Towards conservation of dolphins in the Alborán Sea

Hacia la conservación de los delfines en el mar de Alborán

Ana Cañadas

PhD Thesis - European Doctorate

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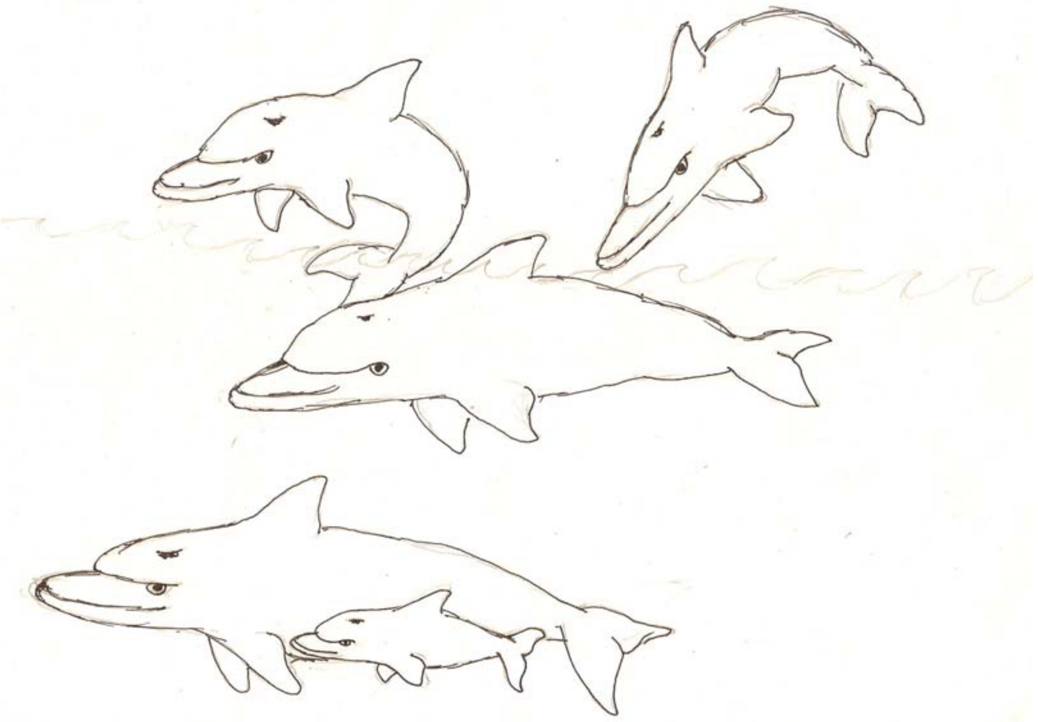
TOWARDS CONSERVATION OF DOLPHINS IN THE ALBORÁN SEA

HACIA LA CONSERVACION DE LOS DELFINES EN EL MAR DE ALBORÁN

Memoria presentada por la Licenciada Ana Cañadas Carbó para optar al grado de Doctor Europeo en Biología por la Universidad Autónoma de Madrid

Madrid, Febrero de 2006

Carolina – 8 years old



Claudia – 11 years old

Claudia – 11 years old

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Arturo Morales Muñiz, Catedrático de zoología del Departamento de Biología de la Universidad Autónoma de Madrid, por la presente

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CHAPTER 1

INTRODUCTION

1.1 CONSERVATION OF THE MARINE ENVIRONMENT

The concept of conservation of the marine environment is a young one. Until a few decades ago, the sea was considered an infinite space so that, on the one hand, it was taken for granted that the sea could provide resources without limits, and on the other hand, it was also assumed that the sea could cope with all our waste with no major consequences. Some time ago it was said that there was so much cod in the North Atlantic that one could walk on their backs to cross from Nova Scotia to Norway. Several decades later, neither this view nor the fisheries resources forecasts are so optimistic. Equally, the pollution of the marine environment, whether by solid debris, hydrocarbons or persistent toxic compounds, shows that the world's oceans have their limits to accommodate the waste materials produced by human activities.

1.1.1. Status, threats and conservation of the marine environment

The Mediterranean is a semi-enclosed sea. Its only connections with the world's oceans are through the Strait of Gibraltar and the Suez Canal. For oceanographers, this makes the Mediterranean a miniature ocean that constitutes an excellent laboratory to study some natural processes in a more manageable scale. Equally, in the field of conservation and management of the marine environment and its natural resources, this small 'laboratory' highlights the extraordinary complexity of this immense three-dimensional environment. It is fundamental to take into account this complexity as we try to conserve the marine environment, by managing the human activities in it.

The threats that are of concern nowadays in the Mediterranean Sea are basically the same that affect all world's seas and oceans: the unsustainable exploitation of natural resources (Pauly *et al.* 2002; 2003; Myers and Worm 2003); mechanical destruction of habitats (Schwinghamer *et al.* 1996; Auster 1998; Watling and Norse 1998; Norse and Walting 1999); degradation and habitat loss (Kemp 1996); acoustic pollution (Gordon and Moscrop 1996; Gordon and Tyack 2001); solid debris and toxic pollution (Morris 1980; EAA 1999; Reijnders *et al.* 1999; Aliani *et al.* 2003); global warming (e.g. MacGarvin and Simmonds 1996; Robinson *et al.* 2005); introduction of exotic species (e.g. Boudouresque and Verlaque 2002; Cangelosi 2004). In the origin of these threats to the marine environment we find, as for the rest of the planet, the increasing pressure of demographic growth that yields an intensification of activities such as navigation, construction, fishing, agriculture, aquaculture, mining, tourism, etc.

There is no doubt that the conservation status of the Mediterranean is a concern (EAA 1999). We can highlight some symptoms that justify this worry, reflected in the cetacean populations, which in this case can serve as approximate indicators of the health status of this sea at a local level. They include the reported gradual decline of bottlenose dolphin in the Mediterranean basin in the form of fragmentation of the populations (Notarbartolo di Sciara and Gordon 1996; Notarbartolo di Sciara 2002); the decline of the common dolphin in, at least, the northern part of the Mediterranean Sea (Bearzi *et al.* 2003); the accumulation of heavy metals and other persistent toxic compounds in the blubber of cetaceans (Borrell and Aguilar 1991; Aguilar *et al.* 1999; Aguilar *et al.* 2002); or the frequent observations of dolphins with feeding strategies taking advantage of the fishing gears (e.g. Fortuna *et al.* 1996; Bearzi and Notarbartolo di Sciara 1997), which could mean a shortage of food.

To establish measures to prevent human activities impacting too negatively on marine ecosystems is important for conservation of biodiversity, an important factor that affects humans directly. The overexploitation of resources and the alteration of habitats that lead to the decline or loss of species are worrying realities. When the consequences of certain anthropogenic pressures on the marine ecosystems are analysed, other dangers should also be included such as increased coastal erosion combined with changes in weather, the effects of which on human populations can be far greater. For example, when mangroves are removed from coastal areas by human activities (mainly due to the pressure for creating beaches for tourism development) they are more vulnerable to damage from tsunamis due to the lack of protection that was offered by the mangroves (Upadhyay *et al.* 2002).

One of the big limitations in the field of conservation of the marine environment is the difficulty of its study. Our poor knowledge of the oceans compared with knowledge of outer space is often highlighted. An example of this ignorance is the information obtained in recent years with the new techniques of satellite tracking. These have revealed data on the lives of pinnipeds, sea turtles or cetaceans that even the most audacious researchers could have not imagined (e.g. McConnell *et al.* 1999; Hays *et al.* 2002; Mate and Urbán-Ramírez 2003).

In the same way that the sea presents a challenge for its exploration and study, it also presents serious problems for its management. The surveillance of huge marine areas is a logistical and economical challenge that is difficult to face. This problem means that, probably more so than on land, we need to be able to convince those people and institutions that are stakeholders of this environment to follow, on their own initiative, the necessary guidelines or regulations, being conscious that in doing so all will benefit.

On the other hand, if the existing regional, national and international regulations and frameworks were respected and taken seriously, most of the problems would be solved. Besides local and national regulations we have also other tools such as the European Union Habitat Directive, the Barcelona Convention, the MARPOL agreement, the ACCOBAMS agreement, the United Nations UNCLOS Convention, the OSPAR agreement, etc. These are briefly described below.

There is no doubt that for the administrators of marine resources in many parts of the world, there are many problems, triggered by overexploitation of marine resources, conflicts in usage, overlapping jurisdictions, badly defined limits, and the direct or indirect degradation of coastal habitats caused by a variety of human activities. However, despite the magnitude of these problems faced by the administrators, there has been good progress during recent years in at least three main areas (Agardy 1997). In science-based management, there has been progress, *inter alia*, in the fields of population dynamics, systems ecology and physical oceanography that are being used to identify truly critical areas for protection if a healthy ecosystem is to be maintained. In the field of resource economies, progress in valorization and simulation has demonstrated that there are good incentives for management of marine and coastal areas. And in the field of sociology, there have been changes during the last decade in the way that the responsibility for environmental protection and resource management are being returned to the stakeholders, with some notable successes (see for example the marine reserve of the island of Tabarca, Alicante http://www.alicante-ayto.es/medioambiente/rmtabarca.html).

1.1.2. Marine Protected Areas

Despite the difficulties in investigating the marine environment, human impact on the sea is clearly 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 and habitats in response to human activities that have caused, or can cause, a negative effect on their status. One of the most common approaches to marine conservation is the establishment of marine protected areas (MPAs) (e.g. Gubbay 1995; Boersma and Parrish 1999; Schwartz 1999; Hyrenbach *et al*. 2000; Reeves 2000; Hooker and Gerber 2004). Although their effectiveness is the subject of much discussion (Boersma and Parrish 1999; Kelleher 1999), MPAs are considered nowadays as important tools for the conservation of biodiversity by many international frameworks (e.g. Barcelona Convention 1976; Bern Convention 1979; ASCOBANS 1991; OSPAR 1992; ACCOBAMS 1996; European Union's Habitat Directive 1992).

MPAs or marine reserves offer a solution to some of the challenges of the management of the marine environment. They allow the focusing of some conservation efforts or management actions at a geographical scale that is more tangible for the general public. In this way, marine reserves can allow the organisation of human activities through zoning, at the same time as preserving the natural attributes of the region and its value as a tool for public awareness and education.

MPAs may be the right solution in some cases for the conservation of certain critical habitats for feeding, reproduction or migration of some marine species. Nevertheless, their success as a conservation and management mechanism will depend on an adequate designation based on scientific studies of the habitats and species to be protected, and also on the involvement of the stakeholders with socio-economic interests in the area. Only when these requisites are fulfilled and when the management of the MPA is the result of a consensus in which all parties are benefited, can its viability and usefulness be possible.

In the selection of candidate MPAs in this work, we follow largely the process suggested by Salm *et al*. (2000) because no formal selection process for these areas exists. According to these authors, the initial step is to define the conservation objectives for the MPA. Once these have been agreed, the selection process should include four steps: (1) data collection (including bibliographic compilation and collection of new data with respect to the target species, human activities and threats); (2) analysis of the data (to determine the areas with concentrations of the target species, human activities and threats to the species); (3) data synthesis (to create maps to help establish the priorities for protection and a better understanding of the spatial relationships among the target species, ecological processes and human activities); and (4) application of selection criteria (to ensure objectivity in site selection, according to the objectives and the legal framework on which they are based).

In summary, the creation of MPAs may represent a step in the conservation process, and can help improve administrations and the public, without which the probability of success would be small. However, without an appropriate implementation of management plans, the MPAs would only represent 'paper parks' providing a false impression of conservation success (Duffus and Dearden 1995). As a general rule, the designation of MPAs should not be considered as an alternative to intelligent conservation and management of the marine environment as a whole. The effectiveness of an MPA will depend on its initial objectives, its design (especially its limits) and its implementation (Boersma and Parrish 1999). The critical steps are to establish clearly quantifiable conservation objectives, to develop a solid long-term management plan to reach these objectives (Gubbay 1995; Salm *et al*. 2000) and to establish an effective monitoring programme to determine if the conservation objectives are being accomplished.

1.2. CONSERVATION OF CETACEANS

It is very difficult to determine with accuracy the conservation status of species and their habitats (Simberloff 1998), and to determine the causes for a decline (see for example Bearzi *et al*. 2003). Generally, we might expect the combination of several threats to combine to cause a deterioration of conservation status.

The conservation of cetaceans is often a cause for concern. They are charismatic species that attract the interest of the general public and therefore it becomes easier to call attention to their conservation problems. For example, issues such as whaling (Sanpera and Aguilar 1992; Reeves and Reijnders 2002; Clapham *et al*. 2003) and fisheries by-catch (Slooten *et al*. 2000; Bearzi 2000; Reeves and Reijnders 2002; Dans *et al*. 2003; Tudela *et al*. 2005) are very visible threats that can even produce strong social turmoil. But there are other threats to cetaceans, not as socially visible, that also affect negatively their conservation status and potentially to a much greater extent. Some examples are the overexploitation of fishing resources, mechanical destruction of habitats by trawling or infrastructure construction, acoustic pollution, toxic pollution, collisions with vessels and harassment.

To regenerate the conservation status of species such as cetaceans is not an easy task (Harwood 2001). First, to have some probability of success, any management measure must be based on knowledge of the species, its ecology and its habitat. These are, or should be, the fundamental basis of the so called 'conservation biology', which basically tries to minimise habitat and biodiversity loss, and of the emerging 'restoration ecology', which tries to repair or recover habitats and biodiversity (Young 2000). A rigorous science constitutes the basic support for conservation with some guarantee of success (Boersma and Parrish 1999; Harwood 2001; Hooker and Gerber 2004). Science can provide information, among other things, on the size of the populations that are to be conserved, its distribution patterns, how the animals use their habitat and the impact of the threats over the populations and their long-term viability. It can, and must, contribute also to the identification of the most effective management actions.

But to maximise the success of conservation measures, it is also necessary to know, and use, conservation frameworks (agreements, legislations, etc.) in which such measures could be framed to give them more strength and legitimacy from an administrative stand point.

It is equally important to involve the stakeholders to reconcile the conservation of biodiversity with economic development. It is necessary to provide them with all the relevant information so they can understand that conservation benefits all in the short and long term, to involve them in the brainstorming and development of ideas on management measures in a fluid horizontal dialogue and to involve them in the whole development process for conservation measures and plans. Without the support and consensus of the stakeholders there would be no guarantee of success for conservation measures.

The fact that cetaceans are emblematic species can help promote actions for their conservation. However, something to be taken into account when trying to conserve emblematic species is that they are part of an ecosystem, and that it is not possible to conserve or recover a population without taking into consideration the ecosystem needs to support it (Simberlof 1998; Zacharias and Roff 2000; Harwood 2001). For this reason, conservation efforts focussed only on the species often end up in failure. There is now an increasing focus on conservation based on ecosystems, or a mix of both concepts (Simberloff 1998).

1.2.1. Legislation and management frameworks in relation with conservation of cetaceans in the Mediterranean Sea

The main objective of this work was to carry out research focussing on the conservation of the common and bottlenose dolphins in the Mediterranean and especially in the Alborán Sea and adjacent waters. However, as mentioned above, to promote their conservation it is essential to take into account not only the scientific information, but also those political and socio-economic factors involved in the conservation of a species and its habitat, as these are the forces that finally, hopefully based on scientific data, will make the decisions regarding the management actions. For this reason, it is necessary to know, in the first place, the legislation and frameworks in force regarding research and conservation of marine mammals, and in particular those dealing with small dolphins which are the target species for this work.

1.2.1.1. International frameworks

UNEP-IUCN

The International Union for the Conservation of Nature (IUCN) and the United Nations Environmental Programme (UNEP), carried out in 1994 a study on the conservation status of cetaceans in the context of the Mediterranean Action Plan (UNEP-IUCN 1994). In 2003 the Mediterranean subpopulation of short-beaked common dolphin was catalogued as “endangered” (EN) in the Red List of endangered species of the IUCN, based on criterion A2, which refers to a 50% decline in abundance over the last three generations, the causes of which ‘may not have ceased or may not be understood or may not be reversible’ (http://www.redlist.org). In the case of bottlenose dolphin, given its confused taxonomy and the considerable overlapping in their distribution ranges, both species (*Tursiops truncatus* and *Tursiops aduncus*) were listed in 1996 as “data deficient” (DF) until the situation is clearer. The other cetacean species of the Mediterranean have not been yet assessed.

Bern Convention

The Bern Convention relates to the conservation of wildlife and the environment in Europe (Bern 1979). Its objectives include guaranteeing the conservation of wild flora and fauna as well as their habitats, focussing especially on those species on the verge of extinction or vulnerable and including also migratory species included in its Appendix II of "Strictly Protected Species of Fauna". Included in this appendix is a list of 29 cetacean species among which are all those inhabiting the Mediterranean Sea. In 1989 the Bern Convention made a recommendation (recommendation nº 18) to its member parties to advance in the designation of Areas of Special Interest for Conservation to ensure that adequate measures would be taken for their conservation, and especially so where these were important for the survival of threatened or endemic species or those included in appendices I and II of the Convention.

Washington Convention - CITES

The CITES regulation controls the international trade of endangered species of fauna and flora and is obligatory to implement for member parties. Annex I of CITES includes all species considered in danger of extinction which are threatened by international trade of their products. Annex II includes all species that could become endangered if no strict controls are implemented on international trade. All cetaceans are included in Annex II.

Bonn Convention

The Bonn Convention deals with the conservation of migratory species. It was created in June 1979 and came into force in 1983 providing a special protection for migratory species listed in Appendix I. It also supports multilateral agreements between parties for the conservation, management and co-operation in research of migratory species included in Appendix II (in which all dolphin species inhabiting the Mediterranean Sea are included). Especially relevant in terms of cetacean conservation are three agreements reached by the member parties and included in Article 4 some years later. These are ASCOBANS, WADDEN SEAL and ACCOBAMS. ACCOBAMS is the only one that at present affects Spain (see below), although ASCOBANS area theoretically includes Spain and it is expected that our country will sign the agreement soon.

1. 2.1.2. Regional frameworks

Barcelona Convention

The Convention for the protection of the Mediterranean Sea against pollution (Barcelona Convention 1976), was modified in 1995 in Barcelona and given the name of "Convention for the Protection of the Marine Environment and the Coastal Regions of the Mediterranean". Among its regulations we can highlight its Protocol on Special Protected Areas and Biological Diversity of the Mediterranean (Monaco 1992), which gives a special protection status to endangered Mediterranean species and the habitats vital for their conservation, through the creation of a network of special protected zones for the Mediterranean (SPAMIs – 'Specially Protected Areas of Mediterranean Importance').

The Barcelona Protocol makes reference to the effects of human activities on the coastal and marine ecosystems of the Mediterranean. Special emphasis is put on the need to preserve the natural and cultural heritage of the Mediterranean. Moreover, the protocol calls for the need to adopt the necessary measures to know the distribution and habitat use of the species and searching for areas of highest natural value that should be given special protection in order to maintain favourable conservation status. The Convention includes an Annex II (Monaco 1996) with a list of species considered threatened or in danger that includes the dolphins of the Mediterranean Sea.

Among the aims of the areas of special protection is the preservation of habitats necessary for the survival of endemic, endangered or threatened species of flora and fauna. In the case of SPAMIs, these can include habitats that are important for endangered species.

Mediterranean Environmental Action Plan (MAP) - Action Plan for the conservation of the cetaceans in the Mediterranean Sea.

Adopted by the contracting parties of the Mediterranean Action Plan in 1991, this action plan has two broad objectives: 1) the protection of cetaceans and conservation of their habitats, and 2) the protection, conservation and regeneration of the cetacean populations of the Mediterranean Sea.

The Action Plan for the Conservation of Cetaceans urges Parties to develop co-ordinated research programmes to determine the conservation status and distribution of cetaceans in the Mediterranean Sea, highlighting the importance of using the most appropriate methodologies according to the research needs of different areas.

ACCOBAMS

The Agreement on the conservation of cetaceans of the Black Sea, Mediterranean Sea and Atlantic contiguous waters (ACCOBAMS) was developed in Monaco in 1996 under the Bonn Convention. Spain was the second country to ratify this agreement which was came into force in 2001. This agreement covers all cetacean species of the Black Sea, Mediterranean Sea and the contiguous Atlantic waters, but puts special emphasis on certain species such as the harbour porpoise (*Phocoena phocoena),* bottlenose dolphin *(Tursiops truncatus),* common dolphin *(Delphinus delphis)* and long-finned pilot whale *(Globicephala melas).* The aims of this agreement are to reduce the threats on cetaceans in the agreement area, to protect them and to establish a network of protected areas important for feeding, breeding and migration. It furthermore urges contracting parties to develop research and monitoring campaigns as well as public awareness and capacity building programmes.

1. 2.1.3. European Union frameworks

Habitat Directive

Within the context of the European Union, the Habitats Directive 97/62/CEE of the Council relates to the conservation of the natural habitats of wild flora and fauna. It includes in its Annex IV all cetaceans not included in its Annex II (bottlenose dolphin and harbour porpoise) as species of Communitary Interest that require strict protection.

For species listed in Annex II of the Habitat Directive (such as the bottlenose dolphin), there is a requirement to create 'Special Areas of Conservation' (SAC). Under Article 1(k) of the Habitat 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". 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 be accepted as part of the European NATURA 2000 Network of protected areas, the proposed SAC should demonstrate being of particular importance for the conservation of the species.

1. 2.1.4. National frameworks

Spain's Royal Decree 1997/95 y 1993/98

As a result of the incorporation of the Habitats Directive into Spanish National legislation, all cetaceans included in Annexes II and IV of the Directive are automatically included in Annexes II and IV of the Royal Decree 1997/1995 which establishes that the necessary measures must be taken to guarantee the maintenance of biodiversity by the protection of the natural habitats of wild flora and fauna. According to Article 10 of this Decree, cetaceans shall benefit from the conservation measures established by the Royal Decree 439/1990, which regulates the National Endangered Species Act and the law 4/1989 of the Conservation of Natural sites and Flora and Fauna reformed and modified both by the laws 40/1997 and 41/1997.

Spain's National Endangered Species Catalogue

Some cetacean species were included in Spain's National Endangered Species Catalogue in 1999. The common dolphin of the Mediterranean Sea, the bottlenose dolphin, the fin whale and the sperm whale were included in the category of "vulnerable". The remaining species were listed as "Of special interest" except for the beaked whales, which were not included in the Catalogue. The category of "Vulnerable Species" refers to species, subspecies or populations that are under threat of being included in the categories of "Sensitive to Habitat Alteration" or "Danger of Extinction" in the near future if the adverse factors affecting them are not mitigated by the adoption of appropriate measures. The law requires the establishment of a "Conservation Plan" for those species, sub-species or populations included in the category "Vulnerable".

1.2.2. Role of cetaceans in promoting marine conservation in the Mediterranean Sea

For a country like Spain, the conservation of the Mediterranean Sea goes well beyond the maintenance of certain ecological values which unfortunately are of concern only to a small section of the population at present. In this case, conservation affects the whole country because it depends directly on the Mediterranean marine ecosystem as it supports two of its major industries, fisheries and tourism.

According to the report of the European Environment Agency, "Mediterranean Sea: Environmental State and Pressures" (EEA 1999) that analyses the conservation status of this region, its resources and its problems, Spain will undergo an important economic growth along its coastal fringe.

This optimistic forecast, however, depends directly on a very important factor, which is the maintenance of a favourable conservation status of the Mediterranean ecosystem. Spain is therefore confronted nowadays with the important challenge of rectifying the present uncontrolled use and abuse of its marine resources to allow for an important economic growth based on the development of sustainable management.

The report of the European Environment Agency also highlights among the threats to the Mediterranean ecosystem, another key factor that is considered as one of the main problems for putting sustainable development in place. This is the fact that neither the local citizens nor the millions of tourists that use and enjoy the Mediterranean Sea, are aware that beyond the beach and the sun, there is in fact a very valuable ecosystem. Making people become aware of this is an important first step towards the conservation of the sea.

In this sense, charismatic species such as dolphins are useful tools as 'flagship species' that can be used to promote conservation campaigns because they stimulate the interest and sympathy of the public (Simberloff 1998; Hoyt 2005). A slogan such as "Save the anchovy" has little chance of success. However, dolphins are an extraordinary tool to sensitize the public about the functioning and importance of a marine ecosystem as the Mediterranean.

In the case of Mediterranean dolphins their utility is three fold: first, their important potential for public awareness (‘flagship species’); second, their utility as ‘umbrella species’ that have such large habitat requirements that saving them automatically means that many other species get saved too (Simberloff 1998); and third, their usefulness as ‘indicator species’ for the conservation status of the ecosystem at a local level (Katona and Whitehead 1988; Viale 1993). Placed at the top of the food web, dolphins can become, under certain circumstances, a useful tool to evaluate the conservation status of a marine ecosystem.

In this way, when considering the challenge of the designation and management of marine protected areas as conservation mechanisms, dolphins allow the creation of a direct link between science, environmental politics and the public, which is considered a key factor in the establishment of marine environment management strategies (Salm *et al*. 2000).

But to protect cetaceans effectively, we must also protect the organisms that live in the ecosystem and the ecosystem itself (Prideaux 2003), which means focussing on what is recently called ‘ecosystem-based management’ (Simberloff 1998; Hooker and Gerber 2004; Hoyt 2005).

As mentioned above, to ensure the efficiency of protected areas in the conservation and restoration of the marine environment, it is essential to basse designation on a thorough analysis taking into account both environmental and socio-economic criteria (Gubbay 1995; Boersma and Parrish 1999; Salm *et al*. 2000). In 1999, the Spanish General Directorate for the Conservation of Nature initiated the ‘Programme for the identification of areas of special interest for the conservation of cetaceans in the Spanish Mediterranean’ (see below), coinciding with the inclusion of several cetacean species in the National Catalogue of Endangered Species and the creation by the same Directorate of a marine biology and conservation experts working group for the development of important tasks such as the whale-watching law. This progress is a clear reflection of a growing interest in the previously unconsidered marine environment.

In January 1998, the Ministry of Environment presented to the public the first National Inventory of Cetaceans (Aguilar *et al*. 1994), resulting from a contract between this Ministry and the University of Barcelona. It clearly highlights in its conclusions the urgent need to start research programmes to assess the conservation status for several species of cetacean and the designation of MPAs.

Since the presentation of the National Inventory of Cetaceans, several meetings at the national (expert meetings convened by the General Directorate for the Conservation of Nature) or international level (e.g, Meeting of experts for the Implementation of the Action Plans for Marine Mammals UNEP, ARTA October 1998, Wokshop “Biological Monitoring of European Marine Special Areas of Conservation Workshop", in London in 1998) showed the increasing interest for the conservation of cetaceans and the importance of designating protected areas of special interest for conservation such as SPAMIs and SAC.

The ACCOBAMS agreement constitutes an important framework that also reflects the important role of cetacean research and conservation in the designation and monitoring of future areas of special interest SPAMIs in the Mediterranean. The signature by France, Monaco and Italy of the International Marine Sanctuary ‘Pelagos’ in the Ligurian Sea in November 1999, is a first step in this direction (Hoyt 2005).

1.2.3. Importance of the knowledge on cetacean distribution, habitat use and abundance to evaluate their threats and promote their conservation

One of the main obstacles when assessing the conservation status of cetaceans in the Mediterranean is the scarcity and heterogeneity, both spatial and temporal, of information available on the past and present of their populations in this sea (Notarbartolo di Sciara 1994; Notarbartolo di Sciara and Gordon 1996; Bearzi *et al*. 2003; Cañadas *et al*. 2004).

