This represents a great improvement over using simple measures of animal occurrence such as simple distribution maps or encounter rates. This can be seen by comparing the predicted distribution map for common bottlenose dolphins (Figure 2(a)) with the encounter rate map given as Figure 10. The model approach allows the creation of continuous areas of highest predicted relative densities and the generation of MPA boundaries that can incorporate given proportions of predicted relative abundance. The use of a long time-series of data as in this study also minimizes the likelihood of false correlations and the choice of inappropriate boundaries — a risk with 'snapshot' studies of highly mobile species such as cetaceans.

Another feature of the approach adopted here is that areas with apparently good habitat but few sightings can be identified where this is due to low searching effort. One example of this is the predicted area of medium to high relative density for common bottlenose dolphins off Málaga, south of Punta Calaburras (Figure 2(b)). It will be worth exploring this area more intensely in future field studies to evaluate this prediction and reconsider possible recommendations for this area. Lack of sightings may also reflect unmodelled features of the areas that are influencing distribution. Either way, the identification of such areas is useful for developing future research or monitoring programmes.

An advantage of the approach is that models can be refitted to incorporate both new sightings and expanded environmental data to clarify preferences (and associated mechanisms) and explore whether habitat preference appears to be changing. Reassessing the relationships between relative abundance and environmental covariates is a useful way of monitoring how well the MPA is likely to be affording protection. It also provides a focus for more detailed studies to explore the mechanisms determining cetacean distribution and hence a better prediction of the effects of anthropogenic factors on their conservation status.

[4]Subdirector of the Hydrographic Office of the Spanish Navy.

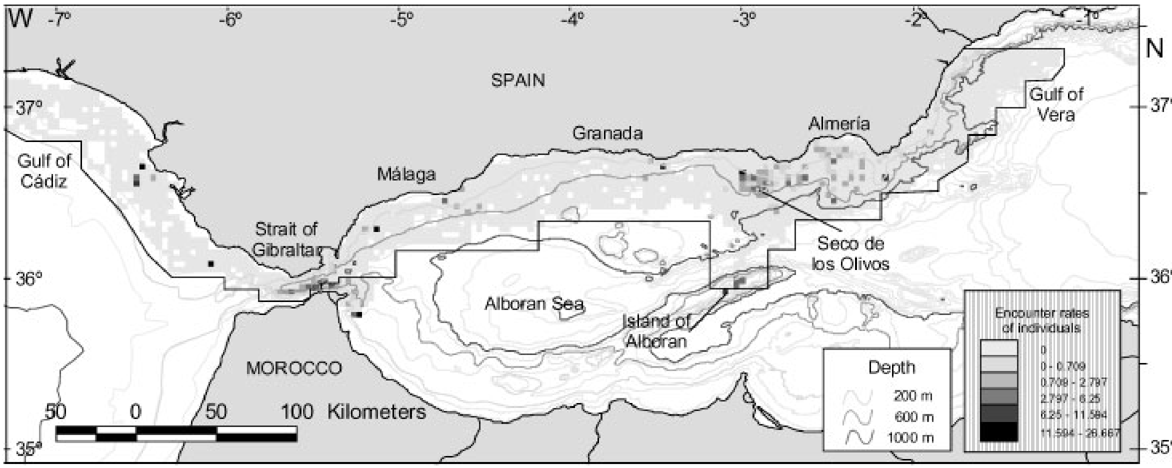

Figure 10. Encounter rates of common bottlenose dolphin in the study area (1992 to 2002).

The focus of this study has been the use of habitat preference modelling as a tool to select areas for proposed MPAs. We have not explicitly considered whether the designation of MPAs is the most appropriate solution to the problems facing cetaceans in the Alboran Sea. Clearly, the conservation of cetaceans requires the development of appropriate and effective conservation strategies. The creation of MPAs may represent one step in this process, and may serve the purpose of involving policy makers and the public — without which the probability of success will be small. However, without the appropriate implementation of management plans, MPAs only represent 'paper parks' that provide a false impression of conservation success (Duffus and Dearden, 1995). As a general rule, the designation of MPAs should not be seen as an alternative to the wise management and conservation of the whole ocean environment. Whether a particular MPA is effective will depend on the initial objectives, its design (especially its boundaries) and its enforcement (Boersma and Parrish, 1999). The critical steps are to set clear, quantified conservation objectives, develop a well-supported long-term management plan to achieve these objectives (Gubbay, 1995; Salm *et al*., 2000), and establish an effective monitoring programme to assess whether or not the conservation objectives are being met.

It is essential that sound science provides the basis for area designation and monitoring goal attainment, as well as providing guidelines for the establishment of the conservation objectives and the development of the management strategy (Boersma and Parrish, 1999; Hooker and Gerber, 2004). However, to date, little scientific rigour has been applied to the designation of MPAs or to the assessment of their effectiveness (Hooker and Gerber, 2004), although this has been increasing during the last decade (Schwartz, 1999; Gerber *et al*., 2003). Our work provides not only a robust scientific approach for the designation of MPAs but also a tool for the objective measurement of their success through monitoring to assess future habitat use both inside and outside the selected areas.

Implications for conservation in the region

This study has made an important contribution to the implementation of the Habitats Directive by the Spanish government, by providing a scientific basis for the definition of SAC to promote the conservation of common bottlenose dolphins in Southern Spain. It also provides valuable information to inform the conservation objectives and management plans for these areas.

It has also highlighted areas that are important for groups of cetacean species. The creation of MPAs that cover identified hotspots for cetaceans, supported by the development and implementation of an effective management strategy, should help the conservation of these species in the region more cost effectively than single-species management initiatives. Furthermore, our results have brought to the attention of several government administrations and international conservation organizations the importance of the Alboran Sea for the conservation of cetaceans and biodiversity in general, not only for Spain but also for the Mediterranean Sea as a whole. The ACCOBAMS Conservation Plan for the Mediterranean short-beaked common dolphin includes the Alboran Sea as one of the key areas for conservation of this species and management actions are being designed for this purpose (Bearzi *et al.*, 2004). This work has also contributed to the joint efforts of several research institutes and other organizations (the Spanish Institute of Oceanography, the University of Malaga, the Spanish Cetacean Society, IUCN and WWF) to promote the creation of an Alboran Sea MPA for the conservation of not only the cetacean species but also the whole of the biodiversity and ecological processes of this area.

In this regard, the development of conservation plans for the species, management plans for the proposed MPAs and long-term monitoring programmes to assess whether or not conservation objectives are being met constitute the main objectives of an ongoing EU LIFE Nature project (LIFE02NAT/E/8610) begun in 2002 in Andalucía and Murcia (http://europa.eu.int/comm/environment/life/project/index.htm).

A final important consideration for cetacean conservation in the Alboran Sea is that some management actions could and should be implemented whether or not specific MPAs are designated. As a minimum this should include the enforcement of regulations that are already in place but still need the political will and, in many cases, the necessary financial support, to be implemented adequately. These include the European ban on driftnets (Council Regulation (EC) No. 1239/98), limitations on fisheries catches (Spanish and European regulations on fishing quotas) and the MARPOL agreement on pollution (International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 (MARPOL 73/78)). In addition, additional steps should be taken to ensure the regulation of active acoustic activities (military sonar, seismic explorations, etc), reduction of fishing effort, and thus overfishing, and the control of incidental capture of cetaceans in fishing gear.

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