To adopt appropriate measures to maintain a favourable conservation status of the Mediterranean cetacean populations, such as the designation of MPAs, it is essential to have a clear picture of the identity of the population, its size, its habitat use and its distribution and dynamics. It is therefore clear that the first step required is the establishment of research programmes that fill in the gaps in our understanding of the ecosystem of which cetaceans are part and their role in it (Boersma and Parrish 1999; Harwood 2001; Hooker and Gerber 2004). A species is only part of an ecosystem and can not be treated individually as something isolated from it. Studying the role that a species play in its ecosystem is necessary to evaluate which changes can have a negative impact on their conservation status.

There are occasions in which management measures and policies must be established without having all the necessary data and information. This is what is know as the ‘Precautionary Principle’: “Management decisions should include a safety factor to allow for the facts that knowledge is limited and institutions are imperfect” and “The magnitude of the safety factor should be proportional to the magnitude of risk” (Holt and Talbot 1998). The necessity for precaution on cetaceans has been widely recognised (e.g. Mayer and Simmonds 1996; Slooten *et al*. 2000; Taylor *et al*. 2000), especially considering that cetaceans are long-lived species and therefore require long-term studies. Otherwise populations can decline to dangerously low levels before the management actions come into force if demonstration of the harm produced by certain human activities is required a priori (Thompson *et al*. 2000). There exist some examples in which this type of precaution has played an important role in the conservation of the marine environment, such as the ban of toxic and radioactive residuals dumping by the London Convention (London Convention 1972: www.londonconvention.org). However, the difficulty in the application in practice of the precautionary principle, has also been recognised mainly due to the lack of the necessary scientific information (Gray and Bewers 1996; Thompson *et al*. 2000).

There are some examples that clearly show the danger of implementing management actions or conservation policies without taking into account the importance of a solid scientific base, such that the action became a threat for the populations that were supposed to be conserved. For example, for five years the nests of loggerhead turtles (*Caretta caretta*) in the beaches of Cyprus were artificially incubated to help the recovery of the species by increasing the hatching rate. Later this action had to be stopped when scientific studies discovered that is the incubation temperature what determines the sex of the hatchlings (Demetropoulos and Hadjichristophorou 1989). Another example is the artificial introduction in the 1970s of the American red crab (*Procambarus clarki)*, originally from the US, into Spanish rivers and marshes as a management action to compensate for the decline of the indigenous red crab (*Austropotamobius pallipes*). The introduced species, due to its extremely fast adaptation, its predation and an associated fungus caused a severe decline of the indigenous crab – even its eradication in some areas – and many other species (Pérez-Bote *et al*. 2004).

In the case of conservation of dolphins, there is some information without which it is impossible to establish management policies without taking the risk of these being completely ineffective or even inappropriate. First, it is necessary to know how many animals there are, which are the population/s that need to be conserved, and what is their distribution and habitat use. It is also important to have information on their diet and natural history.

All this is necessary because it is fundamental to put the threats or the impacts of the human activities into context. If, for example, a given mortality of dolphins is detected due to by-catch in fishing gears, it is necessary to know what is the proportion of the population affected to be able to identify if it is a conservation problem for the population (International Whaling Commission 1995). This is fundamental when prioritising management actions, especially when resources are limited.

Common and bottlenose dolphins are the species that get closest to the coast in the Mediterranean, and are therefore the most susceptible to the impact of human activities that are developed along or close to the coasts. Probably as a consequence of this, both species are considered endangered in the Mediterranean. For this reason, the efforts of this thesis are centred mainly on these two species.

1.2.4. Conservation Plans

1.2.4.1. Why is a Conservation Plan needed

Dolphins are threatened species that could disappear from our waters if correction measures are not taken promptly. MPAs can be established with their corresponding management plans in which the necessary actions are determined so that the target species find in them favourable conditions for feeding, reproduction or migration. But it can not be forgotten that for these species, the dimensions and limits of these protected areas might not have any sense. They can help, but they are not enough, by themselves, to ensure that the conservation objective for the species is achieved: to maintain a favourable conservation status.

Therefore, the MPAs are necessary but not enough and they can not be seen as the global solution for the conservation and sustainable management of the marine environment. The limitations of marine reserves can be highlighted especially in the case of marine species that extend across large areas. The marine environment is characterized mainly by being immense, three-dimensional and extraordinarily dynamic. To limit the conservation efforts to areas with rigid limits is obviously insufficient when dealing with conservation of the vast majority of marine species. It is necessary to take into account the special requirements of these species if conservation is to be effective (Fahrig 2001). In addition, the human activities that might be causing a threat are not usually restricted to a particular area, and the management of activities within an area can not deal with external threats that are transported into the area as a result of the three-dimensional nature of the marine environment (Allison *et al*. 1998; Zacharias and Roff 2000; Jamieson and Levings 2001). This is one of the reasons why MPAs have detractors in the scientific community.

However, MPAs continue nowadays being the main and most extensively used tool for the conservation of cetaceans. There are many areas designated for the conservation of cetaceans, small and large all over world. For example, the SAC for bottlenose dolphins and harbour porpoises under the European Union's Habitat Directive; the extensive cetacean sanctuary 'Pelagos' in the Ligurian Sea (Notarbartolo di Sciara 2001) and many others of small dimensions (Hoyt 1995) such as the 'Losinj Dolphin Reserve' in Croatia (Mackelworth *et al*. 2003) in the Mediterranean; the Stellwagen Bank (Ward 1995) and the Gully Canyon (Hooker *et al*. 1999) in the North-east Atlantic; the 'Hawaiian Islands Humpback Whale Sanctuary' (http://hawaiihumpbackwhale.noaa.gov/) in the Pacific; etc.

Facing this situation, the main challenge of this work is to progress towards the effective conservation of the species and their habitats. Therefore, it needs to be emphasized that the design and creation of MPAs is not the final aim of this work, but just one more action within the future conservation plans for the species, in which these areas and their management plans would be framed.

For this reason we need a conservation plan that brings in the requirements for the conservation of the species at an appropriate scale, as it does not bind itself to a particular protected area but is applied to a more extensive geographical area, usually that of the competences of the involved authorities.

The conservation plan establishes some priority lines of action. There are different types of actions in it: management, legislative, research, monitoring, capacity building and public awareness. In this way, an organised structure is established for implementing, in the most effective possible way, the necessary actions to preserve or reach a favourable conservation status for the target species and its habitat.

Unfortunately, there are few conservation plans in the world that are not framed within particular MPAs, and they are mainly recovery plans for species in sever danger of extinction. Some of these examples are the Recovery Plan for the right whale (*Eubalaena glacialis*) in the north Atlantic, announced in June 2005 (http://www.publicaffairs.noaa.gov/releases2005/jun05/noaa05-r116.html), or the Recovery Plan for the blue whale (*Balaenoptera musculus*) (National Marine Fisheries Services 1998). No conservation plans for cetaceans have been developed yet in Spain, the Mediterranean Sea or Europe. Therefore, this work represents a challenge in its novelty. In Spain there are 'Conservation Strategies' being developed for threatened species such us the Spanish Imperial eagle (*Aquila adalberti*), the bearded vulture (*Gypaetus barbatus*) or the brown bear (*Ursus arctos*) among others (Comisión Nacional de Protección de la Naturaleza 2001a, b, c). With this work we will also contribute to these strategies so that the conservation plans developed become part of a 'National Conservation Strategy' for several species of cetaceans.

1.2.4.2. Why is baseline information needed

The recovery or maintenance of a favourable conservation status for threatened species, either within the framework of management plans for an MPA (SAC, SPAMI, etc) or of conservation plans, needs to be structured over a solid scientific base (Boersma and Parrish 1999; Hooker and Gerber 2004). Even if on occasions some extreme actions must be undertaken urgently more based on the precautionary principle than on knowledge, the examples of important mistakes in conservation actions made in the recent past, based on good intentions, clearly highlights the complexity of appropriate management and therefore the requirement of scientific data.

It is clear that with the present pressures on the marine environment, we cannot afford the luxury of waiting to have "all" the data before taking any action. But it is possible to establish at least which basic data are indispensable. Research at sea is a logistical and economic challenge and it is therefore essential to prioritize the objectives of the investigation focussing on which information is essential for a solid conservation strategy.

Dealing with charismatic species such as dolphins, the scientific basis is even more essential. The simple stranding of an old dolphin or the death of an inexperienced one in fishing gear may generate a severe reaction in the public. This, if misused by the 'selling' interests of the press or conservationist groups may harm rather than benefit the conservation of biodiversity.

The baseline information constitutes, therefore, the scientific foundation of the conservation plan (and of the management plan of an MPA). It consists on the basic information required to support scientifically the conservation actions of the plan. The fundamental need for this baseline information for the analysis of the threats, the identification of the appropriate mitigation measures and the subsequent determination of the priority actions, was recognised by the Scientific Committee of ACCOBAMS in Resolution 2.9 of 2003 (ACCOBAMS, 2003). Without it (together with an adequate monitoring plan) it would not be possible, among other things, to determine if the conservation objectives are being met.

The baseline information basically serves three purposes:

a) First, it puts the threats to the population into context (for example, what proportion of the population it is affecting) to allow an evaluation, with a solid base, of the real impacts of the human activities on the conservation status of a population and on its long-term viability.

b) Second, it provides the necessary data to establish which actions are needed and also feasible, based on scientific information on the populations of the target species, as well as on the human activities involved.

c) Third, it establishes the reference levels that will allow the analysis of trends through monitoring. These reference levels must provide each action of the conservation plan with a feedback mechanism to ensure that it can be adjusted to any change, with the aim of reaching the conservation objectives established for the action according to the general conservation objectives of the conservation plan.

Therefore, it is not only necessary baseline information on the populations of the target species for the conservation plan, but also on the human activities that represent, or may represent, an impact or threat over these populations.

At the population level, it includes scientific information on the species to be conserved, especially in terms of the identity of the population, its abundance, its distribution patterns and its natural history. At the human activities level, it means quantifiable data about them (amount, intensity, levels, etc.). This parallel information will allow the establishment of links – which will need to be tested scientifically – between trends in the populations and changes in the human activities.

1.2.4.1 Why is a monitoring plan needed

To establish the baseline information as scientific reference to guide future conservation actions is the first step. Once this is achieved, monitoring needs to become the spine of the management, as stated by the European Union's Habitat Directive (Article 17): "the development of a Monitoring Plan is required to provide information on the conservation status of the habitats and the species that the SAC have to conserve, and to determine the effectiveness of the Management Plan in achieving its conservation objectives".

A conservation plan does not constitute a definitive and unalterable document. It is rather a document that covers a temporal phase within the framework of the efforts for the conservation and recovery of a species, and therefore needs to be reviewed periodically to adjust the actions to the diverse changes that can occur, either in response to the conservation plan actions themselves or to external factors.

The necessary tool to know how and when the modifications or adaptations of the conservation plan actions are needed is monitoring. This is part of the plan itself in the form of monitoring actions in which the suitable indicators for the follow up have been established, as well as the tools to obtain them. In this way, the plan has a feedback mechanism that ensure its correct functioning and allowing it to adapt to changes in the target species or its environment, or in the threats.

Therefore, it is necessary that monitoring covers not only population parameters, to detect trends in its conservation status, but also human activities so that reliable and long-term information on their development is available.

1.3. REVIEW OF THE NATURAL HISTORY AND THE CONSERVATION STATUS OF THE BOTTLENOSE AND COMMON DOLPHIN

1.3.1. Natural history

This section provides a general overview of current knowledge about the morphology, physiology, feeding, behaviour and world-wide distribution of the bottlenose (Photo 1.1) and the common dolphin (Photo 1.2). All this information can be useful to understand aspects of the following chapters.

1.3.1.1. Bottlenose dolphin

Photo 1.1. Bottlenose dolphin

The bottlenose dolphin is distributed worldwide, showing such an extraordinary adaptation to the diverse conditions in different regions that it is difficult to define fixed characteristics for the species' feeding habits, behaviour and social structure. It is therefore important to bear in mind that the following descriptions are often generalizations which may not be fully relevant to the species in the region concerned by this work.

<u>Taxonomy</u>

Tursiops is a polytypic genus, that has been divided into up to 20 different species (Hershkovitz 1966), although these standard divisions have been based on very few data. More persistent classifications included *T. gilli* and *T. nuuanu* in the northeastern Pacific (Walker 1981) and *T. aduncus* in Australia, the Indian Ocean, the Chinese Sea and South Africa (Ross 1977; Ross and Cockcroft 1990). Different morphotypes differ in coloration pattern, body dimensions and cranial structure, although the distributions of these characters generally overlap (Walter 1981; Ross and Cockcroft 1990). In consequence, *T. truncatus* was recognized as a single species (Ross and Cockcroft 1990; Wilson and Reeder 1993), until molecular data supported the separation of *T. aduncus* as a different species (LeDuc *et al*. 1999; Wang *et al*. 1999).

On the other hand, a distinction between a coastal morphotype and an offshore one has been described in many areas (Ross 1977, 1984; Walter 1981; Duffield *et al.* 1983; Ross and Cockroft 1990; Van Waerebeek *et al*. 1990; Mead and Potter 1995; Torres *et al*. 2003). In almost all cases, this distinction is based fundamentally on morphologic aspects, diet and habitat. But finally in 1998, Hoelzel and collaborators demonstrated that a genetic differentiation between the parapatric coastal and offshore forms of the United States exist (Hoelzel *et al*. 1998).

<u>External characteristics</u>

Mean length is 3 m (maximum 4 m) for males, and slightly smaller for females, which can reach a maximum length of 3.70 m. But these sizes have great variability, especially when comparing both morphotypes described, the coastal being rather smaller than the offshore (Perrin *et al*. 2002). Coloration is a more or less uniform dark grey body with white belly. The general aspect is rather robust, especially in comparison with other small delphinids like the common dolphin or the striped dolphin. Its respiratory rate is about 5 to 20 sec., and dives can reach up to 10 min. The cruising speed is 5-6 knots, but it can reach a maximum velocity of 20 knots (Sylvestre 1990).

Reproduction

Males reach sexual maturity between 8-12 years, and females between 5-10 years (Reynolds *et al*. 2000). The reproductive cycle of the female is 2 to 3 years, with a gestation period of 12 months. Calving intervals are around 3 – 6 years (Perrin *et al*. 2002). Lactation usually lasts 12 to 20 months (Reynolds *et al*. 2000). In Florida, autumn has been described as time of birth, whereas in Europe it would be around mid summer. Longevity is considered to be around 40 to more than 50 years (Reynolds *et al*. 2000; Perrin *et al*. 2002).

Predators

Cetaceans have very few predators. These are mainly sharks, orcas, false killer whales and man (Perrin *et al*. 2002). The importance or magnitude of predation is very difficult to quantify. Although some dolphin scars could be attributed to shark attacks, it is not always easy to determine the origin of the scars or scratches as many of them can be from interactions between cetaceans. In the Mediterranean the presence of orcas and false killer whales is very rare (Sagarminaga and Cañadas 1996), which is why the predators of dolphins here could be reduced to sharks and man (by direct or accidental death).

Pathologies

The first epizootic in marine mammals identified was due to a bottlenose dolphin morbillivirus infection in 1987-88 along the Atlantic coast of the United States of America (Lipscomb *et al*. 1994; Schulman *et al*. 1997). In that occasion, more than half of the population of bottlenose dolphins of the region may have died. In spring of 2004, another mass bottlenose dolphin die off was detected in Florida. In this case the cause could have been neurotoxins produced by a red tide, morvillivirus not having been detected on this occasion (NOAA 2004).

There have been several cases of mass strandings of cetaceans in the Black Sea, apparently related to immuno-depressions increased by the effect of pollutants (including epizootics of morbillivirus) (Birkun *et al*. 1999). In spring 1990 numbers without precedent of dead dolphins were recorded in the Black Sea, along the coasts of Turkey, Crimea, Russia and Bulgaria. The probable cause of the epizootic was a viral infection that is considered to have caused the death of several thousands of animals (of the three present species in this sea: bottlenose dolphins, common dolphins and harbour porpoises (Evans and Addink 1993).

Feeding habits

In general, it is widely believed that the bottlenose dolphin feeds mainly on demersal species (Gunter 1942; Tomilin 1957; Evans 1987; Barros and Odell 1990; Gannier 1995). There are no studies to date relative to the diet of this species in waters of Andalusia. The geographically closest study was carried out in Valencia (Salomón 1997). In this study, 95.8 % of stomach contents were composed by fish, only 3.2 % of cephalopods and 0.9 % of crustaceans. 87.5 % of the stomachs contained benthic or demersal neritic species (*Merluccius merluccius* being the main prey), while only 12.5% were composed of pelagic prey (Salomón 1997). Being a very adaptable and opportunistic species, it is not possible to state that dolphins in Andalusia feed on the same prey as those in Valencia. But the fact that in almost all the literature similar patterns of feeding have been described for this species in diverse geographic places, allows us to infer a similar feeding pattern in the Alborán sea, based mainly on demersal prey, except probably for the zone of the Straits of Gibraltar, where the evidence point more towards a diet based on pelagic fish (R. de Stephanis, com. pers.).

Another study in the Mediterranean, conducted in the Ligurian Sea, showed that in this area the fish constituted more than 85% of the stomach contents, the main prey being blue whiting (*Micromesistius poutasou*), hake, some demersal Trichiuridae and the conger eel (*Conger conger*) (Relini *et al*. 1994). In the adjacent Atlantic waters of Portugal and Galicia, fish constituted 99% of the diet of bottlenose dolphins according to studies of stomach contents, the main prey being some Gadidae, and especially blue whiting (Santos *et al*. 1996; Silva and Sequeira 1997). All these prey have a demersal distribution, in depths between 100 and 600 meters and especially around the edge of the continental shelf (FAO 1987).

Social structure

In general it is considered that group sizes are smaller in the coastal forms than in the offshore forms, but this is very variable. A typical group size is between 2 and 25 animals, although in some occasions there have been reports of groups nearing a hundred and even a thousand individuals (Evans 1987; Perrin *et al*. 2002). In Tampa Bay, the mean group size is 5 animals (Weigle 1990). In the Sado Estuary, the mean group size is about 14 animals (Dos Santos and Lacerda 1987; Gaspar 2003). In Scotland, the mean group size is 4.5 (Wilson 1995) and 5 in the Shannon Estuary, Ireland (Ingram 2002). In South Africa, the mean group size is much larger, about 67 (Peddemors 1999).

It is believed that they have a matriarchal structure, in which the group is dominated by the maternal line and composed typically of adult males, females and young. Also groups of mature females with young of both sexes have been described, and groups of immature males, but in general it seems that they have a very fluid structure (Evans 1987). Two types of group can be distinguished: 'pods' (dolphins that are associated strongly and do similar activities) and 'herds' (temporary aggregations of 'pods') (Shane *et al*. 1986).

World distribution and status

It has a cosmopolitan distribution throughout the entire world's seas except the polar zones, especially in coastal areas, although they can be found also on the high seas. In non-tropical areas, bottlenose dolphins are found mainly in the coastal zones, sometimes up to the continental slope (Klinowska 1991). They can also be found in estuaries (Lacerda and Dos Santos 1987; Gaspar 2003).

Even if the size of the population is not known, apparent declines in Northern Europe, the Mediterranean and the Black Sea have been observed (Evans 1987). The category of the bottlenose dolphin in the Red Book of the IUCN is "Data Deficient" (www.redlist.org). However, the same Red Book recognizes that acute problems of conservation exist for this species, among others, in the Mediterranean and the Black Sea where historical catches, accidental captures and environmental degradation have caused a decline in the populations (IWC 1992).

1.3.1.2. Common dolphin

As for most cetacean species, there are many unknown aspects of the natural history of this species. It is wide-spread all over the world, adapted in each area to very different and changing conditions that do not allow, in many cases, the definition of fixed parameters to the species, which show large variability among populations.

Photo 1.2. Common dolphin

Taxonomy

The common dolphin or *Delphinus delphis* is a delphinid of the suborder odontocetes. The genus *Delphinus* was described by Lineo in 1758. Since then, several species have been named within this genus, although most of them have been questioned. In 1889 True recognised the existence of only four species of *Delphinus*, reducing the others to simple synonyms of these: *D. delphis* Linnaeus, *D. longirostris* Wagner, *D. capensis* Gray and *D. rosiventris* Wagner. More recently *D. bairdi* Dall in the Eastern Pacific (Heyning and Perrin 1994) and *D. tropicalis* van Bree in the Indian Ocean (Heyning and Perrin 1994) have been proposed, but many authors consider them geographical forms or subspecies rather than species.

In the North-east Pacific, where two morphologically distinct forms of common dolphins inhabit sympatrically, Heyning and Perrin (1994) analysed a large number of animals. They did not find any overlapping between the short-beaked and the long-beaked forms based on several morphometric characters. As a result, they proposed two species: the short-beaked form would remain as *Delphinus delphis*, and the long-beaked form was proposed as *Delphinus capensis*. This morphological difference has been supported by genetic analysis that show large differences in the mitochondrial DNA between both forms (Rosel *et al*. 1994), and which suggest that they have been separated for a long time and probably do not interbreed despite living in sympatry. Some authors consider that there exist only one species, *Delphinus delphis*, and that the others are geographic forms or subspecies. Other authors consider the existence of two species; the short-beaked *D. delphis* and the long-beaked *D. capensis*, this being the most accepted and extended classification (Natoli *et al*. in press). Finally, a few researchers discuss that there are at least three species, adding to the previous two *D. tropicalis* (Indian Ocean and Sea of China), with an even longer beak than *capensis* (Jefferson and Van Waerebeek 2002).

However, recent genetic studies lead to some doubts about the speciation in *Delphinus* (LeDuc *et al*. 1999), and even in the definition of the inter-species and inter-genus borders (LeDuc *et al.* 1999; Milinkovitch *et al*. 2001). Le Duc analysed the complete cytochrome B sequence in many delphinid species. He found a close affinity between *Stenella, Tursiops* and *Delphinus,* which form a very well defined group (Delphininae), together with *Sousa* and *Lagenodelphis*. At the same time, *Delphinus* forms also a compact monophyletic group, while *Stenella* and *Tursiops* appear as polyphyletic, with no well defined borders between both genera. Within the genus *Delphinus*, LeDuc found that the two species *D. delphis* and *D. capensis* are not reciprocally monophyletic, but that the sequences of *D. capensis* are rooted inside the sequences of *D. delphis* in the phylogenia, resulting in paraphylia. In addition, the status of the *tropicalis* form is even less clear, and according to the study by LeDuc it would effectively represent a third species, but there are still not enough data to confirm it. This hypothesis, however, has not been supported by a recent genetic study of the genus Delphinus (Natoli *et al*. 2004). Natoli suggests that the *tropicalis* form from South Africa, as well as the described *capensis* forms in the Atlantic would not represent different species but variations of a single *Delphinus delphis* species with large variability in the Atlantic. Therefore, despite all the recent progresses in the study on the complex *Delphinus*, there are still many questions to be answered.

External characteristics

The common dolphin is a small delphinid with an average adult length of 2 m, males being slightly larger than females (Evans 1987). Some gradation in size has been described between the North-east Atlantic and the Black Sea. They are larger in the Atlantic (average 219 to 243 cm and maximum 258 cm for males and average 193 to 211 cm and maximum 230 cm for females) and smaller in the Black Sea (average 178 and maximum 219 cm for males and average 170 and maximum 200 cm for females). The Mediterranean Sea common dolphins have an intermediate size (maximum 222 cm for males and 208 to 222 for females) (Heyning and Perrin 1994; Perrin 1984; Perrin and Reilly 1984). Calves are born at 80 to 90cm in length (Evans 1987; Evans 1994). Adults weight 75 - 85 kg, with a maximum 136 Kg (Evans 1987; Evans 1994).

Common dolphins have 40 to 60 pairs of small pointed teeth in each jaw (Evans 1987; Evans 1994). They have 73 to 74 vertebrae, of which the first two cervical ones are fussed (Evans 1994). The length of the beak varies from 210 – 260 mm in *D. delphis* to 290 – 370 mm in *D. tropicalis* (Evans 1994; Heyning and Perrin 1994). The genus *Delphinus* is distinguished from all other delphinid genera by its two deep lateral grooves located longitudinally in the upper palate (Evans 1994).

The pigmentation pattern is one of the most distinctive characteristics in this species, but presents large variability. The back is dark grey or dark brown, and the chest and belly are very clear. The sides have a usually very well marked 'V' shaped pattern under the dorsal fin, resembling a horizontal ‘eight’, in which the frontal part is yellowish (gilt to cream) and the posterior light grey. The dorsal fin is dark but usually has a cream-coloured patch very variable in size and shape. The pectoral fins vary from a cream or yellow colour to dark grey.

Reproduction

The reproduction of common dolphins has been studied mainly based on the reproductive organs of dead animals. For example, the studies of Collet and Sant-Girons (1984) and Murphy (2004) on *D. delphis* of the North-east Atlantic, and the review by Perrin and Reilly (1984) on the reproductive parameters of several species of delphinids in various geographical areas.

In general, pregnancy is estimated to be 10-11.5 months (Evans 1987; Perrin and Reilly 1984; Murphy 2004) and lactation between 10 and 19 months, being longer in the North Pacific and Atlantic (19 months, Evans 1987) than in the Black Sea (10-11 months; Evans 1987; Perrin and Reilly 1984). The resting period has been estimated at about 4 months both in Eastern Tropical Pacific and Black Sea dolphins (Perrin and Reilly 1984). In total, the intercalf interval has been estimated between 1.3 and 2.6 years.

The conception season is not well defined and in some areas there seem to be more than one peak of maximum conception. These peaks are usually extrapolated from the months of maximum proportion of births. According to a review done by Evans (1987), in the North Pacific there could be two peaks, one in spring (April to June) and another one in autumn (October to December); in the North Atlantic the maximum peak is estimated in summer (July to October), as in the Black Sea. In the Mediterranean, Gannier (1995) also estimated the summer to be the season with maximum conception. The largest number of births in the North Pacific is observed in March-April and September-October, while in the North Atlantic and Black Sea it is in June-September (Evans 1987). The annual birth rate seems to vary between exploited (usually due to intense by-catch in fishing gear) and unexploited populations, being slightly higher in exploited populations probably as a compensation mechanism (Perrin and Reilly 1984). These rates have been estimated as 0.087 and 0.066 for the unexploited populations of the North-eastern Pacific and the Eastern tropical Pacific respectively, and 0.096 and 0.066 for the exploited populations of the Eastern tropical Pacific and the Black Sea.

It seems that the sexual activity of males and females follow a seasonal pattern (Collet and Saint Girons 1984; Murphy 2004), but varying from one population to another. Depending on the season and the population studied, the proportion of sexually mature pregnant females in the population can vary between 25 and 80% (Evans 1994; Perrin and Reilly 1984). The proportion of sexually mature lactating females varies between 36 and 60%, and of resting sexually mature females between 10 and 30% (Evans 1994).

Sexual maturity in males and females also show large variations among populations. In the North Atlantic and the tropical Pacific it has been estimated as 5 to 7 years for both sexes (Evans 1987, Perrin and Reilly 1984), while in the Black Sea it is 2 to 4 years old (Collet and Saint Girons 1984; Perrin and Reilly 1984).

Predators

In this case, as for bottlenose dolphins (sea above) predators in the Mediterranean Sea are probably only sharks and man.

Pathologies

In the Black Sea there have been two epizootic events that have affected the common dolphin, one in 1989-1990 that affected the three species inhabiting that sea (common and bottlenose dolphin and harbour porpoise), and the second in 1994. In neither of these cases the causes could be determined, although it was suspected that the epizootic of 1994 could have been caused by an unidentified viral infection (Birkun *et al*. 1995). In 1990-1991 there was an important epizootic in the Mediterranean causing the death of probably thousands of striped dolphins (*Stenella coeruleoalba*) (Aguilar and Raga 1991; Domingo *et al*. 1991). In this case the cause of the die-off was a morvillivirus (Domingo *et al*. 1991; Androukaki and Tounta 1994). However, this virus has not been detected in samples from common dolphins (Androukaki and Tounta 1994) and there was no increase in strandings of this species at that time. Therefore, it is considered that the epizootic did not affect the common dolphin.

Feeding habits

The common dolphin is considered a very opportunistic species in terms of feeding habits (Klinowska 1991; Young and Cockcroft 1994; Gannier 1995).However, it usually has a predominantly icthyophagous diet, cephalopods being a minor portion of their typical diet (Collet *et al*. 1981; Evans 1987; Relini and Relini 1993; Young and Cockcroft 1994; Berrow and Rogan 1995; Boutiba and Abdelghaní 1995; Gannier 1995; Kenney *et al*. 1995; Cordeiro 1996; Santos *et al*. 1996).

In the Eastern tropical Pacific, Evans (1994) describes a seasonal variation in the diet of common dolphins; in autumn- winter fish constitutes 63% of the diet, mainly *Engraulius* sp. (92%), and cephalopods 37%, of which 99% is *Loligo opalescens*. In spring – summer, fish constitute 70% of the diet but now the most commonly found prey species is *Leuroglossus stilbius* (56%); cephalopods account for 23%, mostly *Onychoteuthidae* (85%); and crustaceans for 7%.

In the North-east Atlantic, there are some detailed studies in Portugal, Ireland, Galicia and Scotland. In Portugal, Silva and Sequira (1996) found fish to account for 90.4% of the prey found in the dolphins' stomachs (43.4% *Micromesistius poutassou*, 32.8% *Sardina pilchardus*) and cephalopods only 9.6% (60% Loliginidae, 36,6% Sepiidae). In Ireland, Berrow and Rogan (1995) found that 85.1% of the stomach contents analyzed contained fish of the family Gadidae (40.7% *Trisopterus* spp., 30.7 % *Merlangus merlangus*), 26.9 % had Clupeidae (*Clupea harengus* and *Sprattus sprattus*) and 11.1% contained Gobidae; cephalopods were found in 51.7% of the samples (40% *Gonatus* sp., 40% *Histioteuthis* sp, 27% *Loligo forbesi*, 33% *Eledone cirrosa* and 13% *Toderopsis* sp). In Galicia, Santos (1998) described the most frequent prey species for common dolphins as the sardine, blue whiting (*Micromesistius poutassou*) and mackerel (*Trachurus trachurus*), which accounted altogether for two thirds of the total estimated weight of prey. The same author described the whiting (*Merlangus merlangus*) as the most frequent prey species in Scotland, constituting by itself more than two thirds of the estimated total weight of the prey.

Within the Mediterranean, in Algeria, the studies carried out by Boutiba and Abdelghaní (1995) showed again a clear prevalence of fish in the diet: 93.6% (45.8% Clupeidae, 38.6% Engraulidae) against 6.4% of cephalopods. In the Ligurian Sea, Relini and Relini (1993) examined only 3 stomachs of common dolphins, with large variability in the results: fish constituted from 0.3 to 100% of the stomach contents, cephalopods between 0 and 96.6%, and crustaceans between 0 and 3.3%.

There are some detailed studies of the diet of the common dolphin in the Black Sea (Tomilin 1957) showing that its main food is pelagic fish, mainly anchovies (*Engraulis encrasiclous*) and European sprat (*Sprattus sprattus*). According to Evans (1994), 100% of the diet of common dolphins in the Black Sea is composed of small pelagic fish such as anchovies.

In summary, common dolphins seem to have a preference for small neritic and epi-pelagic fish, especially of the families Clupeidae and Engraulidae and some Gadidae (Demersal or mesopelagic fish inhabiting preferentially from the coast to 400 m depths), as well as a small amount of cephalopods.

Social structure

All authors coincide in describing the common dolphin as a very gregarious species, which can from groups of several hundreds or even thousands of animals (Evans 1994; Evans 1994; Leatherwood *et al*. 1988). However, all data point out to a basic social unit of around 20 to 30 animals (Evans 1994).

In the Eastern Pacific, Perrin *et al*. (1995) observed group sizes varying between 30 and 400 animals, while Perryman and Linn (1993) describe groups between 30 and 1840 animals. In another study, Heyning and Perrin (1994) mention groups of 10 to several thousands in the North-eastern Pacific. In the Gulf of Viscay (NE Atlantic), Gonzalez *et al*. (1993) estimated an average group size of 17.5 individuals during the sightings cruise "Cetacea-92".

In the Mediterranean, different authors give average group sizes that vary between 6.3 and 76.8 dolphins depending on the areas (Laurent 1991; Politi *et al*. 1992; Notarbartolo di Sciara *et al*. 1993; Azzali *et al*. 1994; Forcada *et al*. 1995; Gannier 1995; Nascetti and Notarbartolo di Sciara 1996; Forcada and Hammond 1998).

As in most highly gregarious species with very little sexual dimorphism, almost nothing is known about the sex/age composition of the groups and their social organisation.

Distribution and World status

The size of the World population is unknown, but it is believed to be one of the most common species (Evans 1987). There is an estimate of 3,112,300 (CV = 0.369) common dolphins for the Eastern tropical Pacific (Holt and Sexton 1990). In the NE Atlantic, Goujon (1993) estimated an abundance of 61,888 (95% CI, 35,461-108,010) for the northern Gulf of Biscay; Hammond *et al*. (1995) estimated 75,449 (95% CI, 2,900-248,900) common dolphins in the Celtic Sea; and Cañadas *et al*. (2004) estimated 273,159 (95% CI = 153,392 – 435,104) animals in the offshore areas south-west of the Faroese Islands.

Its distribution is cosmopolitan in all tropical, subtropical and temperate oceans and seas, including the Mediterranean Sea, the Black Sea, the Red Sea and the Persian Gulf. The northern limit of its distribution in the Atlantic is around Nova Scotia and Ireland, and in the Pacific around Japan and California. Its southern distribution in the Atlantic is around Peninsula Valdés in Argentina and the southern part of South Africa; in the Pacific, south of Australia, New Zealand and south of Chile. In the Indian Ocean it is rarely observed north of the Red Sea and the Arabian Sea (Evans 1987).

Its main problem at a global scale is by-catch in fishing gear, which an FAO report estimated to be more than 8,000 dolphins caught per year (Northridge 1984). Accidental by-catches have been reported in pelagic trawling and driftnets in the NE Atlantic (Morizur *et al*. 1999; Goujon *et al*. 1994), driftnets or other kind of nets in the Mediterranean (Silvani *et al*. 1995; Di Natale and Notarbartolo di Sciara 1994; Duguy *et al*. 1982, Tudela *et al*. 2005), and purse seine and driftnets in the north-east Pacific (Leatherwood *et al*. 1988; Hall 1994; Henshaw *et al*. 1997).

1.3.2. Conservation status in the western Mediterranean

1.3.2.1. Bottlenose dolphin

The bottlenose dolphin is the most common cetacean species on the continental shelf of the Mediterranean (Notarbartolo di Sciara and Demma 1994). Nevertheless, the distribution of these coastal communities seems to be dispersed and fragmented throughout Mediterranean coasts in relatively small units or subpopulations, between which 'empty spaces' seem to be enlarging (Bompar *et al*. 1994, UNEP/IUCN 1994, Notarbartolo di Sciara and Gordon 1997, Universidad de Barcelona 2002). The abundance of this species along the Spanish coasts also seems to have undergone an important decline (Aguilar *et al*. 1997).

Genetic studies indicate that the Mediterranean population of bottlenose dolphin, although predominantly neritic, could find its origins in the offshore form of the North Atlantic population that would have colonized the Mediterranean, showing also evidence of divergence between these areas (Natoli *et al*. 2004, Universidad de Barcelona 2002). Studies with biochemical indicators also show a differentiation between the Mediterranean and the North Atlantic populations (Universidad de Barcelona 2002). In addition, a large diversity has been observed in the samples from the Mediterranean, suggesting the existence of a population structure within this basin (Natoli *et al*. 2004). Some communities of the Mediterranean show in addition high levels of genetic differentiation, suggesting a very limited genetic flow, like the one of the Ionian Sea (Natoli and Hoelzel 2000). Genetic differences have also been observed between dolphins from the Spanish and Italian coasts (Universidad de Barcelona 2002)

Due to its preference, in general, for coastal habitats, this species has been affected to a great extent by the human activities which concentrate here. Three types of threats affecting the bottlenose dolphin can be pointed out (Perrin 1988, IWC 1994, UNEP/IUCN 1994):

a) Chemical contamination of the water: Levels of contamination in Mediterranean dolphins are very high in comparison with levels found in others areas of the world (UNEP/IUCN 1994, Marsili *et al*. 1996), and even compared to adjacent populations of the North Atlantic (University of Barcelona 2002). These high xenobiotic compound concentrations can cause cancer, reproductive disorder, hypertension, infarcts and immunological suppression (Ó'Shea *et al*. 1999).

b) Reduction in the availability of prey due to environmental degradation and overfishing: There is evidence indicating that overfishing in the Mediterranean has resulted in the decline of many stocks of fish (Caddy and Griffiths 1990; de Walle *et al*. 1993; FAO 1997, 1998), causing negative consequences on the ecological balance of the marine ecosystem (Dayton *et al*. 1995, Stanners and Bourdeau 1995). A study has shown unusually long times being dedicated to foraging in some bottlenose dolphin communities studied consistently for more than one decade (Bearzi *et al*. 1997, Politi 1998).

c) Direct and indirect catch in fishing gear: Accidental captures, especially in gill nets although also in drift nets, is a frequent occurrence (Cagnolaro and Notarbartolo di Sciara 1992, Silvani *et al*.

1992), and in some areas cannot be sustainable (IWC 1994). On the other hand, the interaction with coastal fisheries in some regions often results in the dolphins being harpooned, shot or otherwise harrassed (Cagnolaro and Notarbartolo di Sciara 1992, Silvani *et al*. 1995, UNEP/IUCN 1994). Studies in the Balearic islands suggest an annual capture of about 30 dolphins (Forcada *et al*. 2004), which is likely to exceed the 1% of the population threshold considered as a cause of concern (IWC 1995) in this zone (Forcada *et al*. 2004; T. Brotons, pers. comm).

Other potential threats include acoustic pollution (Notarbartolo di Sciara and Gordon 1997) and direct disturbance by recreational navigation and “whale-watching” operations.

In summary, it can be said that there are clear signs of an unfavourable conservation status for the bottlenose dolphin in the Mediterranean reflected by the fragmentation of its populations and the progressive isolation of the different subpopulations.

1.3.2.2. Common dolphin

It is believed that the Mediterranean common dolphin has suffered an important decline during recent decades (Pelegrí 1980; Viale 1980; Evans 1987; Laurent 1991; Aguilar 1991; Viale 1993; Notarbartolo di Sciara 1993; Gannier 1995; Notarbartolo di Sciara and Gordon 1996; UNEP 1998a, b; Bearzi *et al*. 2003). Sightings of this species are nowadays very scarce in areas other than Greece and the Alborán Sea, although nothing is known about the north African coast (Fabri and Laureano 1992; Notarbartolo di Sciara *et al.* 1993; Pulcini *et al.* 1993; Gannier 1995; Forcada and Hammond 1998; Bearzi *et al*. 2003).

The exact causes and the magnitude of this decline are still unknown. The heterogeneity of the historical data, both geographically and chronologically, makes comparison between past and present situations very difficult. This is aggravated by the revision of the osteological collections of some museums that showed the erroneous classification of some specimens of common and striped dolphin (Cagnolaro 1994). For this reason, some authors have argued that the common dolphin was in fact a rare species since a long time ago, but that it has only recently been detected precisely due to the confusion between the two species (Collet 1994). However, there exist some reliable old observations and specimens in scientific collections from the beginning of the last century that contain many more examples of common than of striped dolphins (Viale 1985; Cagnolaro and Notarbartolo di Sciara 1992).

The status of the striped dolphin seems to be opposed to that of the common dolphin because its present abundance in the Mediterranean contrasts with the historical data that described this species as very rare (Viale 1993; Cagnolaro 1994). It has been suggested that there could be a competition for ecological niche between both species, and that the striped dolphin could be displacing the common dolphin (Viale 1980; Casinos 1982; Viale 1985; Notarbartolo di Sciara 1993), although this would not explain, for example, the disappearance of common dolphins from the northern Adriatic where it has not been replaced by striped dolphin (Notarbartolo di Sciara and Gordon 1996). Both species are very close genetically (García 1996) and have some similarities in size, morphology and biology. However, studies have shown a difference in terms of distribution in relation with oceanographic factors such as chlorophyll concentration, temperature and salinity (Reilly and Fielder 1994). In these studies, carried out in the north-eastern Pacific and in the Indian Ocean, striped dolphins showed a random distribution with respect to those variables, while common dolphins’ distribution was significantly associated with them. It is a fact, nevertheless, that the common dolphin is one of the three most frequent species of dolphins in the Mediterranean, and that can be found in sympatry with one of the other two species (striped and bottlenose dolphin) or with both, in many areas. UNEP recommends, therefore, a more in-depth study of the relationships between the three species as a vital step to increase our knowledge of the functioning of the ecosystem and inter-species competition (UNEP 1998a).

Some authors propose also the degradation of water quality, mainly due to pollution, as a probable cause of the decline of the common dolphin, as well as of the epizootic suffered by the striped dolphin and of the generalized deterioration of the cetacean populations in the Mediterranean (Viale 1993), due to the high concentrations of PCBs and heavy metals found in the tissues of stranded animals (Lima and Sequeira 1993; Viale 1993; Corsolini *et al.* 1995; Borrell *et al*. 1998).

In 2003 an exhaustive review of the status of the common dolphin in the Mediterranean was undertaken, in which the author participated (Bearzi *et al.* 2003). It is highlighted in that review that the existing literature and osteological collections confirm that the common dolphin was abundant and widely distributed in most of the Mediterranean until the end of the 1960s when the decline started and proceeded very fast. It is also described how the common dolphin is nowadays relatively abundant in the Alborán Sea, with some records in Algeria and Tunisia, concentrations around the Maltese islands and in areas of the Aegean Sea, and relict groups in the south-eastern section of the Tyrrhenian Sea and eastern Ionian Sea. However, this species is rare, or completely absent, in other area where information is available.

In the same review and based in circumstantial evidence and qualitative judgements, the authors suggest the following factors as possibly contributing to the decline of the common dolphin:

- reduction of prey availability due to overfishing and habitat degradation;
- pollution by chemical xenobiotic compounds resulting in immunodepression and impaired reproduction;
- environmental changes such as increased water temperature affecting ecosystem dynamics; and
- by-catch in fishing gear, especially driftnets.

The accumulative importance of these factors is not well known, and therefore no conservation measures have been practically applied.

Finally, this article reviews the present state of knowledge and suggests priorities for actions targeted to identify and mitigate the main threats that are acting or may act on the common dolphin in the Mediterranean, with the final aim of restoring favourable conservation status of this species in the region.

The accidental capture of, among others, common and striped dolphins in the Moroccan driftnets in the Alborán Sea has recently been reported (Tudela *et al*. 2004). According to this study, around 3,500 dolphins (between both species) get caught in these driftnets in the southern portion of the Alborán Sea. Even if these figures are overestimated, this work highlights the importance of this threat, which could become unsustainable if it is not mitigated soon.

1.4 THIS STUDY

1.4.1. Objectives

The general objective of this work is to contribute to the conservation of cetaceans in the Alborán Sea through two parallel paths: (a) the investigation about aspects of the ecology of the species in this region, and (b) the proposal of management and conservation measures based on science.

Despite having obtained data for several species of cetaceans during the time frame of this study, the work of this thesis focuses especially, as mentioned above, on the common and bottlenose dolphin.

It was decided to work in the Alborán Sea and the Gulf of Vera because this is an area of great oceanographic interest and because it was inferred from previous cruises in this area that it could be of great interest for cetology.

There is a progression in this thesis in terms of the depth and complexity of the applied methods. The main methodology used in the last chapters is spatial analysis, and in fact it became a parallel objective of this work to explore the applicability of this new method, scarcely used in the field of cetology up to now, for the study of habitat selection by cetaceans and for the promotion of their conservation.

Four concrete basic objectives can be defined for this work:

a) To investigate the distribution and habitat preference by several species of cetaceans that are using the area, and especially the common and bottlenose dolphin

b) To estimate the abundance of common and bottlenose dolphins that are using the area

c) To identify the important areas for the conservation of these species in the study area

d) To develop proposals for the conservation of these species in the region

1.4.2. Chronology

1.4.2.1. Before 1992: previous studies in the area

During summer 1990 hundreds of striped dolphins stranded along the coasts of Spain, France and Italy, victims of a viral epizootic that extended during 1991 to the eastern basin of the Mediterranean

(Forcada *et al*. 1991; Domingo *et al*. 1996). This event highlighted the high levels of accumulation of persistent pollutants in the blubber of these animals, but also the lack of knowledge about the ecology of cetaceans in the Mediterranean.

Before 1992, when this research project was initiated, very little research on cetaceans had been carried out in the region of the Alborán Sea. Most of the information available referred to animals found stranded, captured in the whaling stations of Getares and Benzú (Cabrera 1925; Bayed and Beaubrun 1987) or caught accidentally in various fishing gear (Rey and Rey 1979; Rey and Cendrero 1980, 1981; Castells and Mayo 1992; García, P., ANSE, com. pers.).

Data on strandings were not recorded in a regular way until 1995 when CREMA (Centre for the Recovery of Endangered Marine Species) initiated its activities.

Casinos and Vericad (1976) created an updated catalogue of sightings and strandings in Spain. Until then, the first attempt to prepare a catalogue of this kind was made by Graells in 1889 followed by Cabrera (1914). Later, Rey, Rey and Cendrero published several reports during the 1980s where they collected data on sightings and strandings of cetaceans along the Spanish coasts (Rey and Rey 1979; Rey and Cendrero 1979, 1980, 1981, 1982). In 1982 the University of Barcelona organized the cruise “Sur 82” -one day sailing along the Mediterranean coast of Andalusia and three days in the Gulf of Cadiz in November of 1982- (Aguilar *et al*. 1984). The University of Valencia carried out a study of the distribution of cetaceans in Spain using opportunistic sightings collected by several ships (Raga *et al*. 1985), and did another compilation in 1991 with strandings data along the Mediterranean Spanish coasts between 1982 and 1988 (Raga *et al*. 1991).

Greenpeace and the University of Barcelona conducted two large-scale line transect surveys during 1991 and 1992 throughout the whole western Mediterranean Sea. These transects only covered briefly the Alborán Sea and the Gulf of Vera (down to the African coast): five days in 1991 (Forcada *et al*. 1991) and 6 days in 1992 (Forcada and Hammond 1998).

This list of existing previous publications and reports clearly reflects the scarcity of data that existed on cetacean populations in this region prior to this study

1.4.2.2. 1992 - 1999: Start of the study by ALNITAK

In 1989 the non-governmental organization ALNITAK was founded with the aim of carrying out studies in the marine environment, especially in relation to cetaceans and sea turtles, focussing on their conservation.

In 1992 Alnitak initiated the first long-term monitoring programme for cetaceans in the north-eastern part of the Alborán Sea and the Gulf of Vera, on board the research vessel *Toftevaag*. Data on all species were collected, of which the most frequently encountered were common, striped and bottlenose dolphins (*Delphinus delphis*, *Stenella coeruleoalba* and *Tursiops truncatus*) and long-finned pilot whales (*Globicephala melas*). Risso’s dolphins (*Grampus griseus*), sperm whales (*Physeter macrocephalus*), fin whales (*Balaenoptera physalus*) and beaked whales (*Ziphius cavirostris* and *Hiperodoon ampullatus*) were sighted more rarely.

Besides recording data on effort and sightings of these species, data were increasingly recorded on other marine species (sea birds, sea turtles, fish, invertebrates) and on human activities (ships, military manoeuvres, acoustic pollution). In addition, photo-identification of all cetacean species, except striped dolphins and beaked whales, video recording of behaviour and acoustic recordings of their vocalisations (since 1997) were collected.

The first results of these research expeditions confirmed the importance of certain areas of the Alborán Sea and the Gulf of Vera for some cetacean species. For example, common and striped dolphins showed high encounter rates (Sagarminaga and Cañadas 1996); common dolphins from the Alborán Sea are genetically distinct from those in the Eastern Mediterranean but close to the Atlantic ones (Natoli 2005); the long-finned pilot whale has in this region the highest encounter rates of the whole (surveyed) Mediterranean Sea (Cañadas and Sagarminaga 2000); Risso’s dolphins use the area regularly with re-encounters of the same animals along several years (Cañadas and Sagarminaga 1996); and the distribution patterns of several species were determined (Cañadas *et al.* 2002).

1.4.2.3. 2000 - 2002: the 'Mediterranean Project'

The "Mediterranean Project" is an abbreviation of a "programme for the Identification of Areas of Special Interest for the Conservation of Cetaceans in the Spanish Mediterranean" set up by the Spanish Nature Conservation Agency (DGCONA - Ministry of the Environment) in co-operation with the universities of Barcelona, Valencia and Madrid, the last one through Alnitak. Each University was in charge of exploring an area: the University of Barcelona was responsible for Catlonia and the Balearic Islands, the University of Valencia for the regions of Valencia and Murcia, and the University of Madrid – Alnitak for Andalusia, both in the Mediterranean and the Atlantic.

This project, within which is framed part of the work of this thesis (between 2000 and 2002), provided the necessary information for the fulfilment of the Spanish commitments under the European Union's Habitat Directive, the Barcelona Convention and the ACCOBAMS agreement. According to the last two international agreements, it is necessary to record the components of marine biodiversity, especially of cetaceans according to ACCOBAMS, and in particular of the threatened or endangered species according to the Barcelona Convention. Also according to both agreements, it is also necessary to designate areas that require special protection in the Mediterranean and the contiguous Atlantic. This was therefore the aim of this project, which covered the Mediterranean and contiguous Atlantic waters to accomplish these agreements. In addition, the Habitats Directive imposed upon Spain the requirement to designate a network of MPAs (SAC) within the 200 nmi limit, to ensure that protection is given to a sufficient percentage of the habitats of species in Annex I to achieve a favourable conservation status.

With this project the necessary information was obtained and some additional required measures were established to help achieve the favourable conservation status of cetaceans and, in particular (for the objectives of this thesis) of common and bottlenose dolphins. The fundamental information needed to develop the required conservation plans for species included in the National Catalogue of Endangered Species was therefore obtained.

The project was developed in two phases: First, to establish the conservation status of the different species in the Spanish Mediterranean. Second, to identify the areas of special interest for the conservation of cetaceans in the Spanish Mediterranean. The first phase had four general objectives:

a. Review of the previous information.

   An update of the available information was made.

b. Study of the distribution and relative density of the cetacean populations and their habitat use.

   This allowed a better knowledge of the distribution of the species throughout the study area and, for the first time, provided detailed information on the relative density of the different populations in the Spanish Mediterranean. This was complemented with information on the habitat use and several aspects of their biology.

c. Study of the identity of the populations

   This study was centred on the three most representative species of the Spanish Mediterranean: the bottlenose, striped and common dolphin, and was based on molecular analysis of microsatellites and mitochondrial DNA and on other molecular markers such as stable isotopes and pollutants. The analysis for bottlenose dolphin was done by the University of Barcelona, for striped dolphins by the University of Valencia, and for common dolphins by the University of Madrid and Alnitak.

d. Socio-economic analysis of the study areas.

   A socio-economic analysis of the study areas and its associated environmental problems was made, with special reference to the factors that directly or indirectly could affect the conservation of cetaceans and their habitats.

Based on all the information collected during the first phase of the project, the second phase focussed on the identification of the areas of special interest for the conservation of cetaceans in the Spanish Mediterranean and on the selection of those areas that should be protected in one way or another to promote the favourable conservation status of the cetacean populations, and especially of those considered endangered. This would allow implementing the diverse recommendations and requirements established by the international agreements to which Spain is committed. The selection of marine areas was based in some cases on their characteristics that deserved to be designated as SPAMI. In other cases it was based on the requirements of the Habitat Directive for bottlenose dolphins and harbour porpoises

(*Phocoena phocoena*) for which it was necessary to designate or extend the Special Areas for Conservation (SAC).

Guidelines on proposed management measures were also established to support the future management plans of the MPAs, analysing the threats to them and the possible solutions to mitigate them. Finally, many of the aspects highlighted in the Spanish Strategy for the Conservation and Sustainable Use of the Biological Diversity of the Ministry for the Environment were developed, especially in relation to the cataloguing and conservation of the marine biodiversity and to the creation of MPAs.

1.4.2.4. 2002 - 2006: the LIFE-Nature project

In July 2002 the Spanish Cetacean Society (SEC) started a LIFE-Nature Project partially funded by the European Commission (LIFE02NAT/E/8610 “Conservation of cetaceans and turtles in Murcia and Andalucía”) with the aim of designing a network of marine protected areas within the framework of the Natura 2000 Network of the Habitat Directive. This project will end in July 2006. The last four years of the work of this thesis are part of the LIFE project.

Partners of this project are the Ministry of Environment, Ministry of Agriculture, Fisheries and Food, the Councils of Environment and of Agriculture and Fisheries of the Government of Andalusia and of Murcia, the University of Cádiz and the Spanish Oceanographic Institute. In addition, there is the active participation and support of other entities such as the Mediterranean Cooperation Centre of the IUCN, Guardia Civil (SEPRONA and GC del Mar), Civil Protection, Red Cross of the Sea, General Directorate of Merchant Navy, CREPAD service of the National Institute of Aerospatiale Techniques (INTA), APIA (Association of Environmental Journalists), fishermen brotherhoods, whale-watching companies and town halls of towns and cities along the coasts. The non-governmental organizations Alnitak, Circé and ANSE also participate.

The nucleus of this project is the development of management and conservation plans based on the scientific research of Alnitak and SEC. Through the creation of a link between researchers and administration, the aim of SEC is the promotion of science integrated in the national and international biodiversity conservation strategies. Diverse advanced techniques are being used and tested such as modelling the habitat use and the abundance of the populations, molecular analysis of stable isotopes or satellite tracking.

But probably one of the defining characteristics of this project is its philosophy of involving all the stakeholders of the marine environment in the process of development of the conservation plans. Aware that management of the marine environment is only possible through consensus of all the relevant parties, SEC initiated the coastal tours “Todos por la Mar” (“All for the sea”). During the last four years, three striking classic sailing ships, old fishing boats, sailed along the Alborán Sea mooring in the ports of Andalusia and Murcia. Together with an itinerant exhibition, conferences and educational projects, meetings were held with sailors, fishermen, whale-watching companies and scuba diving centres to establish collaboration with a clear objective: to make conservation of biodiversity and sustainable economical development compatible.

Within the Project, there are several actions related to the monitoring of the cetacean populations. In particular, a research programme was developed to:

- Establish the conservation status of the populations and the factors that are affecting it, and to be able to detect changes so that appropriate action can be taken.
- Analyse the suitability of the design of the MPA for these species (SAC “Medio Marino de Murcia”) and of the proposals for MPAs in Andalucía.

1.4.3. Chapters

This thesis is organised into 11 chapters. Below there is a brief description of each of them.

After the present Introduction Chapter, I describe the study area in Chapter 2. Firstly, a very wide review of the natural and anthropogenic characteristics of the Mediterranean Sea is made. Then I focus on a more detailed description of the specific characteristics of the study area, the Alborán Sea and the Gulf of Vera, including physiography, oceanography, meteorology, and biotic characteristics. The chapter finishes with a summary of the ecological importance of the study area.

In Chapter 3 I make a brief description of the general field work methods that are common to all research chapters (5 to 9).

Chapter 4 describes the human activities and possible threats in the study area. Information from the literature and official records is combined with data collected during field work. Activities such as maritime traffic, tourism, fisheries, acoustic pollution, toxic pollution, etc. are described. A brief analysis of the possible impact of these activities on the cetacean populations is presented.

The next five chapters focus on the research on distribution, habitat selection and abundance of dolphins. Chapter 5 is a first approach to the distribution of several cetacean species in relation with the physiography off Almería. An important aspect of this chapter is that it establishes some distribution patterns of several species, analysing the similarities and differences among them and relating these with their feeding habits. The analyses done in this chapter are the simplest, as a first phase before moving into more complex methods in the following chapters. This chapter corresponds to an article published in 2002 in the peer reviewed journal Deep Sea Research II.

Chapter 6 is the result of the "Mediterranean Project" described above. In it, there is progress in two ways: First, the use of spatial analysis methods as a tool to study the distribution and habitat preference of the species is initiated. Second, the information obtained from these analyses is applied to conservation through the proposal of several MPAs. The selection process to achieve an appropriate designation is discussed, highlighting the importance of a scientific basis to the selection process and of an adequate management strategy to ensure the effectiveness of the protected areas. This chapter corresponds to an article published in 2005 in the peer reviewed journal Aquatic Conservation: Marine and Freshwater Ecosystems.

In Chapter 7 a new and more advanced analytical method is introduced. The line transect distance sampling analysis is combined with spatial analysis to obtain abundance estimates in addition to the surface maps of habitat preference. Up to this moment, this novel method had scarcely been applied, this being one of the first case studies of cetaceans in which it has been used. In this chapter, the abundance of bottlenose dolphins in the Alborán Sea is estimated with this method. In addition, it is applied to several periods of years analysing trends in the population during the time frame of the study (12 years). The implications for conservation are also discussed. This chapter corresponds to an article published in 2006 in the peer reviewed Journal of Cetacean Research and Management.

In Chapter 8 the same method as Chapter 7 is applied to the common dolphin. A difference in this case, however, is that the distance sampling analysis is stratified according to the searching conditions, yielding a more complex combination with the spatial analysis. Data are also stratified seasonally. Several sub-areas within the study area and periods of years are analysed and compared. The implications for conservation are also discussed.

In Chapter 9 the same method is applied again for the common dolphin, but in this case the objective was not to estimate abundance but to analyse the habitat preference as a function of several 'intrinsic' factors. There is first a description of the habitat preference in general in relation to environmental variables, comparable to the results from Chapter 8. A comparison is made with the habitat preference depending on the 'intrinsic' factors analysed: groups with or without calves, single species or mixed species (with striped dolphins) groups, and groups undergoing different activities when encountered (feeding, socialising or travelling). The implications for conservation are discussed.

Chapter 10 describes some ideas on how the process for the development of the conservation plan for bottlenose dolphins should be. This process is that followed during the LIFE-Nature Project, which will be finished and submitted to the European Commission and the relevant national and regional Spanish authorities in July 2006.

Finally, the Discussion Chapter focuses in three issues. The first is a discussion about the applicability of the methods used in this study to other areas and species. The second is a summary of the contribution of this thesis to the knowledge of the ecology of cetaceans in the study area, and in particular of common and bottlenose dolphins. The third is oriented towards the conservation of dolphins in the study area. In this sense, I summarise the proposals of MPAs; describe briefly the contribution to the Conservation Plans for common and bottlenose dolphins; describe how the baseline information, previously inexistent, has been established for a future long-term monitoring, providing ideas also for this monitoring; and describe the contribution to the public awareness of the general public. Finally, I give a series of suggestions about future lines of work to increase our knowledge on the ecology of these species and at the same time progress towards their effective conservation.

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CAPÍTULO 1

INTRODUCCIÓN

1.1 CONSERVACIÓN DEL MEDIO MARINO

El concepto de conservación del medio marino es un concepto joven. Hace escasas décadas hubiese sido un concepto extraño, casi absurdo. Absurdo porque hasta hace poco el mar era considerado un espacio infinito. Por una parte se daba por hecho que el mar podía ofrecer sus frutos sin límite. Y por otra porque del mismo modo se consideraba que el mar seria capaz de tragarse toda nuestra basura hasta el infinito sin mayor consecuencia. Hubo un tiempo en que se decía que había tanto bacalao en el Atlántico Norte que uno podría andar sobre sus lomos para cruzar desde Nueva Escocia hasta Noruega. Varias décadas más tarde, ni esta visión ni las previsiones de explotación de los recursos pesqueros parecen tan optimistas. De igual manera la contaminación del medio marino, bien sea por residuos plásticos, hidrocarburos o productos tóxicos persistentes nos muestra hoy que los océanos del planeta tienen también sus limites.

1.1.1. Estado, amenazas y conservación del medio marino

El Mar Mediterráneo es un mar casi cerrado. Sus únicas conexiones con los océanos del planeta son a través del Estrecho de Gibraltar y el Canal de Suez. Para los oceanógrafos, esta característica hace del Mediterráneo un océano en miniatura que constituye un excelente laboratorio para estudiar algunos procesos naturales en una escala más fácilmente abordable. De la misma forma, en el ámbito de nuestros aprendizajes en el marco de la conservación y gestión del medio marino y sus recursos naturales, este “pequeño laboratorio” pone de relieve la extraordinaria complejidad de este inmenso medio tridimensional que es el mar. Tener en cuenta esta complejidad es fundamental si pretendemos gestionar el medio marino, o más bien gestionar nuestras actividades en él.

Las amenazas que hoy nos preocupan en la cuenca mediterránea son básicamente las mismas que afectan a todos los mares y océanos del mundo. La explotación insostenible de recursos naturales (Pauly *et al.* 2002; 2003; Myers and Worm 2003), la destrucción mecánica de hábitats (e.g. Schwinghamer *et al.* 1996; Auster 1998; Watling and Norse 1998; Norse and Walting 1999), la degradación y pérdidad de hábitats (e.g. Kemp 1996); la contaminación acústica (e.g. Gordon and Moscrop 1996; Gordon and Tyack 2001); la contaminación por residuos sólidos y tóxicos persistentes (Morris 1980; EAA 1999; Reijnders *et al.* 1999; Aliani *et al.* 2003); el calentamiento global (e.g. MacGrvin and Simmonds 1996; Robinson *et al.* 2005); la introducción de especies exóticas (e.g. Boudouresque and Verlaque 2002; Cangelosi 2004), etc. En el origen de estas amenazas encontramos al igual que en el resto del planeta la creciente presión por parte de un crecimiento demográfico que se traduce en la intensificación de actividades como la navegación, la urbanización, la pesca, la agricultura, la piscicultura, la minería, el turismo, etc.

No cabe duda de que el estado de conservación del Mar Mediterráneo es preocupante. Decir en qué grado se encuentra este “estado de conservación” es difícil o más bien imposible. Podemos destacar algunos síntomas que justifican esta preocupación y que podemos ver reflejados en las poblaciones de cetáceos, que en este caso nos pueden servir de indicadores del estado de salud de este mar a nivel local. Por ejemplo, podemos destacar la gradual regresión, manifestada fundamentalmente en forma de fragmentación de las poblaciones, del delfín mular en la cuenca mediterránea (Notarbartolo di Sciara and Gordon 1996; Notarbartolo di Sciara 2002); la regresión del delfín común en toda la zona norte del Mediterráneo (Bearzi *et al*. 2003); la acumulación en las grasas de los delfines de metales pesados y otros residuos tóxicos persistentes (Borrell and Aguilar 1991; Aguilar *et al.* 1999; Aguilar *et al*. 2002), que nos revelan una contaminación preocupante de las cadenas alimenticias en el medio marino; o la frecuente observación de delfines con estrategias de alimentación basadas en el aprovechamiento de artes de pesca humanas (Fortuna *et al*. 1996; Bearzi and Notarbartolo di Sciara 1997), que podrían considerarse como indicadoras de una escasez de alimento.

Establecer medidas para que las actividades humanas no impacten de forma tan negativa en los ecosistemas marinos no es solo importante en el ámbito de la conservación de la biodiversidad. Está claro que la diversidad biológica es un factor importante que nos afecta directamente. La sobreexplotación de recursos o las alteraciones de hábitat que conllevan la regresión o desaparición de determinadas especies son realidades preocupantes. Pero cuando analizamos las consecuencias de determinadas presiones antropogénicas en los ecosistemas marinos debemos incluir también otros peligros como el incremento de la erosión costera o el cambio climático cuyos efectos en la población humana pueden alcanzar una escala mucho mayor. Véase, a modo de ejemplo, zonas costeras cuyos manglares han sido arrasados por la actividad humana (básicamente por la presión del turismo para crear playas), que sufren luego de forma inclemente los azotes de tsunamis ante la falta de la protección que ofrecían los manglares (Upadhyay *et al*. 2002).

Uno de los grandes escollos en el ámbito de la conservación del medio marino reside en la dificultad de estudiarlo. Una frase célebre a menudo utilizada hace alusión a lo poco que sabemos acerca de nuestros océanos en relación a nuestros conocimientos del espacio. Un claro reflejo de esta ignorancia nos llega últimamente vía satélite. Las nuevas técnicas de seguimiento por satélite de animales marinos nos han revelado a lo largo de los últimos años datos acerca de las vidas de pinnípedos, tortugas o cetáceos que ni el más atrevido de los investigadores se hubiese aventurado a imaginar (ver por ejemplo McConnell *et al*. 1999; Hays *et al*. 2002; Mate and Urbán-Ramírez 2003).

De igual forma que el mar nos plantea un reto a la hora de descubrir sus misterios, también nos plantea serios problemas para su gestión. Se trata del reto logístico de la vigilancia de enormes extensiones marinas, que se traduce a su vez en un reto económico difícil de afrontar. Este escollo implica que, en mayor medida que en tierra, debemos ser capaces de convencer a aquellas personas o entidades que realizan las actividades en el medio marino para que sean las que de *motu propio* sigan las regulaciones o directrices adecuadas, conscientes de que en ello nos beneficiamos todos.

Por otra parte, si tan solo se tomasen en serio y se respetasen las legislaciones vigentes y las regulaciones tanto a nivel regional, nacional y comunitario como de los diversos foros que regulan las actividades humanas en el medio marino, la mayoría de los problemas estarían resueltos. Y es que además de nuestras normativas autonómicas y estatales disponemos en principio de herramientas como la Directiva Hábitats, el Convenio de Barcelona, el Convenio de Marpol, el acuerdo de ACCOBAMS, la convención de naciones unidas de la ley del mar UNCLOS, el convenio de OSPAR, etc., de los que se habla más adelante.

No cabe duda de que los administradores de recursos marinos en muchas partes del mundo se encuentran con una gran cantidad de problemas propulsados por la explotación de los recursos marinos, de difícil solución a causa de los usos en conflicto, jurisdicciones superpuestas, límites mal definidos, y la degradación directa o indirecta de los hábitats cercanos a la costa causada por una variedad de actividades humanas. Sin embargo, a pesar de la magnitud de estos problemas afrontados por los administradores, se han realizado grandes progresos en los últimos años con adelantos revolucionarios en por lo menos tres áreas principales (Agardy 1997). En la gestión basada en la ciencia, se han hecho adelantos, entre otras cosas, en los campos de la dinámica de poblaciones, ecología de sistemas y oceanografía física, que se están utilizando para identificar áreas verdaderamente críticas para la protección si se quiere mantener el ecosistema en funcionamiento. En el campo de la economía de recursos, los adelantos en la valorización y simulación han demostrado que existen grandes incentivos para la gestión adecuada de las áreas costeras y marinas. Y en el campo de la sociología, la última década ha sido testigo de los cambios en la forma en que la responsabilidad de la protección ambiental y gestión de recursos están siendo devuelto a los usuarios locales mismos, con algunos éxitos notorios (ver por ejemplo la reserva de la isla de Tabarca, Alicante, http://www.alicante-ayto.es/medioambiente/rmtabarca.html).

1.1.2. Áreas Marinas Protegidas

A pesar de las dificultades de investigar el medio ambiente marino, es cada vez más evidente que el impacto humano en los mares es considerable (por ejemplo, Kelleher 1999; Roberts and Hawkins 2000; Salm *et al*. 2000; Harwood 2001; Myers and Worm 2003). Se requieren estrategias a largo plazo para la conservación de poblaciones y hábitats en respuesta a las actividades humanas que han causado, o pueden causar, un efecto negativo sobre su estado. Uno de los acercamientos más comunes a la conservación del medio ambiente marino es el establecimiento de las áreas marinas protegidas (AMPs) (ver por ejemplo Gubbay 1995; Boersma and Parrish 1999; Schwartz 1999; Hyrenbach *et al*. 2000; Reeves 2000; Hooker and Gerber 2004). Aunque su eficacia es objeto de mucha discusión (Boersma and Parrish 1999; Kelleher 1999), las AMPs son consideradas actualmente como herramientas importantes para la conservación de la biodiversidad por muchos marcos internacionales (Convención de Barcelona, 1976; Convención de Berna, 1979; ASCOBANS, 1991; Convención de OSPAR, 1992; ACCOBAMS, 1996; Directiva Hábitat de la Unión Europea, 1992; etc.).

Las áreas marinas protegidas o reservas marinas ofrecen una solución a algunos retos de la gestión del medio marino. Por una parte permiten focalizar determinados esfuerzos o acciones de gestión a nivel geográfico de una forma más tangible para el público. De esta forma estas reservas marinas permiten organizar las actividades humanas desarrolladas en una zona de alto valor zonificándolas de tal forma que permitan a la vez preservar los atributos de la zona y utilizarlos de escaparate de divulgación y educación.

Para la conservación de determinados hábitats costeros o enclaves críticos para la alimentación, reproducción o migración de determinadas especies marinas estas áreas marinas protegidas pueden sin lugar a dudas ofrecer la respuesta idónea. Su éxito como mecanismo de gestión y conservación radicará sin embargo en su adecuada designación, basada en estudios científicos de los requerimientos de los hábitats y especies a proteger y sobretodo en la implicación de los colectivos que tienen intereses socioeconómicos en la región. Es solo cuando se cumplen estos requisitos y sobretodo cuando la gestión del área marina protegida sea fruto de un consenso en el que todas las partes se ven beneficiadas que se puede hablar de viabilidad y utilidad.

Quizás lo que más detractores de áreas marinas protegidas ha suscitado en las últimas décadas haya sido el afloramiento de reservas sin fundamento, reservas con deslumbrantes fachadas pero sin siquiera un mínimo plan de gestión en su base. Reservas creadas más para su inauguración por parte de la clase política ante las cámaras de los medios de comunicación en sonados y solemnes actos, que para la puesta en marcha de una política de gestión.

En la selección de AMPs candidatas en este trabajo, seguimos en gran parte el proceso sugerido por Salm *et al*. (2000), ya que no se ha especificado ningún proceso de selección formal para dichas áreas. Según esos autores, el paso inicial es definir los objetivos de conservación para el AMP. Una vez que se hayan convenido éstos, el proceso de selección debe incluir cuatro pasos: (1) recolección de datos (incluyendo investigación bibliográfica y recolección de nuevos datos con respecto a la especie objetivo, las actividades humanas y las amenazas); (2) análisis de los datos (determinar las áreas con concentraciones de la especie objetivo, actividades humanas y amenazas para la especie); (3) síntesis de los datos (crear mapas para ayudar a establecer las prioridades de protección y a entender mejor las relaciones espaciales entre la especie objetivo, los procesos ecológicos y las actividades humanas); y (4) aplicación de los criterios de selección (asegurar objetividad en la elección de los sitios, de acuerdo con los objetivos y el marco jurídico en los cuales se basan).

En resumen, la creación de AMPs puede representar un paso en el proceso de conservación, y puede responder al propósito de implicar a las administraciones y al público - sin lo cuál la probabilidad de éxito sería pequeña. Sin embargo, sin la apropiada puesta en práctica de planes de gestión, las AMPs representarían solamente papel mojado proporcionando una falsa impresión de éxito de conservación (Duffus and Dearden 1995). Como regla general, la designación de AMPs no se debe considerar una alternativa a la gestión y conservación inteligentes del medio ambiente de los mares en su totalidad. El que un AMP en particular sea eficaz dependerá de los objetivos iniciales, su diseño (especialmente sus límites) y su aplicación (Boersma and Parrish 1999). Los pasos críticos son fijar objetivos de conservación claramente cuantificados, desarrollar un sólido plan de gestión a largo plazo para alcanzar estos objetivos (Gubbay 1995; Salm *et al*. 2000), y establecer un programa de monitorización eficaz para determinar si se están alcanzando los objetivos de conservación.

1.2. CONSERVACIÓN DE CETÁCEOS

Determinar con exactitud el estado de conservación de las especies y su hábitat es muy difícil (Simberloff 1998). Así como lo es determinar una causa de regresión o declive (ver por ejemplo Bearzi *et al*. 2003). Generalmente, se trata de situaciones en las que diversas amenazas se conjugan causando un deterioro en el estado de conservación.

Los cetáceos son a menudo causa de preocupación en cuanto a su conservación. Son especies muy carismáticas que atraen el interés del público general y por lo tanto resulta más fácil llamar la atención sobre sus problemas de conservación. Por ejemplo, temas como la caza ballenera (Oshumi 1980; Santera and Aguilar 1992; Reeves and Reijnders 2002; Clapham *et al*. 2003; Givens 2003) y la captura accidental en artes de pesca (Slooten *et al*. 2000; Bearzi 2000; Reeves and Reijnders 2002; Dans *et al*. 2003; Lennert-Cody *et al*. 2004; Tudela *et al*. 2005) son amenazas muy visibles que pueden incluso producir en ocasiones gran revuelo social. Pero existen otras amenazas sobre estas especies, no tan visibles socialmente, que también están afectando negativamente, a menudo en mayor medida que las mencionadas, al estado de conservación de los cetáceos. Algunos ejemplos pueden ser la sobreexplotación de recursos pesqueros, destrucción mecánica de hábitats por arrastre o por construcción de infraestructuras, contaminación acústica, contaminación química, colisiones con embarcaciones, acoso, etc.

Regenerar el estado de conservación de especies como los cetáceos no es tarea fácil (Harwood 2001). En primer lugar, para tener alguna posibilidad de éxito, cualquier medida de gestión debe estar fundamentada en un conocimiento básico de la especie, su ecología y su hábitat. Son éstas, o deben ser, las bases fundamentales de la llamada 'biología de la conservación', que básicamente busca minimizar las pérdidas de hábitat y biodiversidad, y de la emergente 'ecología de la restauración', que busca reparar o recuperar los hábitats y la biodiversidad (Young 2000). Una ciencia rigurosa constituye el pilar básico para una conservación con unas mínimas garantías de éxito (Boersma and Parrish 1999; Harwood 2001; Hooker and Gerber 2004). La ciencia puede aportar la información necesaria, entre otras cosas, sobre el tamaño de las poblaciones que se pretende conservar, sus patrones de distribución, cómo usan el hábitat y el impacto de las amenazas sobre las poblaciones y su efecto en la viabilidad de las mismas a largo plazo. Puede, y debe además, contribuir también a la identificación de las acciones de gestión que resulten más efectivas en la conservación.

Pero para favorecer el éxito de las medidas de conservación, es necesario también conocer, y usar, los marcos de conservación (acuerdos, legislaciones, etc.) en los cuales se pueden enmarcar dichas medidas para darles mayor fuerza y legitimidad de cara a las administraciones.

Es igualmente fundamental involucrar a los usuarios del medio en el que se pretenden aplicar las medidas de gestión, de forma que se puedan hacer compatibles la conservación de la biodiversidad y el desarrollo económico. Es necesario proveerles de la información necesaria para que comprendan que la conservación beneficia a todos a corto o largo plazo, involucrarles en el desarrollo de las ideas sobre acciones de gestión mediante un diálogo fluido horizontal (sin actitudes distanciadoras de arriba hacia abajo) e implicarles en todo el proceso de elaboración de los planes y medidas de conservación. Sin el apoyo y consenso de estos sectores no habría garantía de éxito de estas medidas de conservación.

El hecho de que los cetáceos sean especies carismáticas, como se menciona más arriba, puede ayudar en gran medida a promover acciones para su conservación. Sin embargo, un factor a tener en cuenta a la hora de obstinarnos en conservar especies emblemáticas es que son parte de un ecosistema, y que no se puede pretender conservar o restaurar una población sin tener en cuenta que es lo que requiere su ecosistema para soportarla (Simberlof 1998; Zacharias and Roff 2000; Harwood 2001). Por esta razón, en muchas ocasiones los esfuerzo de conservación enfocados únicamente a la especie suelen acabar en fracaso, y de ahí el creciente enfoque que se está dando en los últimos años a una conservación basada en el ecosistema, o a una mezcla de ambos conceptos (Simberloff 1998).

1.2.1. Legislación y marcos de gestión en relación a la conservación de los cetáceos en el Mediterráneo

El objetivo principal de este trabajo es la realización de una investigación encaminada hacia la conservación del delfín común y el delfín mular en el mar Mediterráneo y, más específicamente, en el mar de Alborán y aguas adyacentes. Pero para promover su conservación hay que tener en cuenta aspectos, no sólo puramente científicos, sino también aquellos factores políticos y socio-económicos involucrados en la práctica de la conservación de una especie y su hábitat, pues son estas fuerzas las que, en última instancia y sobre la base de los datos científicos, decidirán sobre la gestión de las áreas y especies protegidas. Por esta razón, es necesario conocer, en primer lugar, la legislación vigente en relación con la investigación, conservación y gestión de los mamíferos marinos, y en particular aquella que afecte más directamente a los pequeños delfines, que son las especies objetivo de este trabajo.

1.2.1.1. Legislación y gestión internacional

UNEP-UICN

La Unión Internacional para la Conservación de la Naturaleza (UICN) y el United Nations Environmental Program (Programa sobre el medio ambiente de las Naciones Unidas - UNEP) realizaron, en relación con el Plan de Acción Mediterráneo, un estudio sobre el estado de los cetáceos en el Mediterráneo (UNEP-UICN 1994). En 2003 la subpoblación mediterránea de delfín común se clasificó como "amenazada" (EN) en la Lista Roja de especies amenazadas de la UICN, basado en el criterio A2, que se refiere a un declive en la abundancia de un 50% a lo largo de las ultimas tres generaciones, cuyas causas "pueden no haber cesado *o* pueden no ser entendidas *o* puedes no ser reversibles" (http://www.redlist.org). En el caso del delfín mular, debido a su todavía confusa taxonomía y al considerable solapamiento en sus rangos de distribución, ambas especies (*Tursiops truncatus* y *Tursiops aduncus*) se listaron en 1996 como "deficiente en datos" (DD) hasta que se obtenga más claridad respecto a ellas. Las demás especies de cetáceos del Mediterráneo no han sido aún evaluadas.

Convenio de Berna

El Convenio de Berna relativo a la Conservación de Vida Silvestre y el medio natural en Europa (Berna 1979) tiene como objeto garantizar la conservación de la flora y de la fauna silvestres y de sus hábitats naturales, concediendo especial atención a las especies amenazadas de extinción y vulnerables, incluidas las especies migratorias y en especial a aquellas que relata en su apéndice II como "Especies de la fauna estrictamente protegidas". Entre ellas se encuentran todas las especies de delfines que habitan el Mediterráneo. Posteriormente, en 1989, se recomendó a las partes que avanzaran en la designación de áreas de especial interés en la conservación para asegurar que se tomen las medidas de conservación necesarias sobre todo respecto a aquellas áreas que contribuyan substancialmente a la supervivencia de especies amenazadas, endémicas o aquellas especies de las listas I y II del convenio.

Convenio de Washington

El Reglamento CITES que regula el Comercio de Especies Amenazadas de Fauna y Flora Silvestres es de obligado cumplimiento. El apéndice II incluye todas las especies que si bien en la actualidad no se encuentran necesariamente en peligro de extinción podrían llegar a esa situación a menos que el comercio de especimenes de dichas especies esté sujeto a una reglamentación estricta. Este anexo II incluye a los cetáceos.

Convenio de Bonn

El Convenio sobre la conservación de las especies migratorias de animales silvestres entró en vigor en 1983 e insta también a que se realicen acuerdos multilaterales para la conservación y gestión de las especies migratorias incluidas en el apéndice II (en la cual están incluidos todas las especies de delfines del Mediterráneo) y a promover la cooperación en actividades de investigación. La mayor relevancia del convenio de Bonn para los mamíferos marinos ha sido los acuerdos que se han tomado varios años después: ASCOBANS, SEAL WADDEN, y ACCOBAMS, siendo este último el único que por ahora afecta a España (ver más adelante), aunque está pendiente la incorporación de España al acuerdo de ASCOBANS.

1. 2.1.2. Legislación territorial

Convenio de Barcelona

Convenio para la protección del Mar Mediterráneo contra la contaminación (Barcelona Convention 1976), modificado en 1995 en Barcelona y denominado desde entonces "Convention for the Protection of the Marine Environment and the Coastal Regions of the Mediterranean". Entre sus protocolos destaca el Protocolo sobre las Zonas Especialmente Protegidas y la Diversidad Biológica en el Mediterráneo. Este protocolo proporciona una especial protección a las especies mediterráneas en peligro y a los hábitats vitales para su conservación a través de una red de Zonas especialmente protegidas para el Mediterráneo (ZEPIMS).

En el protocolo de Barcelona se hace hincapié en la importancia de proteger, y en su caso mejorar, el estado del patrimonio natural y cultural del Mediterráneo. Asimismo, en el protocolo se insta a tomar las medidas necesarias para conocer la distribución y uso del hábitat de las especies, "buscando" aquellas áreas de alto valor natural o que debieran ser protegidas para lograr que dichas especies se mantengan en un estado favorable de conservación. El Convenio incluye un anexo II con una lista de especies amenazadas o en peligro que incluye a los delfines del Mediterráneo.

Entre los objetivos de las zonas especialmente protegidas está salvaguardar los hábitats necesarios para la supervivencia, reproducción y recuperación de las especies de flora y fauna en peligro, amenazadas o endémicas, y en el caso de las ZEPIMS, zonas especialmente protegidas de importancia para el Mediterráneo, se podrán incluir espacios que sean hábitats de especies en peligro.

Plan De Acción Medioambiental para el Mediterráneo (PAM) - Plan de Acción para la conservación de los cetáceos del mar Mediterráneo.

Adoptado por las partes contratantes del Plan de Acción del Mediterráneo en 1991 tiene dos objetivos globales básicos: 1) la protección de los cetáceos y conservación de sus hábitats, y 2) la protección, conservación y recuperación de las poblaciones de cetáceos en la zona del mar Mediterráneo

El Plan de Acción para la Conservación de los Cetáceos del Mar Mediterráneo insta a desarrollar y aplicar programas de estudio coordinados destinados a determinar la situación y la distribución de los cetáceos en el Mediterráneo, incidiendo en la importancia de trabajar sobre las metodologías más adecuadas que se han de aplicar en interés común, teniendo en cuenta las necesidades de información en las diferentes áreas.

ACCOBAMS

El Acuerdo sobre la conservación de los cetáceos del mar Negro, el mar Mediterráneo y la zona Atlántica contigua (ACCOBAMS) se realizó en Mónaco en 1996 en el marco del Convenio de Bonn. España fue el segundo país en ratificarlo y entró en vigor en el año 2001. Este acuerdo cubre a todas las especies de cetáceos del Mar Negro, Mar Mediterráneo y la zona del Atlántico contigua al Mediterráneo, aunque presta una especial atención a especies como la marsopa (*Phocoena phocoena)*, el delfín mular, el delfín común y el calderón negro *(Globicephala melas).* Los fines de este acuerdo son: reducir las amenazas a los cetáceos en dichas aguas, protegerlos y establecer una red de áreas protegidas importantes para la alimentación, reproducción y cría. Así mismo, insta a realizar labores de investigación y monitorización, desarrollar programas de información, educación pública y adiestramiento o formación.

1. 2.1.3. Legislación comunitaria

Directiva Hábitat

En el ámbito de la Unión Europea, la Directiva 97/62/CEE del Consejo relativa a la conservación de los Hábitats Naturales y de la fauna y flora silvestres, incluye en su Anexo IV a todos los cetáceos no incluidos en el Anexo II (delfín mular y marsopa común) como especies animales de interés comunitario que requieren protección estricta.

Para las especies listadas en el Anexo II de la Directiva Hábitats (como el delfín mular), se requiere la creación de "Áreas Especiales de Conservación" o LIC (Lugar de Interés Comunitario). Bajo el artículo 1(k) de la Directiva Hábitats, un lugar de importancia comunitaria se define como un lugar que contribuya significativamente al mantenimiento o restauración de un estado de conservación favorable de un tipo de hábitat natural en el Anexo I o de una especie en el Anexo II. En el artículo 1(l) se define un Área Especial de Conservación (LIC) como un lugar de importancia comunitaria donde es necesario aplicar medidas para mantener o restaurar a un estado de conservación favorable, los hábitats o poblaciones de especies para los cuales se ha designado el área (European Union Habitats Directive, 1992). Para ser aceptado como parte de la Red NATURA 2000 Europea de áreas protegidas, los LIC propuestos deben mostrar ser de importancia particular para la conservación de las especies.

1. 2.1.4. Legislación nacional

Real Decreto 1997/95 y 1993/98

Como consecuencia de la transposición al ordenamiento jurídico español de la Directiva Hábitat, los cetáceos quedan igualmente incluidos en los Anexos II y IV del Real Decreto 1997/1995, por el que se establecen medidas para garantizar la biodiversidad mediante la conservación de los hábitats naturales y de la flora y fauna silvestres, modificado por el Real Decreto 1993/1998. Según su artículo 10 los cetáceos gozarán de las medidas de protección establecidas por el Real Decreto 439/1990 por el que se regula el Catálogo

Nacional de Especies Amenazadas y por la Ley 4/1989 de Conservación de los Espacios Naturales y de la Flora y Fauna Silvestres, reformada y modificada, respectivamente, por las Leyes 40/1997 y 41/1997.

Catálogo Nacional de Especies Amenazadas

Algunas especies de cetáceos fueron incluidas en el Catálogo Nacional de Especies Amenazadas en 1999. Entre estas especies entran en la categoría de "Vulnerable" el delfín mular, el delfín común del Mediterráneo, el rorcual común y el cachalote. Las demás especies presentes en el Mediterráneo entran en la categoría “de interés especial”, excepto los zifios que no fueron catalogados. En la categoría de vulnerable se incluyen aquellas especies, subespecies y poblaciones que corren el riesgo de pasar a las categorías de "sensibles a la alteración del hábitat" o "en peligro de extinción" en un futuro inmediato si los factores adversos que actúan sobre ellas no son corregidos. La catalogación como "vulnerable" exige la redacción de un Plan de Conservación.

1.2.2. Rol de los cetáceos en la promoción de la conservación del medio marino en el mar Mediterráneo

Para un país como España, la conservación del mar Mediterráneo reviste una especial importancia que va mas allá del mantenimiento de unos valores ecológicos que desafortunadamente preocupan únicamente a una pequeña porción de su población. En este caso, la palabra conservación afecta a la integridad del país, puesto que el ecosistema mediterráneo constituye el sustento de dos de sus principales industrias, la pesca y el turismo.

Según el informe “Mediterranean Sea: Environmental State and Pressures” de la Agencia Europea de Medio Ambiente (EEA 1999) que analiza el estado de conservación del Mediterráneo, sus problemas y sus recursos, las perspectivas económicas para España prevén un importante crecimiento económico a lo largo de la costa mediterránea.

Este pronóstico optimista esta sujeto, eso sí, a un factor de vital importancia, que es la conservación de un adecuado estado de salud del Mar Mediterráneo. España se encuentra por tanto hoy en día ante el importante reto de transformar su actual incontrolado uso y abuso de este ecosistema marino en una explotación sostenible que asegure el futuro de su crecimiento económico.

En el citado informe de la Agencia Europea de Medio Ambiente, se resalta entre las amenazas que ponen en peligro el ecosistema mediterráneo, un factor que aparece hoy como uno de los principales obstáculos a franquear para la puesta en marcha de un desarrollo sostenible. Se trata del hecho de que tanto los ciudadanos ribereños como los turistas que viven y disfrutan gracias al Mar Mediterráneo, sorprendentemente viven de espaldas a él, ignorando que más allá de la playa y del sol la superficie azul del Mar Mediterráneo esconde un ecosistema de extraordinaria riqueza. Si conseguimos mostrar al público esta riqueza habremos dado el principal paso hacia la conservación de nuestro mar.

En este sentido, especies carismáticas como los delfines cobran una nueva importancia en el marco de los esfuerzos de conservación bajo la denominación de "especies banderas", especies que pueden ser usadas para promover campañas de conservación porque estimulan el interés y la simpatía del público (Simberloff 1998; Hoyt 2005). Un eslogan como "salvemos el boquerón" tiene pocas perspectivas de éxito. Sin embargo, los delfines resultan una extraordinaria herramienta para sensibilizar al público acerca del funcionamiento y la importancia de un ecosistema marino como el mediterráneo.

En el caso de los delfines del Mediterráneo, su utilidad es triple. Por una parte tenemos su importante potencial para la sensibilización del público (especie bandera), y por otra parte tenemos su utilidad como “especies paraguas”, especies que necesitan tales dimensiones de hábitat que salvándolas a ellas automáticamente se salva a muchas otras especies (Simberloff 1998), y como “especies indicadoras” del estado de conservación del ecosistema a nivel local (Katona and Whitehead 1988; Viale 1993). Situados en la cima de su cadena alimenticia, los delfines pueden ofrecen al científico, en determinadas situaciones, una herramienta útil para valorar el estado de conservación de un ecosistema marino.

De esta forma, cuando consideramos el reto de la designación y posterior gestión de áreas marinas protegidas como mecanismos de conservación, los delfines, gracias a su triple utilidad, nos permiten mantener un vínculo directo entre la ciencia, la política ambiental y el público, que está considerado como un factor clave en el establecimiento de sistemas de gestión del medio ambiente marino (Salm *et al*. 2000).

Por otro lado, para proteger a los cetáceos de forma efectiva, se requiere proteger a los organismos que viven en el ecosistema y al ecosistema mismo (Prideaux 2003), por lo que normalmente se requiere tener un enfoque más en la línea de lo que se ha venido a llamar recientemente “conservación basada en el ecosistema” (Simberloff 1998; Hooker and Gerber 2004; Hoyt 2005).

Como ya se comenta más arriba, con el objeto de asegurar la eficacia de zonas protegidas en la regeneración del ecosistema marino, es imprescindible una óptima designación de éstas, que sea fruto de un minucioso análisis que tome en consideración criterios tanto ecológicos como socioeconómicos (Gubbay 1995; Boersma and Parrish 1999; Salm *et al.* 2000). En este sentido la Dirección General de Conservación de la Naturaleza puso en marcha en 1999 el "Programa de Identificación de Áreas de Especial Interés para la Conservación de los Cetáceos del Mediterráneo Español" (ver más abajo), coincidiendo en el mismo año con la inclusión de varias especies de cetáceos en el Catálogo Nacional de Especies Amenazadas así como la puesta en marcha por parte de la misma Dirección General de un grupo de trabajo de expertos en temas marinos para la realización de trabajos tan importantes como la "Ley del whale-watching". Estos avances aparecen como un claro reflejo de un creciente interés por el hasta ahora olvidado medio ambiente marino.

En Enero de 1998, el Ministerio de Medio Ambiente presentó públicamente el Primer Inventario Nacional de Cetáceos (Aguilar *et al*. 1994), fruto de un convenio entre este ministerio y la Universidad de Barcelona. En él, quedó claramente reflejada la necesidad y urgencia de la puesta en marcha de programas de investigación cuyos objetivos fuesen el establecimiento del estado de conservación de las distintas especies de cetáceos y la designación de zonas de especial interés con miras a satisfacer los requisitos de la Red Natura 2000.

Desde la presentación del Inventario Nacional de Cetáceos, varias reuniones tanto en el ámbito nacional (reuniones de expertos convocadas por la Dirección General de la Conservación de la Naturaleza), como internacional (por ejemplo, Reunión de expertos para la Implementación de Planes de Actuación para Mamíferos Marinos UNEP, ARTA Octubre 1998, Reunión de Trabajo “Biological Monitoring of European Marine Special Areas of Conservation Workshop", celebrado en Londres en 1998), mostraron el interés general que suscita la conservación de los cetáceos y la importancia de la designación de zonas de especial interés para la conservación ZEPIMS y de LIC.

Pendiente de ratificación por varios estados miembros, el acuerdo internacional de conservación ACCOBAMS, constituye sin lugar a duda un marco de acción importante que refleja una vez más el trascendente papel de la investigación y conservación de los cetáceos en la designación y posterior monitorización de las futuras zonas de especial interés ZEPIM en el Mar Mediterráneo. La firma, en Noviembre de 1999, por parte de Francia, Principado de Mónaco e Italia del Santuario Internacional Marino del Mar de Liguria ‘Pelagos’ es un primer paso en esta dirección (Hoyt 2005).

1.2.3. Importancia del conocimiento sobre la distribución, uso del hábitat y abundancia de cetáceos para evaluar sus amenazas y promover su conservación

Uno de los principales escollos a la hora de establecer el estado de conservación de los cetáceos en el Mediterráneo es sin duda la escasez de información acerca del pasado e incluso del presente de las poblaciones que habitan este mar. Los datos históricos de los que disponemos son muy escasos y los esfuerzos de investigación sufren de una importante heterogeneidad tanto a escala temporal como espacial (Notarbartolo di Sciara 1994; Notarbartolo di Sciara and Gordon 1996; Bearzi *et al*. 2003; Cañadas *et al*. 2004).

Un mejor conocimiento del estado actual de conservación de las distintas especies de cetáceos incluyendo aspectos de su tamaño de población, distribución y dinámica, uso de hábitat, etc. es indispensable para apoyar políticas de conservación eficientes como la designación de áreas de protección especial. De esta forma, el primer paso debe ser la investigación científica para llegar al conocimiento y entendimiento del ecosistema del cual es parte la especie, y del nicho específico de la misma (Boersma and Parrish 1999; Harwood 2001; Hooker and Gerber 2004). Una especie es parte de su ecosistema y no se puede aislar de él. Por esta razón, es de vital importancia examinar el papel de una especie particular en su ecosistema y las relaciones o nexos que se dan dentro de él para poder evaluar cuales son las posibles variaciones o alteraciones de dicho ecosistema que pueden producir un impacto potencial sobre la especie en estudio.

Existen ocasiones en las que se deben establecer políticas de gestión y conservación sin que se disponga de todos los datos y todas las informaciones necesarias. Esto es lo que se denomina el Principio de Precaución: "Las decisiones de gestión deben incluir un factor de seguridad que de cabida al hecho de que el conocimiento es limitado y las instituciones son imperfectas" y "La magnitud del factor de seguridad debe ser proporcional a la magnitud del riesgo" (Holt and Talbot 1998). La necesidad de precaución en el caso de los cetáceos ha sido reconocida ampliamente (Mayer and Simmonds 1996; Slooten *et al*. 2000; Taylor *et al*. 2000), sobretodo teniendo en cuenta que los cetáceos son especies longevas y por lo tanto requieren estudios a largo plazo, por lo que las poblaciones pueden sufrir declives hasta niveles peligrosamente bajos antes de que las acciones de gestión se pongan en práctica si se requiere *a priori* una demostración del daño que producen determinadas actividades humanas (Thompson *et al*. 2000). Existen algunos ejemplos en los que este tipo de políticas de precaución ha jugado un papel primordial en la conservación del medio marino, como las prohibiciones de vertidos desde barcos de residuos tóxicos o radiactivos al medio marino establecidos por la Convención de Londres de vertidos (London Convention 1972: www.londonconvention.org). Sin embargo, también ha sido reconocida la dificultad de la aplicación del principio de precaución en la práctica, sobretodo debido a la falta de la información científica necesaria (Gray and Bewers 1996; Thompson *et al*. 2000).

Por otra parte, existen ejemplos que muestran claramente el peligro que existe en la realización de acciones de gestión o políticas de conservación que no toman en cuenta la importancia de una base científica sólida, revelándose finalmente como una amenaza para las poblaciones que se pretendía conservar. Por ejemplo, durante cinco años se incubaron de forma artificial los nidos de tortuga boba (*Caretta caretta*) de las playas de Chipre con la intención de ayudar a la especie aumentando la tasa de eclosión de las puestas de huevos. Poco después se detuvo esta acción de gestión al revelar estudios científicos que la temperatura de incubación es la que determina el sexo de las tortugas (Demetropoulos and Hadjichristophorou 1989). Otro ejemplo es la introducción artificial en los años 70 del cangrejo rojo americano (*Procambarus clarki)* procedente de Estados Unidos en los ríos y humedales españoles como medida de gestión para compensar la disminución del cangrejo rojo autóctono (*Austropotamobius pallipes*), pero que debido a su rapidísima adaptación, predación y un hongo asociado causó un grave declive del cangrejo autóctono y muchas otras especies (Pérez-Bote *et al*. 2004).

En el caso de la conservación de delfines, existen determinadas informaciones sin las cuales es imposible establecer políticas de gestión sin arriesgarse a que éstas sean totalmente inefectivas o incluso inapropiadas. En primer lugar es necesario saber de cuántos delfines se está hablando, determinar cual es, o cuales son las poblaciones o sub-poblaciones que hay que conservar, y cual es su distribución. Hay que saber también hasta cierto grado de detalle como utilizan su hábitat, así como tener información de base acerca su alimentación y de su historia natural.

El porqué de este requerimiento de información es simple. Es necesario poner las amenazas o los impactos de las actividades humanas en contexto. Si se detecta una determinada mortandad de delfines debido a la captura accidental en artes de pesca, es necesario saber de qué proporción de la población estamos hablando, para identificar si estamos ante un problema de conservación para la población o es 'simplemente' un problema para los individuos afectados (por mucho que sean carismáticos y que el bienestar de los animales particulares sea también una preocupación) pero que no pone en riesgo la viabilidad de la población al tratarse de un porcentaje sostenible por la misma (Internacional Whaling Commission 1995). Esto es fundamental a la hora de priorizar actuaciones de gestión, sobretodo cuando se dispone de recursos limitados.

El delfín común y el delfín mular son las especies que más se acercan a costa en el Mediterráneo, y por lo tanto las que más susceptibles son de sufrir el impacto de las actividades humanas que se desarrollan fundamentalmente en o cerca de las costas. Posiblemente como consecuencia de esto, estas dos especies se encuentran amenazadas en el Mediterráneo. Por esta razón los esfuerzos de esta tesis se centran sobretodo en estas dos especies.

1.2.4. Planes de Conservación

1.2.4.1. Porqué es necesario un plan de conservación

Los delfines son especies amenazadas que podrían desaparecer de nuestras aguas si no tomamos una serie de medidas correctoras. Se pueden establecer áreas marinas protegidas con sus correspondientes planes de gestión en las que se determinen las acciones necesarias para que estas especies objetivo encuentren en ellas condiciones favorables para su alimentación, reproducción o migración. Pero no se puede olvidar que para estas especies las dimensiones y los limites de estas áreas marinas pueden no tener sentido. Pueden ser una ayuda, pero por si solas no bastan para asegurar que se cumplan los objetivos de conservación para la especie: el mantenimiento de un estado de conservación favorable.

Por lo tanto, las áreas marinas protegidas son necesarias pero no suficientes y no se pueden contemplar como la solución global para la conservación y gestión sostenible del medio marino. Especialmente cuando hablamos de especies marinas que abarcan grandes territorios como los cetáceos se pueden destacar las limitaciones de una reserva marina. El medio marino se caracteriza principalmente por ser gigantesco, tridimensional y extraordinariamente dinámico. Limitar los esfuerzos de gestión a áreas con límites rígidos es evidentemente insuficiente cuando se habla de conservación de la gran mayoría de las especies marinas. Es necesario tomar en cuenta los requerimientos espaciales de estas especies si se quiere una conservación efectiva (Fahrig 2001). Por otra parte, las actividades humanas que pueden estar causando una amenaza no suelen restringirse a un área particular, y la gestión de actividades dentro de un área no puede lidiar con amenazas externas que son transportadas a dentro del área como resultado de la naturaleza tridimensional de los componentes del medio ambiente marino (Allison *et al*. 1998; Zacharias and Roff 2000; Jamieson and Levings 2001). Es esta una de las razones por la cual las áreas marinas protegidas cuentan también con detractores en la comunidad científica.

Hoy por hoy, sin embargo, las AMPs siguen siendo la herramienta principal y más extendida utilizada en cuanto a conservación de cetáceos. Muchas son las designaciones de áreas, pequeñas y grandes, a lo largo de los mares y océanos del mundo enfocadas a la conservación de los cetáceos. Por ejemplo, los LIC para delfín mular y marsopa de la Directiva Hábitat de la Unión Europea; el extenso Santuario de Cetáceos "Pelagos" en el Mar de Liguria (Notarbartolo di Sciara 2001), la 'Losinj Dolphin Reserve' en Croacia (Mackelworth *et al*. 2003) y varias otras de pequeñas dimensiones, en el Mediterráneo (Hoyt 1995); el Stellwagen Bank (Ward 1995) y el Cañón del Gully (Hooker *et al*. 1999) en el Atlántico Noroeste; el 'Hawaiian Islands Humpback Whale Sanctuary' (http://hawaiihumpbackwhale.noaa.gov/) en el Pacífico; etc.

Frente a esta situación, el principal reto de este trabajo consiste en avanzar hacia la conservación efectiva de las especies y sus hábitats. Por lo tanto, hay que destacar que la creación y diseño de áreas marinas protegidas no es la meta final de este trabajo, sino una acción más dentro de unos futuros Planes de Conservación para las especies, en las que estas áreas marinas y sus consiguientes Planes de Gestión estarían enmarcados.

Por esta razón necesitamos un Plan de Conservación que recoja los requerimientos para la conservación de la especie en una escala adecuada, ya que no se ciñe a un área protegida en particular sino que se aplica a un área geográfica más extensa, normalmente la abarcada por las competencias de las autoridades implicadas.

El Plan de Conservación tiene por objeto establecer unas líneas de actuación prioritarias. En él se recogen acciones de distinto tipo, acciones de gestión, acciones legislativas, acciones de capacitación, acciones de divulgación, acciones de monitorización o seguimiento y acciones de investigación. De esta forma se establece una estructura organizativa para que se realicen de la forma más eficaz posible aquellas actuaciones necesarias para preservar un estado de conservación favorable de la especie objetivo y de su hábitat.

Desafortunadamente, son aun pocos los planes de conservación para cetáceos en el mundo no enmarcados en AMPs concretas, y se tratan fundamentalmente de planes de recuperación de especies en grave peligro. Algunos de estos ejemplos son el Plan de Recuperación de la ballena franca (*Eubalaena glacialis*) en el Atlántico norte anunciado en Junio de 2005 (http://www.publicaffairs.noaa.gov/releases2005/jun05/noaa05-r116.html), o el Plan de Recuperación para la ballena azul (*Balaenoptera musculus*) (National Marine Fisheries Services 1998). Ningún Plan de Conservación se ha desarrollado aún para cetáceos en España ni en el Mediterráneo ni en Europa, por lo que este trabajo se presenta como un desafío por su novedad. En el caso español, se están desarrollando

'Estrategias de Conservación' para especies amenazadas como el águila imperial ibérica (*Aquila adalberti*), el quebrantahuesos (*Gypaetus barbatus*) o el oso pardo (*Ursus arctos*) entre otros (Comisión Nacional de Protección de la Naturaleza 2001a, b, c). Se pretende con este trabajo contribuir a estas estrategias de forma que los Planes de Conservación desarrollados pasen a formar parte de una Estrategia Nacional para la Conservación de varias especies de cetáceos.

1.2.4.2. Porqué es necesaria la información de base

La recuperación o el mantenimiento de un estado de conservación favorable de especies amenazadas, en el marco de los planes de gestión de un AMP (LIC, ZEPIM, etc.) o de un plan más general de conservación, necesita ser estructurado sobre una base científica sólida (Boersma and Parrish 1999; Hooker and Gerber 2004). Incluso si hay ocasiones en que acciones extremas puedan tener que ser emprendidas urgentemente basado más en el principio de precaución que en conocimiento, los ejemplos de errores importantes cometidos en el pasado reciente en acciones de conservación, basado en buenas intenciones, destacan claramente la complejidad de una gestión adecuada y por lo tanto el requerimiento de datos científicos.

Está claro que con las presiones actuales en el ambiente marino no podemos darnos el lujo de esperar para tener "todos" los datos antes de tomar acción, pero si podemos establecer qué datos básicos son imprescindibles. La investigación en el mar es un desafío logístico y económico y es por lo tanto esencial priorizar los objetivos de la investigación centrándose en qué información es esencial para unas estrategias sólidas de conservación.

Al ocuparnos especialmente de especies carismáticas como los delfines, la base científica es aún más esencial. Un simple varamiento de un delfín viejo o la muerte de uno inexperto en un arte de pesca pueden generar un alboroto público increíble. Esto, si mal empleado por los intereses de 'venta' de la prensa o de grupos ecologistas puede hacer más daño que beneficio a la conservación de la biodiversidad.

La información de base constituye, pues, el cimiento científico del Plan de Conservación (y del Plan de Gestión de un área marina protegida). Consiste en la información básica requerida para apoyar científicamente las acciones de conservación del plan. La necesidad fundamental de esta información de base para el análisis de las amenazas, la identificación de las medidas de mitigación apropiadas y la consiguiente determinación de las acciones prioritarias, sin la cual (junto con un plan de monitorización adecuado) no sería posible, entre otras cosas, determinar si los objetivos de conservación se cumplen, fue reconocida por el comité científico de ACCOBAMS en su Resolución 2.9 de 2003 (ACCOBAMS 2003).

La información de base sirve fundamentalmente tres propósitos:

a) En primer lugar, pone en contexto las amenazas sobre la población (por ejemplo, a que proporción de la población afecta, a que sector, etc.) para de esa forma poder evaluar con una base sólida los impactos reales de las actividades humanas sobre el estado de conservación de dicha población y sobre su viabilidad a largo plazo.

b) En segundo lugar, provee los datos necesarios para establecer qué acciones son necesarias y además viables, en base a información científica sobre la población de la especie objetivo y su historia natural, así como sobre las actividades humanas implicadas.

c) Por último, establece los niveles de referencia que permitirán el análisis de las tendencias a través de la monitorización. Estos niveles de referencia deben proveer a cada acción del plan de conservación con un mecanismo de retroalimentación para asegurar que ésta se pueda ajustar a cualquier cambio, con el fin de alcanzar los objetivos establecidos para la acción de acuerdo con los objetivos generales del plan de conservación.

Por lo tanto no solo es necesaria una información de base sobre las poblaciones o la especie objetivo del plan de conservación, sino también sobre las actividades humanas que representan, o pueden representar, un impacto o amenaza sobre estas poblaciones.

Al nivel de poblaciones, se trata de información científica sobre la especie a conservar, especialmente en términos de la identidad de su población, su abundancia, sus patrones de distribución y su historia natural. A nivel de actividades humanas, se trata de información cuantificable sobre las mismas (cantidad, intensidad, niveles, etc.). Esta información paralela permitirá establecer vínculos – que habrán de ser testados científicamente – entre tendencias de las poblaciones y cambios en las actividades humanas.

1.2.4.1 Porqué es necesario un plan de monitorización

Establecer la información de base como referencia científica para guiar las futuras acciones de conservación es el primer paso. Una vez conseguido esto, la monitorización necesita convertirse en la columna vertebral de la gestión, como estipula la Directiva Hábitat de la Unión Europea (Artículo 17): "se requiere el desarrollo de un Plan de Monitorización para proveer información sobre el estado de conservación de los hábitats y las especies que los LIC han de conservar, y para determinar la efectividad del Plan de Gestión en alcanzar sus objetivos de conservación".

El Plan de Conservación no constituye un documento definitivo e inalterable. Se trata de un documento que cubre una fase temporal en el marco de los esfuerzos para la recuperación y conservación de una especie, y por tanto necesita ser revisado periódicamente con el fin de ajustar sus acciones a los diversos cambios que pueden producirse bien en respuesta a las propias acciones del plan de conservación o por factores externos.

La herramienta necesaria para saber cómo y cuando son necesarias las adecuaciones o modificaciones de las acciones del plan de conservación es la monitorización o seguimiento. Este seguimiento es parte del propio plan en forma de acciones de monitorización en las cuales se han establecido los indicadores de seguimiento idóneos así como las herramientas para obtenerlos. De esta forma se otorga al plan de un mecanismo de retroalimentación que asegura su correcto funcionamiento adaptándose a posibles cambios en la situación tanto de la especie objetivo como de su entorno o de las amenazas.

Es fundamental que la monitorización se realice no solo sobre los parámetros de la población, para detectar tendencias en su estado de conservación. Es necesario que ésta se realice también sobre las actividades humanas, de forma que se tenga información fiable y a largo plazo sobre el desarrollo de las mismas, por las razones expuestas en el apartado anterior.

1.3. REVISIÓN DE LA HISTORIA NATURAL Y EL ESTADO DE CONSERVACIÓN DE LOS DELFINES MULAR Y COMÚN

1.3.1. Historia natural

Este apartado proporcionará una visión general sobre los conocimientos actuales acerca de la morfología, fisiología, alimentación, comportamiento y distribución mundial del delfín mular (Foto 1.1) y el delfín común (Foto 1.2). Toda esta información puede ser de utilidad para comprender muchos de los aspectos que serán tratados en posteriores capítulos.

1.3.1.1. Delfín mular

El delfín mular es un delfín con una amplia distribución a lo largo de todo el mundo, adaptado en cada zona a condiciones diversas y cambiantes que no permiten, en muchos casos, definir parámetros como fijos a la especie, presentando gran variabilidad de población a población. Esto es cierto sobretodo para aspectos como los hábitos de alimentación, comportamiento y estructura social. Por esta razón, aunque todos estos datos nos proporcionan una idea general sobre la especie, es muy importante no extrapolar excesivamente y recordar que en la población bajo estudio las condiciones pueden ser diferentes.

Taxonomía

Tursiops es un género politípico, que ha llegado a ser dividido hasta en 20 especies diferentes (Hershkovitz 1966), aunque estas divisiones normalmente se han basado en muy pocos datos. Las clasificaciones más persistentes incluían *T. gilli* y *T. nuuanu* en el Pacífico nororiental (Walker 1981) y *T. aduncus* en Australia, el Océano Índico, China y Sudáfrica (Ross 1977; Ross and Cockcroft 1990). Los distintos morfotipos difieren en el patrón de coloración, dimensiones corporales y estructura craneal, aunque las distribuciones de los caracteres generalmente se solapan (Walter 1981; Ross and Cockcroft 1990). Como consecuencia, solo se reconoció como única especie a *T. truncatus* (Ross and Cockcroft 1990; Wilson and Reeder 1993), hasta que los datos moleculares apoyaron la separación de *T. aduncus* como especie diferente (LeDuc *et al*. 1999; Wang *et al*. 1999).

Por otro lado, se ha descrito en muchas zonas una distinción entre lo que sería un morfotipo costero y otro pelágico (Ross 1977, 1984; Walter 1981; Duffield *et al*. 1983; Ross and Cockroft 1990; Van Waerebeek *et al*. 1990; Mead and Potter 1995; Torres *et al*. 2003). En casi todos los casos, esta distinción se basa fundamentalmente en aspectos morfológicos, de dieta y de hábitat. Pero finalmente en 1998, Hoelzel y colaboradores demostraron que existe también una diferenciación genética entre formas parapátricas costera y pelágica en la costa este de Estados Unidos (Hoelzel *et al*. 1998).

Foto 1.1. Delfín mular

Características externas

Su tamaño medio es de 3 m (máximo 4 m) para los machos, y algo más pequeño para las hembras, que pueden alcanzar los 3.70 m. Pero estos tamaños tienen gran variabilidad, especialmente al comparar los dos morfotipos descrito,: siendo por lo general el costero bastante más pequeño que el pelágico (Perrin *et al*. 2002).

Su coloración gris oscuro más o menos uniforme con vientre blanco y su aspecto es más bien robusto, sobretodo en comparación con otros pequeños delfínidos como el delfín común o el listado. Su ritmo respiratorio es de unos 5 a 20 seg., y la inmersión puede alcanzar hasta 10 min. La velocidad de crucero es de 5-6 nudos, pero puede alcanzar una velocidad máxima de 20 nudos (Sylvestre 1990).

Reproducción

Adquieren la madurez sexual a los 8-12 años los machos, y las hembras a los 5-10 años (Reynolds *et al*. 2000). El ciclo reproductivo de la hembra dura de 2 a 3 años, con una gestación de 12 meses. Los períodos entre crías suelen ser de 3 – 6 años (Perrin *et al*. 2002). La lactancia suele durar de 12 a 19 meses. En Florida se ha descrito como mayor época de nacimientos el otoño, mientras que en Europa hacia mediados de verano. Se estima una longevidad media de 40 a más de 50 años (Reynolds *et al*. 2000; Perrin *et al*. 2002).

Depredadores

Los cetáceos tienen muy pocos depredadores, que prácticamente se reducen a tiburones, orcas, falsas orcas y el hombre. La importancia o magnitud de la predación producida por tiburones y orcas o falsas orcas es muy difícil de cuantificar, aunque algunas de las cicatrices que presentan los delfines se podrían achacar a ataques de tiburones. Pero no es fácil atribuir el origen de las cicatrices o arañazos pues muchas de ellas pueden ser debidas a interacciones entre individuos de la misma especie. En el Mediterráneo la presencia de orcas y de falsas orcas es muy puntual (Sagarminaga y Cañadas 1996), por lo que los depredadores del delfín común en este mar se podrían reducir al tiburón y al hombre (tanto por muerte directa como accidental).

Enfermedades

La primera epidemia identificada debida a morbilivirus en mamíferos marinos se produjo en 1987-88 en la costa Atlántica de los Estados Unidos de América (Lipscomb *et al*. 1994; Schulman *et al*. 1997). En aquella ocasión, más de la mitad de la población de los delfines mulares de la zona pudieron haber muerto. Se detectó otra mortandad masiva de delfines mulares en las costas de Florida en primavera de 2004, y en este la causa podría ser neurotoxinas producidas por una marea roja, no habiéndose detectado morvilivirus en esta ocasión (NOAA 2004).

Ha habido varios casos de varamientos masivos de cetáceos en el Mar Negro, aparentemente relacionados con inmunodeficiencias exacerbadas por la contaminación (incluidas epidemias de morbillivirus) (Birkun *et al*. 1999). En la primavera de 1990 se hallaron números sin precedente de cetáceos del Mar Negro muertos en las costas turcas, crimeas, rusas y búlgaras. La causa probable de la epizootia fue una infección viral que, se estima, provocó la muerte de varios miles de animales (de las tres especies presentes en este mar: delfines mulares y comunes y marsopas) (Evans y Addink 1993).

Hábitos de alimentación

En general, ha sido ampliamente considerado que el delfín mular tiene una alimentación demersal (Gunter 1942; Tomilin 1957; Evans 1987; Barros and Odell 1990; Gannier 1995). No hay hasta la fecha estudios relativos a la dieta de esta especie en aguas de Andalucía. El estudio geográficamente más cercano se llevó a cabo en Valencia (Salomón 1997). En este estudio, el 95.8 % de los contenidos estomacales estaba compuesto de pescado, sólo un 3.2 % de cefalópodos y un 0.9 % de crustáceos, y un 87.5 % de los estómagos contenían especies neríticas bentónicas o demersales (siendo la merluza, Merluccius merluccius la presa principal), mientras sólo un 12.5 % estaba compuesto de presas pelágicas (Salomón 1997). Siendo el delfín mular una especie muy adaptable y oportunista, no se puede asegurar que los delfines de Andalucía se alimenten de las mismas presas que los de Valencia. Pero el hecho de que en casi toda la literatura se describen patrones de alimentación similares en esta especie en diversos lugares geográficos, permite sugerir que en general los delfines presentes en el Sector Sur se puedan alimentar también fundamentalmente de peces demersales (excepto probablemente en la zona del Estrecho de Gibraltar, donde las evidencias apuntan más hacia una dieta basada en peces pelágicos: preferencia por mayores profundidades y observaciones directas de alimentación) (R. de Stephanis, com. pers.).

Otro estudio en el Mediterráneo, en el mar de Liguria, mostró que en esta especie los peces constituían más del 85 % de los contenidos estomacales, siendo las principales presas la bacaladilla (Micromesistius poutasou), la merluza, algunos Trichiuridae demersales y el congrio (Conger conger) (Relini et al. 1994). En las aguas atlánticas adyacentes, en Portugal y Galicia, los peces constituyen el 99% de la dieta del delfín mular según estudios de contenidos estomacales, siendo las principales presas algunos Gadidae, y especialmente la bacaladilla (Santos et al. 1996; Silva and Sequeira 1997). Todas estas presas tienen una distribución eminentemente demersal, en profundidades de entre 100 y 600 metros y especialmente alrededor de la caída de la plataforma (FAO 1987).

Estructura social

En general se considera que los tamaños de grupo son menores en la forma costera que en la forma pelágica, pero es muy variable. Un tamaño de grupo típico está entre 2 y 25 animales, aunque en algunas ocasiones se han llegado a ver grupos cerca de un centenar y de hasta un millar de individuos (Evans 1987). En la Bahía de Tampa, el tamaño medio de los grupos es de 5 animales (Weigle 1990). En el Estuario del Sado, el tamaño medio es de unos 14 (dos Santos and Lacerda 1987; Gaspar 2003). En Escocia, el tamaño medio de los grupos es de 4.5 (Wilson 1995) y 5 en el Estuario de Shannon, Irlanda (Ingram 2002). En Sudáfrica, los tamaños de grupo son mucho mayores, en torno a los 67 (Peddemors 1999).

Se considera que tienen una estructura patriarcal, en la cual el grupo estaría dominado por la línea materna y constituido normalmente por machos adultos, hembras y crías. También se han descrito grupos de hembras maduras con crías y juveniles de ambos sexos, y grupos de machos inmaduros, pero en general parece ser que tienen una estructura muy fluida (Evans 1987). Se pueden distinguir dos tipos de grupo: los 'pods' (pequeñas unidades de delfines que se asocian fuertemente y realizan actividades similares) y 'herds' (que son agregaciones temporales de 'pods' (Shane *et al.* 1986).

<u>*Distribución y estatus mundial*</u>

Tiene una distribución cosmopolita a lo largo de todos los mares del mundo excepto las zonas polares, y especialmente en zonas costeras, aunque también se le encuentra en alta mar. En las zonas no tropicales, se encuentra mayoritariamente en las zonas costeras, a veces hasta el talud continental (Klinowska 1991). También se le puede encontrar en estuarios (dos Santos and Lacerda 1987; Gaspar 2003).

Se desconoce el tamaño de la población, pero se han observado regresiones en Europa del Norte, el Mediterráneo y el Mar Negro (Evans 1987). La categoría del delfín mular en el Libro Rojo de la UICN es de "Data Deficient" (UICN 1996). Sin embargo, en el mismo Libro Rojo se reconoce que existen problemas agudos de conservación de esta especie, entre otros, en el Mediterráneo y el Mar Negro donde cazas históricas, capturas accidentales y la degradación ambiental han causado declive en las poblaciones (IWC 1992).

1.3.1.2. Delfín común

Como en el caso de la mayoría de los cetáceos, muchos son los aspectos aun muy desconocidos sobre la historia natural de esta especie. Especialmente si se toma en cuenta que es un delfín con una amplia distribución a lo largo de todo el mundo, adaptada en cada zona a condiciones diversas y cambiantes que no permiten, en muchos casos, definir parámetros como fijos a la especie, presentando gran variabilidad de población a población. Esto es cierto sobretodo para aspectos como los hábitos de alimentación, comportamiento y estructura social. Por esta razón, aunque todos estos datos nos proporcionan una idea general sobre la especie, es muy importante no extrapolar excesivamente y recordar que en la población bajo estudio las condiciones pueden ser diferentes.

Foto 1.2. Delfín común

<u>*Taxonomía*</u>

El delfín común o *Delphinus delphis* es un delfínido del suborden de los odontocetos (orden Cetacea). El género *Delphinus* fue descrito por Lineo en 1758. Desde entonces, se han nombrado varias especies dentro de este género, aunque la mayoría de ellas se han cuestionado. En 1889 True reconoció la existencia de sólo cuatro especies de *Delphinus*, reduciendo las demás a simples sinónimos de alguna de éstas. Las cuatro especies aceptadas entonces fueron: *D. delphis* Linnaeus, *D. longirostris* Wagner, *D. capensis* Gray y *D. rosiventris* Wagner. Más recientemente se han mencionado también *D. bairdi* Dall en el Pacífico oriental (Heyning and Perrin 1994) y *D. tropicalis* van Bree en el Océano Indico (Heyning and Perrin 1994), pero muchos autores consideran que se trata más bien de formas geográficas o subespecies y no tanto de especies. En aguas del Pacifico Nor-oriental, donde cohabitan en simpatría dos formas de delfín común que se diferencian morfológicamente por el tamaño de sus hocicos, Heyning y Perrin (1994) analizaron gran cantidad de individuos y no encontraron solapamiento entre las formas de hocico corto y de hocico largo, basándose en diversos caracteres morfométricos, por lo que han propuesto considerar dos especies: la forma de hocico corto permanecería como *Delphinus delphis*, y la forma de hocico largo se propone como *D. capensis*. Esta evidencia morfológica ha sido también respaldada por análisis genéticos que muestran grandes diferencias en secuencias de ADN mitocondrial entre ambas formas (Rosel *et al*. 1994) y que sugieren que dichas formas han estado separadas durante bastante tiempo y probablemente no se cruzan entre sí a pesar de vivir en simpatría. Así pues, el tema de la especiación del género *Delphinus* no está decidido. Algunos autores consideran que existe una sóla especie, *D. delphis*, y que las demás son formas geográficas o subespecies; otros autores consideran la existencia de dos especies, *D. delphis* de hocico corto y *D. capensis* de hocico largo, siendo esta acepción la más extendida y aceptada (Natoli *et al*. in press). Por ultimo, unos pocos investigadores consideran que se puede hablar de al menos tres especies, añadiendo a las anteriores *D. tropicalis* (Océano Indico y Mar de China, con hocico aún más largo que el *capensis*) (Jefferson and Van Waerebeek 2002).

Recientes estudios genéticos, sin embargo, arrojan ciertas dudas sobre el tema de la especiación en *Delphinus* (LeDuc *et al*. 1999), e incluso sobre la definición de las barreras interespecíficas e intergenéricas (LeDuc *et al.* 1999; Milinkovitch *et al*. 2001). LeDuc analizó la secuencia completa de citocromo B de muchas especies de delfínidos. Encontró, en primer lugar, una gran afinidad entre *Stenella, Tursiops* y *Delphinus*, que forman juntos un grupo muy bien definido (Delphininae), junto con *Sousa* y *Lagenodelphis*. A su vez, *Delphinus* forma también un grupo compacto monofilético, mientras que *Stenella* y *Tursiops* aparecen como polifiléticos, con barreras no muy bien definidas entre ambos géneros. Dentro del género *Delphinus*, LeDuc encontró que las dos especies *D. delphis* y *D. capensis* no son recíprocamente monofiléticas, sino que las secuencias de *D. capensis* están enraizadas dentro de las secuencias de *D. delphis* en la filogenia, lo cual resulta en parafilia. Por otra parte, el estatus de la forma *tropicalis* está menos clara aún, y según el estudio de LeDuc, representaría efectivamente una tercera especie, aunque no hay datos suficientes para confirmarlo. Esta tesis, sin embargo, no ha sido apoyada por un reciente estudio genético del género *Delphinus* llevado a cabo por A. Natoli (Natoli 2004). Natoli sugiere también que la forma *tropicalis* de Sudáfrica, así como formas descritas como *capensis* en el Atlántico no representarían especies diferentes sino variaciones de una única especie *Delphinus delphis* con gran variabilidad en el Atlántico.

Así pues, a pesar de los recientes avances en el estudio del complejo *Delphinus*, quedan aún muchas preguntas sin contestar.

<u>*Características externas*</u>

El delfín común es un delfínido pequeño que suele medir una media de 2 metros en edad adulta, siendo los machos ligeramente más grandes que las hembras (Evans 1987). Se ha descrito una cierta gradación en el tamaño de los delfines comunes entre el Atlántico nor-oriental y el Mar Negro, siendo más grandes en el Atlántico (media de 219 a 243 cm y 258 cm de máxima para los machos y media de 193 a 211 cm con máximo de 230 cm para las hembras) y más pequeños en el mar Negro (media de 178 cm y máximo de 219 cm para los machos y media de 170 cm y máximo de 200 para las hembras), con un tamaño intermedio en el mar Mediterráneo (222 cm de máxima para los machos y 208 a 222 de máxima para las hembras) (Heyning and Perrin 1994; Perrin 1984; Perrin and Reilly 1984). Las crías nacen con una longitud de 80 a 90 cm (Evans 1987; Evans 1994). El individuo adulto pesa entre 75 y 85 kg, con un máximo de 136 kg (Evans 1987; Evans 1994).

Tienen 40 a 60 pares de dientes pequeños y puntiagudos en cada mandíbula (Evans 1987; Evans 1994). Presentan 73 a 74 vértebras, de las cuales las dos primeras cervicales están fusionadas. (Evans 1994). La longitud del hocico varía desde 210 a 260 mm en *D. delphis* hasta 290 a 370 mm en *D. tropicalis* (Evans 1994; Heyning and Perrin 1994) y es una de las características clave para la diferenciación entre especies tratada en la sección anterior. El género *Delphinus* se distingue de todos los otros géneros de delfínidos por presentar dos surcos laterales profundos situados longitudinalmente en el paladar superior (Evans 1994).

La coloración de esta especie es una de las características más distintivas de la misma, resultando muy llamativa, pero presenta una gran variabilidad. El dorso es gris oscuro a marrón oscuro, y el pecho y el vientre son muy claros, de blanco a color crema claro. Los flancos tienen un dibujo, normalmente muy marcado, en forma de V debajo de la aleta dorsal, semejando a un ocho o un reloj de arena horizontales en los que la porción delantera es de un color que varía del amarillo dorado al crema grisáceo o amarillento y la porción trasera muestra una tonalidad gris claro. La aleta dorsal es oscura pero suele presentar una mancha de color crema variable en forma y tamaño. Las aletas pectorales varían de un color crema o amarillento similar al de la porción delantera del dibujo del flanco hasta el gris oscuro.

Reproducción

La reproducción del delfín común ha sido estudiada por varios investigadores, basándose fundamentalmente en el estudio de los órganos reproductores de animales muertos. Es el caso de los estudios de Collet and Saint Girons (1984) y Murphy (2004) en *D. delphis* del Atlántico nor-occidental, y la revisión que hacen Perrin and Reilly (1984) sobre los parámetros reproductivos de varias especies de delfínidos de diversas áreas geográficas.

El período reproductivo se puede dividir en varias fases: gestación, lactancia, y período de descanso. En general, se calcula el período de gestación del delfín común en unos 10 a 11.5 meses (Evans 1987; Perrin and Reilly 1984; Murphy 2004) y el período de lactancia entre 10 y 19 meses, estimándose mucho más largo en el Atlántico y Pacífico Nortes (19 meses) (Evans 1987) que en el Mar Negro (10 a 11 meses) (Evans 1987; Perrin and Reilly 1984). El período de descanso se ha estimado en unos 4 meses tanto en individuos del Pacífico Este tropical como del Mar Negro (Perrin and Reilly 1984). En total, el intervalo entre crías se ha calculado que puede oscilar entre 1.3 y 2.6 años.

La época de concepción no parece estar muy bien definida y en algunas zonas parece haber más de un pico de máxima concepción. Estos "picos" o épocas de concepción son normalmente extrapolados según las fechas de máxima proporción de nacimientos y retrocediendo en el tiempo según el período de gestación calculado. Según una revisión realizada por Evans (1987), en el Pacífico norte podrían darse dos picos, uno en primavera, de abril a junio, y otro en otoño, de octubre a diciembre; en el atlántico norte se observa un pico durante el verano, entre julio y octubre, lo mismo que en el mar Negro. En el Mediterráneo Gannier (1995) también estima la época de máxima concepción durante el verano. Las épocas de mayor número de nacimientos observados en el Pacífico Norte son en marzo-abril y septiembre-octubre, mientras que en el Atlántico Norte y el mar Negro este pico se observa entre junio y septiembre (Evans 1987). La tasa de nacimiento anual parece variar entre poblaciones explotadas (normalmente debido a intensa captura accidental en artes de pesca) y no explotadas, siendo algo superior en las poblaciones sujetas a explotación, probablemente como mecanismo de intento de compensación (Perrin and Reilly 1984). De este modo, se han calculado unas tasas de 0.087 y 0.066 para el Pacífico oriental norte y para el Pacífico oriental tropical sur respectivamente, que se consideran poblaciones no explotadas, y 0.096 y 0.106 para las poblaciones explotadas del Pacífico E tropical y el Mar Negro.

Parece ser que la actividad sexual de machos y hembras sigue unos patrones estacionales (Collet and Saint Girons 1984), pero que difieren de población a población en duración y momento. Según la época y la población estudiada, la proporción de hembras sexualmente maduras embarazadas en dicha población puede variar entre el 25 y el 80 por ciento (Evans 1994; Perrin and Reilly 1984). La proporción de hembras lactando oscila entre el 36 y el 60% y la de hembras en reposo entre el 10 y el 30%, siempre hablando de hembras sexualmente maduras (Evans 1994).

También la edad de madurez sexual tanto de machos como de hembras presenta grandes variaciones de una población a otra. Se ha estimado la edad de madurez sexual en el Atlántico norte y el Pacífico tropical en unos 5 a 7 años para ambos sexos (Evans 1987, Perrin and Reilly 1984), mientras que en el Mar Negro se ha estimado que tanto el macho como la hembra alcanzan la madurez sexual mucho más tempranamente, hacia los 2 o 4 años (Collet and Saint-Girons 1984; Perrin and Reilly 1984).

Depredadores

Como en el caso del delfín mular (ver más arriba), los depredadores del delfín común en este mar se podrían reducir al tiburón y al hombre (tanto por muerte directa como accidental).

Patologías

En el Mar Negro se han detectado dos procesos epizooticos en relación al delfín común, uno en 1989-1990 que afectó a las tres especies de cetáceos que habitan en ese mar (delfín común, delfín mular y marsopa) y el segundo en 1994. En ninguno de los dos casos se pudo determinar las causas, aunque en la epizootia de 1994 se sospechó que había sido causada por una infección viral sin identificar (Birkun *et al*. 1995). En los años 1990 a 91 se desató una importante epizootia en el Mediterráneo que afectó al delfín listado (*Stenella coeruleoalba*) y que causó la baja de, probablemente, varios miles de individuos (Aguilar and Raga 1991;

Domingo *et al*. 1991). En este caso, se detectó como causa de la epizootia un morvilivirus (Domingo *et al*. 1991; Androukaki and Tounta 1994). Sin embargo, en las muestras analizadas de delfín común del Mediterráneo, no se ha detectado este virus (Androukaki and Tounta 1994), ni se detectó en su momento ningún incremento en el número de varamientos de esta especie, por lo que no se ha considerado que esta epidemia afectase al delfín común.

Hábitos de alimentación

El delfín común es considerado una especie bastante oportunista en cuanto a hábitos de alimentación (Klinowska 1991; Young and Cockcroft 1994; Gannier 1995). Sin embargo, suele tener una dieta predominantemente ictiófaga, constituyendo los cefalópodos una porción menor de su alimentación habitual (Collet *et al*. 1981; Evans 1987; Relini and Relini 1993; Young and Cockcroft 1994; Berrow and Rogan 1995; Boutiba and Abdelghaní 1995; Gannier 1995; Kenney *et al*. 1995; Cordeiro 1996; Santos *et al*. 1996).

En el Pacífico E tropical, Evans (1994) describe una variación estacional en la dieta de los delfines comunes de la zona: en otoño - invierno, los peces constituyen el 63% de la dieta, siendo la principal presa *Engraulius* sp. (92%), y los cefalópodos el 37%, el 99% de los mismos constituyéndolo la especie *Loligo opalescens*. En primavera - verano, los peces constituyen el 70% de la dieta, pero ahora la especie más encontrada es *Leuroglossus stilbius* (56%); los cefalópodos constituyen el 23% con *Onychoteuthidae* en cabeza (85%) y los crustáceos representan el 7%.

En el Atlántico nor-oriental, se han realizado estudios detallados en Portugal, Irlanda, Galicia y Escocia. En Portugal, Silva y Sequeira (1996) encontraron que los peces constituían el 90,4% de las presas encontradas en los estómagos de los delfines (43,4% *Micromesistius poutassou*, 32,8% *Sardina pilchardus*), y los cefalópodos sólo el 9,6% (60% Loliginidae, 36,6% Sepiidae). Berrow y Rogan (1995) encontraron que en Irlanda el 85,1% de los contenidos estomacales analizados tenían peces de la familia de los Gadidae (40,7% *Trisopterus* spp., 30,7 % *Merlangus merlangus*), 26,9 % tenían Clupeidae (*Clupea harengus* y *Sprattus sprattus*) y 11,1% tenían Gobidae; los cefalópodos se encontraron en el 51,7% de las muestras (40% *Gonatus* sp., 40% *Histioteuthis* sp, 27% *Loligo forbesi*, 33% *Eledone cirrosa* y 13% *Toderopsis* sp). En Galicia, Santos (1998) describió como especies de presa más frecuentes a la sardina, la bacaladilla (*Micromesistius poutassou*) y el jurel (*Trachurus trachurus*), que juntas sumaban dos tercios del peso total estimado de las presas. La misma autora señala como presa más frecuente en Escocia al merlán (*Merlangus merlangus*), que constituye él solo más de los dos tercios del peso total estimado de las presas.

Dentro del Mediterráneo, en Argelia, los estudios realizados por Boutiba y Abdelghaní (1995) mostraron de nuevo una clara prevalencia de peces en la dieta: el 93,6% (45,8% Clupeidae, 38,6% Engraulidae), frente al 6,4% de cefalópodos. En Liguria Relini y Relini (1993) examinaron sólo 3 estómagos de delfín común, con unos resultados que mostraban una gran variabilidad, constituyendo los peces entre el 0,3 y el 100% del contenido estomacal, los cefalópodos entre el 0 y el 86,6% y los crustáceos de 0 a 3,3%.

En el Mar Negro se han realizado estudios detallados de la dieta del delfín común (Tomilin 1957), y se encontró que el principal alimento de esta especie eran peces pelágicos, principalmente anchoas (*Engraulis encrasiclous*) y espadines (*Sprattus sprattus*). También según Evans (1994), en el Mar Negro, el 100% de la dieta la constituyen peces del tipo anchoas y otros pequeños pelágicos.

Así pues, el delfín común parece tener preferencia por pequeños peces neríticos epi-pelágicos, especialmente de las familias Clupeidae y Engaulidae y algunos Gadidae (peces demersales o mesopelágicos que habitan preferencialmente áreas desde la costa hasta los 400 m de profundidad), así como una pequeña cantidad de cefalópodos.

Estructura social

Todos los autores coinciden en calificar al delfín común como una especie altamente gregaria, que puede ir en grupos de hasta varios cientos e incluso miles de individuos (Evans 1994; Evans 1994; Leatherwood *et al*. 1988). Sin embargo, todos los datos apuntan a que la unidad social básica puede rondar los 20 a 30 individuos (Evans 1994).

En las aguas del Pacífico oriental, Perrin *et al*. (1995) observaron grupos cuyos tamaños variaban entre 30 y 400 animales por grupo, mientras que Perryman y Linn (1993) describen grupos de entre 30 y 1840 delfines. En otro estudio, Heyning y Perrin (1994) hablan de grupos desde 10 individuos hasta varios miles en el Pacífico oriental norte. En el Golfo de Vizcaya, en el Atlántico nor-oriental, Gonzalez, Gümes y Gutierrez (1993) calcularon una media de tamaño de grupo de 17,5 individuos (n = 15) durante su crucero de avistamientos "Cetacea-92".

En el Mediterráneo los distintos autores dan tamaños de grupo cuyas medias oscilan entre 6.3 y 76.8 delfines por grupo (Laurent 1991; Politi *et al*. 1992; Notarbartolo di Sciara *et al*. 1993; Azzali *et al*. 1994; Forcada *et al*. 1995; Gannier 1995; Nascetti and Notarbartolo di Sciara 1996; Forcada y Hammond 1998).

Como en casi todas las especies altamente gregarias de delfínidos y con escaso dimorfismo sexual, prácticamente nada se sabe de la composición por edad y sexo de los grupos ni de su organización social.

Distribución y estatus mundial

Se desconoce el tamaño de la población mundial, pero se considera que debe ser una de las especies más comunes (Evans 1987). Sólo para el Pacífico E tropical se ha estimado que hay un total de 3,112,300 delfines comunes (CV = 0.369) (Holt and Sexton 1990). En el Atlántico NE, Goujon (1993) estimó la abundancia de delfín común en el norte del Golfo de Vizcaya en 61,888 (95% CI, 35,461-108,010), Hammond *et al*. (1995) estimaron en 75,449 (95% CI, 2,900-248,900) la abundancia en el mar Celta, y Cañadas et al. (2004) estimó 273,159 (95% CI = 153,392 – 435,104) animales en las aguas profundas al sudoeste de las Islas Faeroe.

Su distribución es cosmopolita en todos los mares tropicales, subtropicales y templados de todo el mundo, incluyendo el mar Mediterráneo, el mar Negro, el mar Rojo y el Golfo Pérsico. El límite norte de su distribución en el Atlántico se considera que es alrededor de Nueva Escocia e Irlanda, y en el Pacífico alrededor de Japón y el norte de California. Se toma como límite sur de su distribución en el Atlántico los alrededores de Penísula Valdes en Argentina y la punta sur de Sudáfrica; en el Pacífico, el sur de Australia, Nueva Zelanda y el sur de Chile. En el Océano Índico se observa poco al norte en el mar Rojo y el mar de Arabia (Evans 1987).

Su principal problema a nivel mundial consiste en las capturas accidentales en artes de pesca, que en un informe de la FAO de 1984 se estimaba en más de 8.000 delfines capturados al año (Northridge 1984). Se han registrado capturas accidentales especialmente en arrastres pelágicos y redes de deriva en el Atlántico noroccidental (Morizur *et al*. 1999; Goujon *et al*. 1994), redes de deriva o redes en general en el Mediterráneo (Silvani *et al*. 1995; Di Natale and Notarbartolo di Sciara 1994; Duguy *et al*. 1982, Tudela *et al*. 2005) y en redes de cerco y redes de deriva en el Pacífico nororiental (Leatherwood *et al*. 1988; Hall 1994; Henshaw *et al*. 1997).

1.3.2. Estado de conservación en el Mediterráneo occidental

1.3.2.1. Delfín mular

El delfín mular es la especie de cetáceo más común sobre la plataforma continental del Mediterráneo (Notarbartolo di Sciara y Demma 1994). Sin embargo, la distribución de estas comunidades costeras parece estar dispersa y fragmentada a lo largo de las costas Mediterráneas en unidades relativamente pequeñas o subpoblaciones (de unos pocos centenares de animales cada una como máximo), entre las cuales los ‘espacios vacíos’ parecen estarse agrandando (Bompar *et al*. 1994, UNEP/IUCN 1994, Notarbartolo di Sciara and Gordon 1997, Universidad de Barcelona 2002). La abundancia de esta especie en las costas españolas también parece haber sufrido un declive importante (Aguilar *et al*. 1997).

Los estudios genéticos realizados hasta la fecha indican que la población Mediterránea de delfín mular, aunque predominantemente nerítica, puede haberse originado de una forma pelágica de la población del Atlántico Norte que colonizaría el Mediterráneo, pero también existe evidencia de divergencia entre estas áreas (Natoli *et a*l. 2004, Universidad de Barcelona 2002). Estudios con indicadores bioquímicos también muestran una diferenciación entre la población Mediterránea y la del Atlántico Norte (Universidad de Barcelona 2002). Por otra parte, se ha observado una gran diversidad en las muestras obtenidas en el Mediterráneo, sugiriendo la existencia de una estructura poblacional dentro de esta cuenca (Natoli *et al.* 2004). Algunas comunidades del Mediterráneo muestran además altos niveles de diferenciación genética, sugiriendo un flujo genético muy limitado, como la del mar Jónico (Natoli and Hoelzel 2000). También se ha observado diferencias genéticas entre los delfines de las costas españolas y las italianas (Universidad de Barcelona 2002).

Debido a su preferencia, en general, por hábitats predominantemente costeros, esta especie se ha visto afectada en gran medida por las actividades humanas. Se sugiere que hay tres tipos de amenazas que pueden estar afectando al delfín mular (Perrin 1988, IWC 1994, UNEP/IUCN 1994):

a) Contaminación química del agua: Los niveles de contaminación en delfines del Mediterráneo son muy altos en comparación con los niveles encontrados en otras zonas del mundo (UNEP/IUCN 1994, Marsili *et al*. 1996), e incluso comparando con las poblaciones adyacentes del Atlántico Norte (Universidad de Barcelona 2002). Estas altas concentraciones de compuestos xenobióticos pueden causar cáncer, desordenes reproductivos, hipertensión, infartos y supresión inmunológica (O'Shea *et al*. 1999).

b) Reducción en la disponibilidad de presas debido a la degradación ambiental y la sobreexplotación pesquera: Hay evidencias de que la sobreexplotación pesquera en el Mediterráneo ha llevado al declive de muchos stocks de peces (Caddy and Griffiths 1990, De Walle *et al*. 1993, FAO 1997, 1998), y presenta potencialmente consecuencias negativas para el balance ecológico del ecosistema marino (Dayton *et al*. 1995, Stanners and Bourdeau 1995). Se ha constatado un esfuerzo energético inusualmente alto dedicado a la búsqueda de comida en algunas comunidades de delfín mular estudiadas consistentemente desde hace más de una década (Bearzi *et al*. 1997, Politi 1998).

c) Capturas directas o accidentales en artes de pesca: Las capturas accidentales, especialmente en trasmallos, aunque también en redes de deriva, es un hecho bastante frecuente (Cagnolaro and Notarbartolo di Sciara 1992, Silvani *et al*. 1992), y en algunas áreas puede no ser sostenible (IWC 1994). Por otra parte, la interacción con las pesquerías costeras en algunas zonas a menudo resulta en la muerte de animales por arpón, disparo u otros métodos (Cagnolaro and Notarbartolo di Sciara 1992, Silvani *et al*. 1995, UNEP/IUCN 1994). En Baleares algunos estudios sugieren que se capturan unos 30 delfines al año en las artes de pesca (Forcada *et al*. 2004), lo cual puede estar excediendo el límite 'aceptable' para ser sostenible del 1% de la población (IWC 1995) en esta zona (Forcada *et al*. 2004, T. Brotons, pers. comm).

Otras amenazas potenciales incluyen la contaminación acústica (Notarbartolo di Sciara and Gordon 1997) y la perturbación directa por la navegación de recreo y las operaciones de "whale-watching" u observación comercial de cetáceos.

En resumen, se puede decir que el principal signo de un estado de conservación no favorable del delfín mular en el Mediterráneo es la fragmentación de su población y el progresivo aislamiento de las distintas subpoblaciones.

1.3.2.2. Delfín común

Se considera que la población del delfín común del Mediterráneo ha sufrido una importante regresión durante las últimas tres o cuatro décadas (Pelegrí 1980; Viale 1980; Evans 1987; Laurent 1991; Aguilar 1991; Viale 1993; Notarbartolo di Sciara 1993; Gannier 1995; Notarbartolo di Sciara and Gordon 1996; UNEP 1998a, b; Bearzi *et al*. 2003). Hoy en día los avistamientos son muy escasos, si no nulos, de otras zonas que no sean Grecia y el mar de Alborán (Fabri and Laureano 1992; Notarbartolo di Sciara *et al.* 1993; Pulcini *et al.* 1993; Gannier 1995; Forcada and Hammond 1998; Bearzi *et al*. 2003).

Las causas exactas y la magnitud de este declive de la población se desconocen todavía. La heterogeneidad de los datos históricos, tanto geográfica como cronológicamente, hacen muy difícil el intento de comparación entre las situaciones pasada y presente. Este hecho se agrava considerablemente tras la revisión de colecciones óseas de algunos museos que mostraron la clasificación errónea de algunos ejemplares de delfín común y delfín listado (Cagnolaro 1994). Por esta razón, algunos autores han argüido que el delfín común era una especie en realidad rara desde hacía mucho tiempo, pero que sólo se ha detectado recientemente precisamente debido a esta confusión entre ambas especies (Collet 1994). Sin embargo, si que existen algunas observaciones antiguas fiables y especímenes en colecciones científicas de principio de siglo que contienen muchos más ejemplos de delfín común que de delfín listado (Viale 1985; Cagnolaro and Notarbartolo di Sciara 1992).

El estatus del delfín listado parece ser el opuesto al del delfín común, ya que su actual abundancia en el Mediterráneo contrasta con los datos históricos que describían a esta especie como muy rara (Viale 1993; Cagnolaro 1994). Se ha sugerido que podríamos estar en presencia de competición por nicho ecológico entre ambas especies, y que el delfín listado podría estar desplazando al delfín común (Viale 1980; Casinos 1982; Viale 1985; Notarbartolo di Sciara 1993), aunque esto no explicaría, por ejemplo, la desaparición del delfín común del Adriático norte, donde no ha sido reemplazado por delfín listado (Notarbartolo di Sciara and Gordon 1996). Ambas especies están muy relacionadas genéticamente (García 1996) y exhiben una serie de similitudes en tamaño, morfología y biología. Sin embargo recientes estudios han puesto de manifiesto una interesante diferencia en cuanto a la distribución de estas dos especies en relación a los factores oceanográficos tales como la concentración de clorofila, la temperatura y la salinidad (Reilly and Fielder 1994). En estos estudios, llevados a cabo en el océano Pacífico nor-oriental y en el océano Índico, el delfín listado mostró una distribución aleatoria respecto a estos parámetros, de forma opuesta al delfín común cuya distribución se mostraba significantemente relacionada con dichos factores. De todos modos, es un hecho que el delfín común es una de las tres especies más frecuentes de pequeños delfínidos en el Mediterráneo, y se pueden encontrar en simpatría con una de las otras dos especies (delfín listado y delfín mular), o con las dos, en muchas áreas. La UNEP recomienda, en este sentido, un estudio más profundo de las relaciones entre las tres especies, como paso vital para incrementar nuestros conocimientos sobre el funcionamiento del ecosistema y el fenómeno de la competición inter-específica (UNEP 1998a).

Algunos autores proponen también la degradación de la calidad del agua, principalmente debido a la contaminación, como causa probable de la regresión de la población del delfín común, así como de la epizootia sufrida por el delfín listado y el deterioro generalizado de las poblaciones de cetáceos del Mediterráneo (Viale 1993), debido a las altas concentraciones de PCBs y metales pesados encontrados en los tejidos de animales varados examinados (Lima and Sequeira 1993; Viale 1993; Corsolini *et al*. 1995; Borrell *et al*. 1998).

En 2003 se realizó una revisión exhaustiva sobre la situación del delfín común en el Mediterráneo, en la cual participó la autora de esta tesis (Bearzi *et al*. 2003). En dicha revisión se hace hincapié en que la literatura existente y las colecciones osteológicas confirman que el delfín común se hallaba ampliamente distribuido y era abundante en gran parte del Mediterráneo hasta finales de los años 60 y que desde entonces su regresión ha ocurrido con bastante rapidez. Se describe cómo hoy en día el delfín común se mantiene relativamente abundante en el Mar de Alborán, con algunos registros ocasionales en Argelia y Túnez, concentraciones alrededor de las islas Maltesas y en partes del Mar Egeo, y grupos relictos en el sector sur-oriental del Mar Tirreno y el sector oriental del Mar Jónico. Sin embargo, esta especie es rara, o se encuentra completamente ausente, en otras áreas donde existe información disponible.

En la misma revisión y en base a evidencia circunstancial y juicios cualitativos, los autores sugerimos que los siguientes factores pueden haber contribuido a la regresión del delfín común:

- reducción en la disponibilidad de presas causada por la sobreexplotación pesquera y la degradación del hábitat;
- contaminación por compuestos químicos xenobióticos resultantes en inmunosupresión y alteración de la reproducción;
- cambios ambientales como el aumento de la temperatura del agua, afectando a la dinámica de los ecosistemas; y
- mortalidad accidental en artes de pesca, especialmente redes de deriva

La importancia acumulativa de estos factores no es bien conocida, y como consecuencia, prácticamente no se han aplicado medidas de conservación.

Por último, este artículo hace una revisión del estado de conocimiento actual y sugiere prioridades de acción enfocadas a identificar y mitigar las principales amenazas que actúan o pueden actuar sobre el delfín común en el Mediterráneo, con el objetivo final de restaurar el estado de conservación favorable de esta especie en la región.

Recientemente se ha publicado también un artículo sobre la captura accidental de, entre otros, delfines comunes y listados en las redes de deriva de Marruecos en el Mar de Alborán (Tudela *et al*. 2004). Según estudio, alrededor de 3500 delfines (entre las dos especies) caerían en las redes de deriva Marroquíes en la zona sur del Mar de Alborán. Incluso si las cifras de captura accidental están sobreestimadas, este trabajo resalta la importancia de esta amenaza, que podría resultar insostenible si no se le pone remedio pronto.

1.4 ESTE ESTUDIO

1.4.1. Objetivos

El objetivo general de este trabajo es el de contribuir a la conservación de los cetáceos en el Mar de Alborán, básicamente mediante dos vías paralelas: (a) la investigación sobre aspectos de la ecología de las especies en esta zona, y (b) la propuesta de medidas de gestión y conservación basadas en la ciencia.

Aun teniendo datos para varias especies de cetáceos a lo largo de los años que dura este estudio, el trabajo de esta tesis se centra muy especialmente, como se menciona más arriba, en el delfín común y el delfín mular.

Se eligió trabajar en el mar de Alborán y el Golfo de Vera por ser ésta una zona de gran interés nivel oceanográfico y por haberse detectado en pasajes previos por la misma el gran interés que suponía también en el campo de la cetología.

En el campo de la investigación científica, hay una progresión sucesiva en este trabajo en cuanto a la profundidad y la complejidad en los métodos aplicados. La principal metodología utilizada en los últimos capítulos es el análisis espacial, y de hecho se convirtió en objetivo paralelo de este trabajo el explorar la aplicabilidad de esta nueva metodología, hasta ahora muy escasamente empleada en el campo de la cetología, para el estudio de la selección de hábitats por parte de los cetáceos y para la promoción de su conservación.

De forma concreta, se pueden definir 4 objetivos básicos de este trabajo:

a) Investigar la distribución y preferencia de hábitats de las distintas especies de cetáceos que usan el área de estudio, y en especial de l os delfines mulares y comunes

b) Estimar la abundancia de delfines mulares y comunes que usan el área de estudio

c) Identificar los hábitats importantes para la conservación de estas especies en el área de estudio

d) Desarrollar propuestas para la conservación de estas especies en la zona

1.4.2. Cronología

1.4.2.1. Antes de 1992: estudios previos en la zona

En el verano de 1990 varaban a lo largo de las costas del levante español, Francia e Italia cientos de delfines listados víctimas de una epidemia vírica que se extendería en 1991 hasta la cuenca oriental del Mar Mediterráneo (Forcada *et al*. 1991; Domingo *et al*. 1996). Este hecho puso de relieve por una parte el alto grado de acumulación de contaminantes persistentes en las grasas de estos odontocetos, y por otra la falta de conocimientos acerca de la ecología de los cetáceos en la región biogeográfica mediterránea.

Antes de 1992, cuando comienza este estudio, se había realizado muy poca investigación sobre cetáceos en la zona. La mayor parte de los datos disponibles provenían de varamientos, capturas en las estaciones balleneras de Getares y Benzou (Cabrera 1925; Bayed and Beaubrun 1987) o capturas accidentales en artes de pesca (Rey and Rey 1979; Rey and Cendrero 1980, 1981; Castells and Mayo 1992; García, P., ANSE, com. pers.), que por otra parte no fueron registrados de forma regular hasta 1995 gracias al CREMA (Centro de Recuperación de Especies Marinas Amenazadas).

Casinos y Vericad (1976) crearon un catálogo actualizado de avistamientos y varamientos de cetáceos en España. Hasta la fecha, los primeros intentos de preparar un catálogo de este tipo fueron llevados a cabo por Graells en 1889, seguido por Cabrera en 1914 (Cabrera 1914). Más tarde, J. C. Rey, J. Rey y O. Cendrero publicaron varios informes durante los años 80 donde recogían datos de avistamientos y varamientos de cetáceos en las costas españolas (Rey and Rey 1979; Rey and Cendrero 1979, 1980, 1981, 1982). En 1982, la Universidad de Barcelona organizó la campaña “Sur 82” a lo largo de las costas sur y este de España, pero el único tramo que fue navegado con luz diurna en el Mar de Alborán fue un día entre Cabo de Gata y la Bahía de Málaga (Aguilar *et al*. 1984). La Universidad de Valencia llevó a cabo un estudio en

1985 sobre la distribución de cetáceos en el Mediterráneo y Atlántico Ibéricos, utilizando datos oportunistas recogidos por varios barcos (Raga *et al*. 1985), y realizó otra recopilación en 1991 con datos de varamientos en las costas Mediterráneas españolas entre 1982 y 1988 (Raga *et al*. 1991).

Por otra parte, Greenpeace y la Universidad de Barcelona llevaron a cabo dos estudios de transecto lineal a gran escala, en 1991 y 1992, por todo el Mediterráneo occidental, pero que solo cubrieron brevemente el Mar de Alborán y el Golfo de Vera (hasta la costa africana): 5 días en 1991 (Forcada *et al*. 1991) y 6 días en 1992 (Forcada & Hammond 1998).

Así pues, la escasez de datos previos al comienzo del presente trabajo de investigación es más que evidente.

1.4.2.2. 1992 - 1999: comienzo del estudio por ALNITAK

En 1989 se fundó la organización no gubernamental ALNITAK con la finalidad de llevar a cabo estudios en el medio marino, sobre todo relacionados con cetáceos y tortugas marinas, y enfocados a su conservación.

En 1992 ALNITAK inició en la región nororiental de Alborán y el Golfo de Vera el primer programa de monitorización a largo plazo de las poblaciones de cetáceos, a bordo del velero de investigación *Toftevaag*. Se comenzó a recoger datos de todas las especies avistadas, de las cuales las más frecuentes resultaron ser los delfines comunes, listados y mulares (*Delphinus delphis, Stenella coeruleoalba* y *Tursiops truncatus*) y los calderones negros (*Globicephala melas*). Con menos frecuencia se encontraron calderones grises (*Grampus griseus*), cachalotes (*Physeter macrocephalus*), rorcuales (*Balaenoptera physalus*) y zifios (*Ziphius cavirostris*, *Hiperodoon ampullatus* y zifios sin identificar).

Aparte de registrar los datos de esfuerzo y de avistamientos de estas especies, se fueron registrando también de forma progresiva datos de otras especies marinas (aves, tortugas, peces, invertebrados) y de actividades humanas (barcos, maniobras militares, contaminación acústica). Por otra parte, durante los avistamientos de cetáceos se realizó foto-identificación de todas las especies (menos el delfín listado) y filmación en vídeo de comportamiento, así como grabaciones acústicas de sus vocalizaciones (desde 1997).

Muy pronto, los primeros resultados de estas campañas de investigación empezaron a confirmar la importancia de determinadas zonas del mar de Alborán y el Golfo de Vera para algunas especies de cetáceos. Por ejemplo, los delfines comunes y listados presentan unas elevadas tasas de encuentro (Sagarminaga and Cañadas 1996); los delfines comunes del Mar de Alborán se diferencian genéticamente de los del Mediterráneo oriental y del Atlántico nor-oriental (Natoli 2005); el calderón negro presenta en esta zona las tasas de encuentro más elevadas de todo el Mediterráneo occidental (Cañadas and Sagarminaga 2000); el calderón gris utiliza habitualmente la zona reencontrándose los mismos animales a lo largo de varios años según el estudio de foto-identificación (Cañadas and Sagarminaga 1996); y se determinaron los patrones de distribución de varias especies (Cañadas *et al*. 2002).

1.4.2.3. 2000 - 2002: el 'Proyecto Mediterráneo'

El llamado Proyecto Mediterráneo es el proyecto denominado "Programa de identificación de las áreas de especial interés para la conservación de los cetáceos en el Mediterráneo Español", producto de un convenio firmado en diciembre de 1999 entre la Dirección General de Conservación de la Naturaleza (Secretaría General de Medio Ambiente del Ministerio de Medio Ambiente) y la Universidad de Valencia, y realizado por las Universidades de Barcelona, Valencia y Autónoma de Madrid, esta última a través de la organización no gubernamental ALNITAK. Cada Universidad se hizo cargo de un área, siendo la Universidad de Barcelona responsable de la Comunidad Catalana y la Balear, la Universidad de Valencia de la Comunidad Valenciana y la Murciana, y la Universidad Autónoma de Madrid - Alnitak responsable de la Comunidad Andaluza, tanto en sus vertientes mediterránea como atlántica.

Este proyecto, dentro del cual se enmarca una parte del presente trabajo de tesis doctoral (entre el año 2000 y el 2002), aportó información necesaria para el adecuado cumplimiento de los compromisos que el estado español ha adquirido al ratificar el Convenio de Barcelona (en 1998) y con el acuerdo de Mónaco para la Conservación de los Cetáceos en el Mar Negro, Mar Mediterráneo y Atlántico Contiguo (ACCOBAMS) (ratificado por España en 1999). Según ambos acuerdos internacionales es necesario inventariar los componentes de la biodiversidad marina, en especial los cetáceos, según ACCOBAMS**,** y en particular los de especies amenazadas o en peligro según Barcelona, siendo necesaria además, según los mismos convenios, la designación de áreas que requieran una especial protección (zonas de especial conservación, o zonas de especial conservación para el Mediterráneo) en el Mediterráneo y Atlántico contiguo. Objetivo este que fue la finalidad de este proyecto que cubrió la zona del Mediterráneo y Atlántico contiguo para dar cumplimiento a los tratados expuestos. Por otra parte, la Directiva Hábitats de la Unión Europea impone a España la necesidad de designar una serie de áreas marinas protegidas (LIC), dentro del límite de las 200 millas náuticas, para asegurar que se le da la suficiente protección a un porcentaje adecuado de los hábitats de las especies en el Anexo I con el fin de conseguir un adecuado estado de conservación.

Con este proyecto se obtuvo la información necesaria y se establecieron algunas medidas adicionales necesarias para ayudar a alcanzar el estado de conservación favorable de los cetáceos, y en el caso particular de esta tesis, del delfín común y del delfín mular. Se obtuvo de esta manera una información fundamental para poder desarrollar los planes de conservación que es obligatorio desarrollar para las especies incluidas en el Catálogo Nacional de Especies Amenazadas.

El proyecto se desarrolló en dos fases, una primera fase encaminada a establecer el estado de conservación de las distintas especies y poblaciones de cetáceos en el Mediterráneo español y una segunda fase de identificación de áreas de especial interés para la conservación de los cetáceos del Mediterráneo español. La primera fase constó de cuatro grandes objetivos que consistieron en:

a. Revisión de toda la información previa.

   Se realizó una actualización de la información existente.

b. Estudio de la distribución y densidad relativa de las poblaciones de cetáceos y su uso del hábitat.

   Este apartado permitió conocer con mayor precisión la distribución de las especies a lo largo de la zona de estudio y, sobre todo, aportar por primera vez información precisa sobre las densidades relativas de las poblaciones de cetáceos en el Mediterráneo español. Este punto se vio complementado con la obtención de información sobre el uso de hábitat de las principales especies y sobre diversos aspectos de su biología.

c. Estudio de la identidad de las poblaciones de cetáceos

   Este estudio se centró en las tres especies más representativas del Mediterráneo español: el delfín mular, el delfín listado y el delfín común, y se basó en el análisis molecular del ADN mitocondrial y nuclear, así como en la identificación de diferencias en el perfil de la carga de contaminantes organoclorados de las distintas poblaciones. El estudio de este aspecto del delfín mular lo llevó a cabo la Universidad de Barcelona, el del delfín listado la Universidad de Valencia y el del delfín común por la Universidad Autónoma de Madrid y ALNITAK.

d. Análisis socioeconómico de las áreas de estudio.

   Se realizó un análisis socioeconómico de las áreas de estudio y de su problemática ambiental, en relación sobre todo con los factores que directa o indirectamente pueden afectar a la conservación de los cetáceos y de sus hábitats.

Sobre la base de toda la información recopilada, la segunda fase de proyecto se centró en la identificación de áreas de especial interés para la conservación de los cetáceos del Mediterráneo español y en la selección de aquellas áreas que debieran ser protegidas de una u otra forma para promover el estado de conservación favorable de las diferentes poblaciones de cetáceos, y fundamentalmente de las consideradas como amenazadas, y de esta forma dar también respuesta a las diversas recomendaciones y requerimientos establecidos en distintos compromisos, convenios o acuerdos internacionales suscritos por España. La selección de las áreas marinas se sustentó en varios casos en su consideración de áreas de especial interés para los cetáceos que por sus características merecieran ser designadas Zonas Especialmente Protegidas de Importancia para el Mediterráneo (ZEPIM). En otros casos, basándose en los requerimientos de la Directiva Hábitats por lo que se refiere a las especies *Tursiops truncatus* y *Phocoena phocoena*, consideradas como de interés comunitario para cuya conservación es necesario designar o ampliar los Lugares de Importancia Comunitaria (LIC).

Se estableció igualmente un plan de directrices sobre las áreas seleccionadas que sirviese de apoyo a los futuros planes de gestión de las mismas, analizando las amenazas que sobre ellas recaen y las posibles soluciones en orden a minimizar estos impactos. Y por último, se desarrollaron muchos de los aspectos destacados en la Estrategia Española para la Conservación y el uso sostenible de la Diversidad Biológica desarrollada por el Ministerio de Medio Ambiente, sobre todo en lo que se refiere a la catalogación y conservación de la biodiversidad marina y en la creación de áreas marinas protegidas por las que apuesta dicha estrategia.

1.4.2.4. 2002 - 2006: el proyecto LIFE-Naturaleza

En julio de 2002, la Sociedad Española de Cetáceos (SEC) puso en marcha un proyecto LIFE-Naturaleza financiado en un 50% por la Comisión Europea (LIFE02NAT/E/8610 “Conservación de cetáceos y tortugas en Murcia y Andalucía”) con el fin de diseñar una red de espacios marinos protegidos en el marco de la Red Natura 2000 de la Directiva Hábitats, la contribución de la Unión Europea a la Cumbre para la Conservación de la Biodiversidad de Río de Janeiro (1992). Este proyecto finalizará en julio de 2006. Los últimos tres años de estudio incluidos en este estudio (2002 a 2004) se enmarcan dentro de este proyecto LIFE.

Como socios de este proyecto LIFE Naturaleza están el Ministerio de Medio Ambiente, el Ministerio de Agricultura, Pesca y Alimentación, las Consejerías de Medio Ambiente y Agricultura y Pesca de la Junta de Andalucía y del Gobierno de Murcia, la Universidad de Cádiz y el Instituto Español de Oceanografía. Además de estos socios, la SEC cuenta con la participación activa y el apoyo de otras entidades como el Centro de Cooperación Mediterránea de la UICN, la Guardia Civil (SEPRONA, GC del Mar), Protección Civil, Cruz Roja del Mar, la Dirección General de Marina Mercante, el servicio CREPAD del Instituto Nacional de Técnicas Aeroespaciales, la asociación de Periodistas Ambientales, las cofradías de pescadores, las empresas de turismo de avistamiento de cetáceos así como los ayuntamientos de los pueblos y las ciudades del litoral de Andalucía y Murcia. Participan también las organizaciones no gubernamentales ALNITAK, Circè y ANSE.

El núcleo de este proyecto constituye la elaboración de unos planes de gestión y conservación basados en las investigaciones científicas de ALNITAK y la SEC. A través de la creación de un vínculo entre investigadores y administración el objetivo de la SEC es el fomento de una ciencia integrada en las estrategias nacionales e internacionales de conservación de la biodiversidad. En este sentido se están desarrollando diversas técnicas de investigación a nivel experimental, utilizando las más avanzadas herramientas disponibles, como la modelización del uso de hábitat y de la densidad, el análisis molecular de isótopos estables o el seguimiento por satélite.

Pero quizás lo más característico de este proyecto es su filosofía de implicar a todos los usuarios del medio marino en el proceso de elaboración de los planes de conservación. Consciente de que la gestión del medio marino es solo posible a través del consenso de todas las partes implicadas, la SEC puso en marcha las giras “Todos por la Mar”. A lo largo de los cuatro años del proyecto, tres llamativos veleros de época, antiguos pesqueros, surcan el Mar de Alborán recalando en los puertos de Andalucía y Murcia. Junto con una exposición itinerante, ciclos de conferencias, cuenta cuentos y proyectos educativos se llevan a cabo reuniones con navegantes, pescadores, empresas de turismo de avistamiento de cetáceos y centros de buceo con el fin de establecer una colaboración con un objetivo claro: hacer compatible la conservación de la biodiversidad marina con un desarrollo económico sostenible.

Dentro de este proyecto LIFE, hay una serie de acciones relativas a la monitorización de las poblaciones de cetáceos. En particular, se desarrolló un programa de investigación aplicada para:

- Conocer el estado de conservación de las poblaciones y los factores que están incidiendo sobre éste y poder observar los cambios que se puedan dar sobre esa situación para actuar en consecuencia
- Analizar la Idoneidad del diseño de las Áreas Marinas Protegidas para estas especies (LIC Marino Medio Marino de Murcia) y las propuestas de las que van a ser designadas en Andalucía

El trabajo desarrollado en esta tesis se enmarca, en concreto, dentro de la acción “Seguimiento de la distribución y uso del hábitat de las poblaciones y tendencia de las poblaciones”, cuyo objetivo es realizar un seguimiento de la distribución, uso del hábitat y abundancia de los delfines mulares en aguas de Andalucía y Murcia y su relación con las variables ambientales y antrópicas que pudiesen afectarles.

1.4.3. Capítulos

Esta tesis está organizada en 11 capítulos. Aquí describiré brevemente el contenido de cada uno de ellos.

Después de este capítulo de introducción, en el capítulo 2 hago una descripción del área de estudio. Primero una visión muy general sobre las características naturales y antrópicas del mar Mediterráneo. Me centro luego en una descripción algo más detallada de las características específicas de la zona de estudio: el mar de Alborán y el Golfo de Vera, pasando por los aspectos fisiográficos, oceanográficos, meteorológicos y bióticos más relevantes. Termina el capítulo con un breve sumario de la importancia ecológica de esta zona de estudio.

En el capítulo 3 hago una breve descripción de los métodos generales de trabajo de campo, que son comunes a todos los capítulos de investigación.

El capítulo 4 hace una descripción de las actividades humanas y posibles amenazas en la zona de estudio. Se conjuga información procedente de fuentes bibliográficas con los datos obtenidos durante el trabajo de campo. Se describe aspectos relacionados con el tráfico marítimo, turismo, pesquerías, contaminación acústica, actividades militares y residuos urbanos e industriales. Se analiza luego los posibles impactos de estas actividades sobre las poblaciones de cetáceos de la zona.

A continuación desarrollo cinco capítulos que tratan específicamente acerca de la investigación sobre la distribución, selección de hábitats y abundancia de las especies de delfines. El capítulo 5 es una primera aproximación a la distribución de varias especies de cetáceos en la zona de Almería, con respecto a la fisiografía del fondo. Un aspecto importante de este capítulo es que se establecen unos patrones de distribución de las distintas especies, analizando las semejanzas y diferencias entre ellas, y relacionándolo con sus distintos hábitos de alimentación. Los análisis realizados en este capítulo son los más sencillos, como primera fase antes de entrar en los más complejos métodos de los siguientes capítulos. Este capítulo corresponde a un artículo publicado en 2002 en la revista científica Deep Sea Research II.

El capítulo 6 es el resultado del ‘Proyecto Mediterráneo’ financiado por el Ministerio de Medio Ambiente del que se habla en el apartado anterior. En él se avanza en dos sentidos: por un lado se empieza a aplicar el método del análisis espacial como herramienta para estudiar la distribución y preferencia de hábitats de las especies, y por otro se aplica la información obtenida de estos análisis a la conservación mediante la propuesta de una serie de áreas marinas protegidas. Pero no sólo se proponen una serie de áreas, sino que se discute el proceso por el cual se debe llegar a la selección apropiada de las áreas que deben ser protegidas, incidiendo en la importancia de la base científica de dicha selección y en la importancia de una adecuada estrategia de gestión de las áreas para asegurar su efectividad. Este capítulo consiste en un artículo publicado en 2005 en la revista científica Aquatic Conservation: Marine and Freshwater Ecosystems.

En el capítulo 7 se introduce una nueva y más avanzada metodología analítica. Se combina el análisis ‘Distance’ de transecto lineal con el análisis espacial con el fin de obtener, además de los mapas de superficie de preferencia de hábitats, estimas de abundancia. Hasta este momento este método, muy novedoso, había sido aplicado muy escasamente, siendo éste uno de los primeros casos de estudio de cetáceos en los que se aplica. Este capítulo se centra en la estima de abundancia por este método del delfín mular en la zona del mar de Alborán. Pero no solo se obtiene una estima puntual, sino que se aplica a distintos períodos de años, con lo que se analizan las tendencias de la población en los años estudiados. Se hace también una discusión sobre las implicaciones de este trabajo sobre la conservación. Este capítulo consiste en un artículo publicado en 2006 en la revista científica Journal of Cetacean Research and Management.

En el capítulo 8 se aplica el mismo método que en el capítulo anterior, pero esta vez para el delfín común. Una diferencia en el método aplicado, sin embargo, es que en este caso se estratifica el análisis de ‘Distance’ de acuerdo a distintas condiciones de búsqueda, con lo que su combinación con el análisis espacial resulta algo más complejo. Los datos se estratifican también de forma estacional, separando los meses de verano del resto. Se analizan y comparan además distintas sub-áreas dentro del área de estudio, y distintos períodos de años para evaluar las tendencias. Se discuten igualmente las implicaciones de los resultados en la conservación.

Finalmente, en el capítulo 9 se aplican las mismas técnicas de análisis que en el capítulo previo, también para el delfín común, pero en este caso el objetivo no es estimar la abundancia de delfines sino analizar sus preferencias o selección de hábitats en función de una serie de características ‘intrínsecas’ de los animales. Se describe primero la selección de hábitats en general (es decir, en función de las variables ambientales utilizadas), en base a los resultados del análisis espacial del capítulo anterior. Se hace luego una comparación con la selección de hábitats dependiendo de las características 'intrínsecas' analizadas: grupos con crías o sin crías, grupos simples o mixtos con delfín listado, y grupos que se encontraban realizando distintas actividades cuando se avistaron: alimentándose, socializando, desplazándose o 'remoloneando'. Se discuten igualmente las implicaciones para la conservación.

El Capítulo 10 describe algunas ideas sobre cómo debe ser el desarrollo del plan de conservación del delfín mular. Este es el proceso seguido en el marco del proyecto LIFE-Naturaleza, y que será entregado a la Comisión Europea y las autoridades españolas competentes nacionales y autonómicas en Julio de 2006.

Por último, en la discusión me centro en tres aspectos. El primero es una discusión acerca de la aplicabilidad de los métodos utilizados en este estudio a otras áreas y especies. El segundo aspecto es un resumen sobre la contribución de esta tesis al conocimiento de la ecología de los cetáceos, y en particular de los delfines mulares y comunes en el área de estudio. El tercero está orientado a la conservación de los delfines. En este sentido, resumo brevemente las propuestas de áreas marinas protegidas; describo la contribución a los planes de conservación para estas especies; describo cómo se han establecido finalmente unas líneas de base, previamente inexistentes, para una futura monitorización a largo plazo, proponiendo además ideas para dicha monitorización; y describo también brevemente la contribución de este trabajo a lo largo de los años a la sensibilización pública respecto a los problemas de conservación de los cetáceos y el medio marino. Por último, hago una serie de sugerencias sobre futuras líneas de trabajo para continuar aumentando nuestros conocimientos sobre la ecología de estas especies y al mismo tiempo ir avanzando hacia su conservación efectiva.

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CHAPTER 2

DESCRIPTION OF THE STUDY AREA

2.1. STUDY AREA

The study area comprises the waters of the Autonomous Comunity of Andalucía and the southern waters of the Region of Murcia, in Southern Spain (westernmost end of the Mediterranean Sea) (Figure 2.1). The area was divided into several sub-areas with different oceanographic and physiographic characteristics (Figure 2.2):

- Gulf of Vera: between Cabo de Gata and Cabo de Palos (including Eastern Almería and Southern Murcia)
- Southern Almería: between Cabo de Gata and 3º10' W
- Western Alborán: between Punta Europa (Gibraltar) and 3º10' W
- Strait of Gibraltar: between Punta Europa and 6º00' W (Barbate)
- Gulf of Cádiz: between 6º00' W and the border with Portugal

From 1992 to 1999, only the areas of the Gulf of Vera and Southern Almería were studied. The study area was extended to the rest of the sub-areas to the west since 2000. The study area in 1992 - 1999, was selected due to its particular oceanographic characteristics, which are described in the present chapter, and also due to the total lack of knowledge of the cetofauna of the region at that time. Before the start of this study, no research had been undertaken in connection with the cetacean populations that could inhabit or transit this area. In 2000 the study area was extended to the west for the Mediterranean Project (Cañadas *et al*. 2004) and later for the LIFE project (LIFE02NAT/E/8610).

Figure 2.1. Mediterranean Sea (above) and Alborán Sea (below)

The following sections describe the most relevant characteristics of the region, which make it especially important not only for Mediterranean cetaceans but in general for its entire fauna, its hydrology and the conservation of the marine environment. A knowledge of the environmental as well as anthropogenic factors that can directly or indirectly affect the habitat of a species, is crucial to an understanding of how each species makes use of its habitat, how it evolves in it and how minor or major variations that may occur can affect its distribution, its natural history and in turn its survival and conservation.

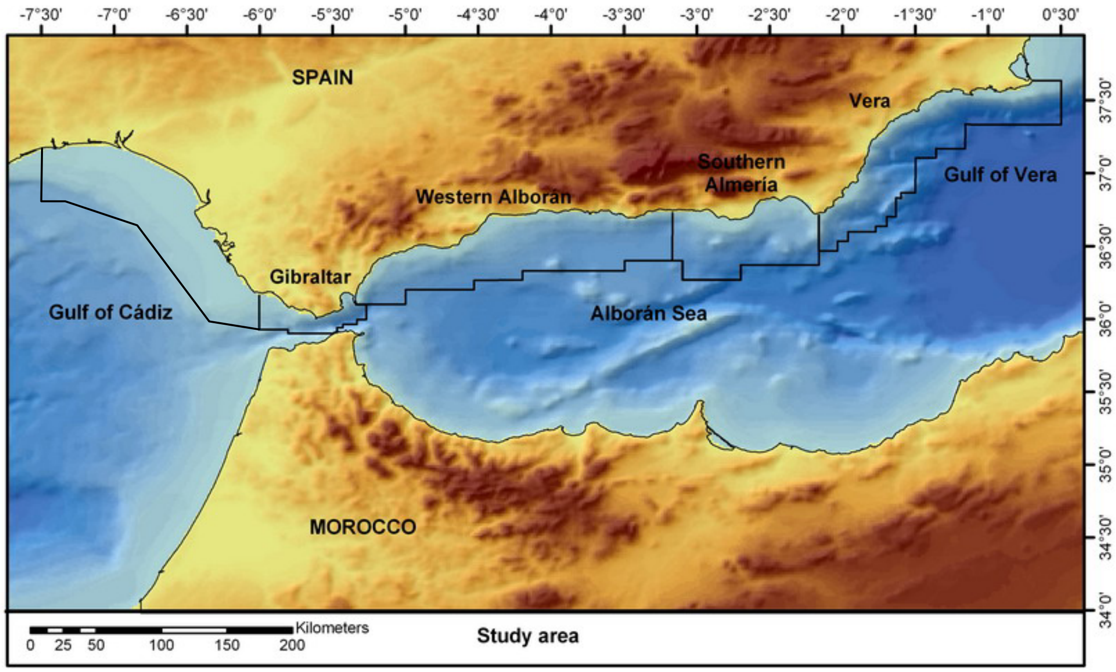

Figure 2.2. Sub-areas of the study area

2.2. GENERAL CHARACTERISTICS OF THE MEDITERRANEAN SEA

2.2.1. Natural characteristics

The Mediterranean is a semi-enclosed sea which covers an area of approximately 2.5 million km^2. It is connected to the Atlantic Ocean through the Strait of Gibraltar, to the Black Sea through the Dardanelles Strait and to the Red Sea through the Suez Channel. Of these three seaways, the first is the most important one and is responsible for the characteristics of this sea (Rodriguez 1982).

The Mediterranean Sea comprises various basins (Figure 2.3). A first east/west division can be made into two main large basins separated by the Sicily Channel that is approximately 150 km wide and 400 m deep. The western basin can be divided into three sub-basins: the Alborán basin to the west, between the south of Spain, Morocco and the western end of Algeria; the Algerian-Provençal basin, between Algeria, eastern Spain, France, the north of Italy, Corsica and Sardinia; and the Tyrrhenian basin, bounded by Sicily, Corsica, Sardinia and the Italian coast.

The eastern basin also has various sub-basins. The Adriatic Sea extends between the old Yugoslavian coasts and the eastern coast of the Italian peninsula. The Ionian Sea covers the central area of the Mediterranean, bounded by Sicily, Italy, Albany, Greece, Libya, Tunisia, Crete to the east, and the Sicily Channel to the west. The Aegean Sea is bounded by Greece, Turkey and Crete and has a connection with the Black Sea through the small Sea of Marmara. The most eastern basin, the Levantine basin, is bounded by Crete, Libya, Egypt, Israel, Lebanon and Syria, and is connected to the Red sea through the Suez Canal.

In general, the continental shelf of the Mediterranean basin is quite narrow, with a few exceptions such as the eastern coast of Tunisia and the Adriatic Sea (Figure 2.3). The average depth of the Mediterranean is approximately 1,500 m, less than that of the oceans, although it has some deep trenches which exceed 4,000 m and reach up to 5,000 m especially in the Ionian Sea (Rodríguez 1982; EEA 1999).

The Mediterranean can be defined as a "concentration basin" because evaporation exceeds water inputs from rainfall and rivers. This results in a deficit which is the basis of all the hydrologic mechanisms of this sea. This deficit is partly compensated by the entry of Atlantic waters through the Strait of Gibraltar and to a much lesser extent by the contribution of waters coming from the Black Sea through the Bosphorus. This concentration leads to the relatively higher salinity of the Mediterranean compared to the Atlantic (Rodríguez 1982; Miller 1983; EEA 1999).

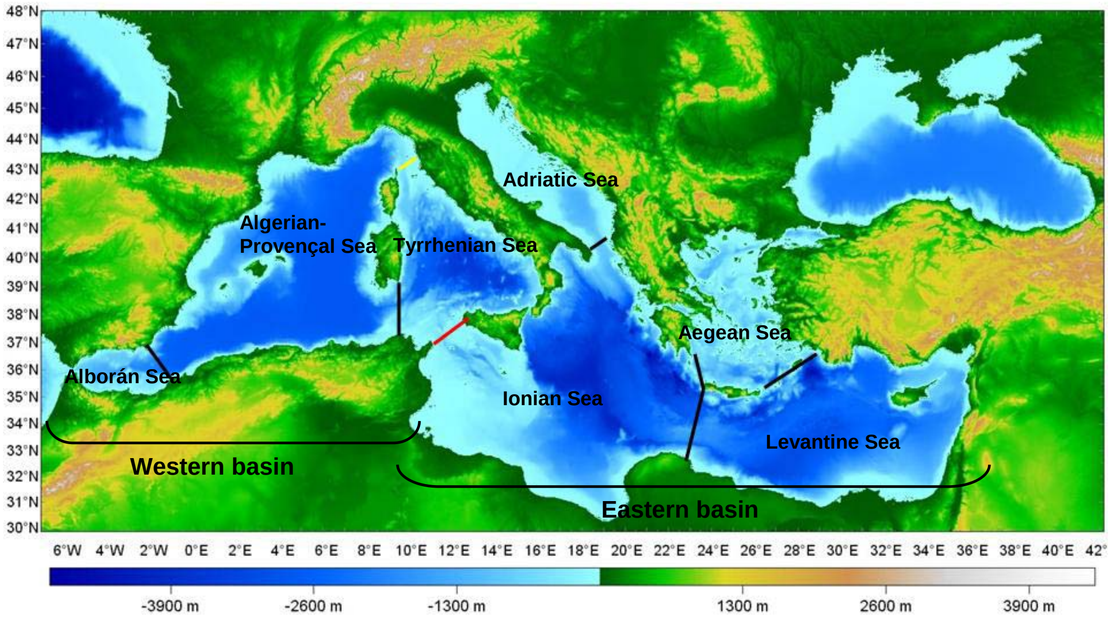

Figure 2.3. Basins and sub-basins of the Mediterranean Sea. Red line indicates division between Western and Eastern basins. Black lines indicate approximate divisions of the sub-basins.

In the Strait of Gibraltar, there are overlapping and inverse flows of water whereby Atlantic waters enter on the surface and Mediterranean waters leave at depth. As a result, the surface water currents produce a migration of Atlantic waters towards the east with many eddies and diversions of branches on its way, resulting in the formation of cyclonic circuits due to the Coriolis effect. There is no return system on the surface; the return occurs in the intermediate layers coming from the Levantine basin which has a general movement towards the west but also following large cyclonic circuits (Rodríguez 1982; Miller 1983).

The Mediterranean also has strong vertical water movements, which determine the distribution of salinity and produce a vertical recycling of nutrients and other dissolved substances (Rodríguez 1982; Miller 1983).

Most authors consider the Mediterranean as an oligothrophic sea; that is, poor in nutrients (Rodríguez 1982; Miller 1983; EEA 1999) where the majority of its biological productivity occurs within the euphotic zone and exhibits an extreme variation (UNEP 1989). The incoming Atlantic waters are only at the surface and therefore poorer than the Mediterranean water that leaves at depth. The only sources of nutrients in the Mediterranean come from rivers, the Atlantic and atmospheric emissions. The main reason for its oligotrophy is connected with the hydrology of the Mediterranean Sea as a concentration basin (Souvermezoglou 1988). However, despite this poor nutrient content, paradoxically the primary production values measured in the Mediterranean are higher than expected (Sournia 1973). This situation could be due to an efficient recycling of the nutrients as a result of the vertical movements which are especially strong in Mediterranean waters and that enable the use of all the nutrients contained within the water column (Miller 1983).

Generally speaking, life in the Mediterranean is characterised by a relatively low biomass and a high diversity. This sea represents only 0.8% of the area and 0.25% of the volume of the world oceans. However, it contains approximately 7% of all the known marine fauna and 18% of the flora of which 28% are endemic (EEA 1999). A total of 10,000 to 12,000 marine species have been described for the Mediterranean, of which 8,500 are macroscopic fauna species (Fredj *et al.* 1992). This biodiversity is greater in the western area of the Mediterranean than in the eastern; twice as great for the fauna (UNEP 1997).

2.2.2. Anthropogenic characteristics

Some anthropogenic characteristics of the Mediterranean Sea are or could become major problems for the region's environment. One of these is maritime traffic. It is estimated that approximately 30% of the world's marine commercial traffic crosses the Mediterranean including 20% of the oil tankers, which results in approximately 220,000 ships over 100 tonnes navigating this sea. Hydrocarbon transport is of primary importance in the Mediterranean and it is estimated that between 4,400 to 4,500 oil tankers cross the Strait of Gibraltar each year (circa one fifth of the world's total). Each year there is an average of 60 maritime accidents, of which 15 involve large spills of hydrocarbons or chemical products (EEA 1999).

Because the Mediterranean is an evaporation basin, any particle or substance introduced at the surface, unless it is volatile or capable of mixing with deeper waters leaving the Mediterranean, will remain there (Miller 1983).

Land based industries are the major source of contamination for the Mediterranean, especially in the case of TPBs (toxic-persistent-bioaccumulatives). An example is TBT (tributyltin) which is used as a biocide in the antifouling paints of ships and it is therefore disseminated by them throughout the Mediterranean. Although many types of industries are based all round the Mediterranean, the areas of most conflict are located in the north-west, generated by large industrial states. All the coastal cities of the Mediterranean dispose of their waste, both treated (approximately 2,830.23 million m^3/year or 48%), and untreated (approximately 3,067.11 million m^3/year or 52%), into the marine environment (EEA 1999).

A total of 80 rivers have been identified which contribute significantly to the contamination of the Mediterranean, with contributions of heavy metals, phosphates, nitrates, PCBs (polychlorinated biphenyls), PAHs (Polycyclic aromatic hydrocarbons), solvents and bacteria (especially faecal coliforms) amongst others. Many of these contributions come from agriculture (UNEP 1984; EEA 1999).

Fisheries are also an important activity in the Mediterranean. Currently there is an over-exploitation of fish resources, with an estimate of 1.35 million tonnes for the total captures in 1994 (FAO, 1977). Fisheries not only reduce target species abundance but also, as a secondary effect, that of other species either directly through accidental captures or indirectly by changing the energy transfer between trophic levels resulting in a decrease in the number of species (Caddy and Sharp, 1986). Demersal communities are currently over-exploited with a general trend towards a decrease in the size of animals caught and the habitats are frequently destroyed by trawling close to the coast. In contrast, communities of small pelagic species vary greatly according to the environmental conditions and are probably not fully exploited except for the anchovy. Large pelagic fish such as tuna and the swordfish are also heavily exploited; the Mediterranean is an important spawning area for bluefin tuna (EEA 1999).

Fisheries also have important interactions with cetaceans. The FAO report on interactions between marine mammals and world fisheries (Northridge 1984) establishes two types of interactions: operational (accidental captures) and biological (competition for resources). The same report considers the common, striped and bottlenose dolphins as the three species most affected by accidental captures in fishing gear in the Mediterranean.

2.3. PHYSICAL CHARACTERISTICS OF THE STUDY AREA

2.3.1. Geography and hydrology

The Gulf of Cádiz has a general eastwards current over the continental slope. This current divides into two branches at the entrance of the Strait of Gibraltar: one enters into the Mediterranean and the other turns to the southwest to form an anticyclonic gyre that occupies most of the Gulf. The current close to the shore also goes to the southeast, and between both there is a cross-current towards the northwest. Over this circulation pattern, there is an oscillating tide current, amplitude of which over the shelf is about 10 cm/s, increasing towards the Strait of Gibraltar (Rubín *et al*. 1997).

The Alborán Sea, the most western part of the Mediterranean Sea, is open to the Atlantic Ocean through the Strait of Gibraltar, becoming a transition area between these two basins which have totally opposite oceanographic characteristics. The differences in level between both basins enables a water exchange which results in the flow of surface Atlantic water towards the Mediterranean compensated by a flow of Mediterranean waters in the opposite direction on the bottom of the Strait (Rubín *et al*. 1992; Parrilla and Kinder 1987; Miller 1983). Although the surface Atlantic water mass is not rich from the biological point of view, its lower salinity and temperature makes this flow the motor of the Alborán Sea dynamics resulting in oceanographic features of great relevance by creating a strong thermohaline front (Cortés *et al.*1985; Gil 1985: La Violette 1986; Cheney and Doblar 1979; Millot 1987). The physical aspects of these oceanographic features have been thoroughly studied (Parrilla and Kinder 1987; Wannamaker 1979).

The Atlantic flow enters along the northern coast of the Alborán Sea diverting to the south and creating an anticyclonic gyre in the western basin of this sea (Parrilla and Kinder 1987; Gascard and Richez 1985). After this permanent gyre, the Atlantic flow extends towards the east creating eddies and small meanders as well as a second gyre in the eastern basin of Alborán to create the so-called Almeria-Orán front (Tintoré *et al.* 1988) and the African current (Arnone and La Violette 1984; Millot 1985) (Figure 2.4). These gyres, driven by the topography of the Alborán Sea floor (Parrilla and Kinder 1987) and enhanced by the meteorological and atmospheric conditions (Cheney and Doblar 1979) create convergence and divergence of the water masses producing areas of high productivity (Rubín *et al.* 1992).

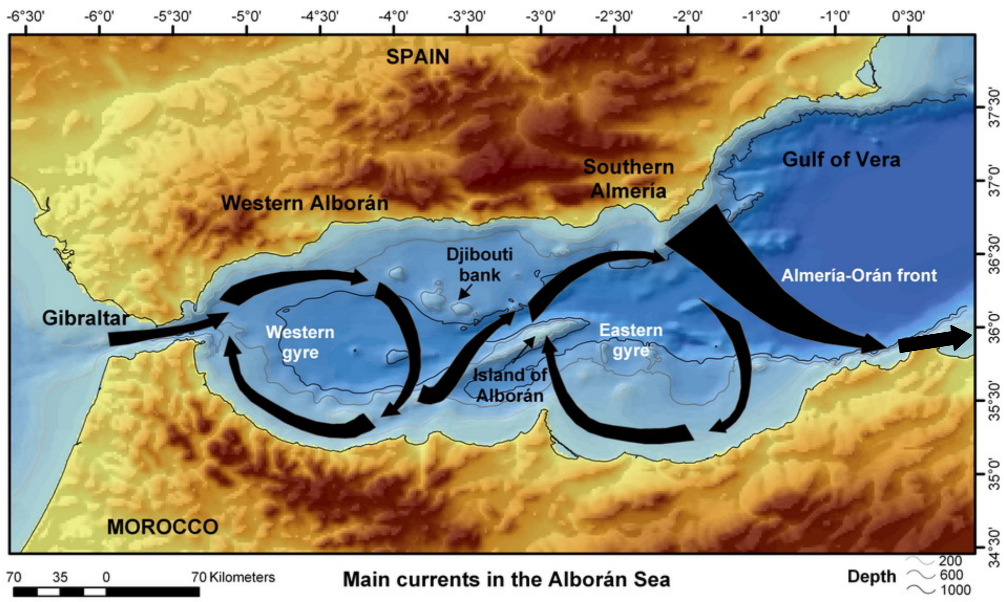

Figure 2.4. Currents of superficial Atlantic waters at the entrance of the Mediterranean Sea.

The important Atlantic influence in the Alborán Sea not only results in the formation of high productivity areas or in the direct entry of ichthyoplankton from the Atlantic (Rubín *et al.* 1992), but also in the distribution of Atlantic species into the Mediterranean. The traditional research effort invested in physical oceanography in the Alborán Sea contrasts with the little research undertaken in the biological field, where research on the features associated with the Atlantic water flow only started a few years ago.

The region covered by this study is especially important oceanographically because it covers waters with both Atlantic and Mediterranean influence. The Gulf of Vera, located between Cabo de Gata and Cabo de Palos is primarily Mediterranean but has some Atlantic influence. This results in a cyclonic flow induced by the Coriolis force, of less dense and saline water that travels from Cabo de Gata to Cabo de Palos (Figure 2.5), where a particularly saline and warm water mass is fed by the Mar Menor and a Mediterranean water mass inside the Gulf of Vera next to the coast, which is more saline than the modified Atlantic water since it is out of the direct reach of the entering Atlantic water (Díaz 1991). Due to the oceanographic differences between the Gulf of Vera and the Alborán Sea, many of the following sections address these regions separately.

2.3.2. Meteorology

The region's climate is mainly determined by the Azores anticyclone. Winters (November to February) are characterised by low-pressure systems which cross the Iberian Peninsula, resulting in prevailing westerly winds. In this period, the weather is unstable, humid and windy (Parrilla and Kinder 1987). During summer months (June to September), the well established high pressure system of the Azores produces dry and temperate weather with easterly winds which is combined with solar breezes created by the desert coastal mountains. In spring (March to May) there is an alternation of wintry and summery weather periods. Autumn is very short (October), so the transition between summer and winter is very abrupt (Parrilla and Kinder 1987).

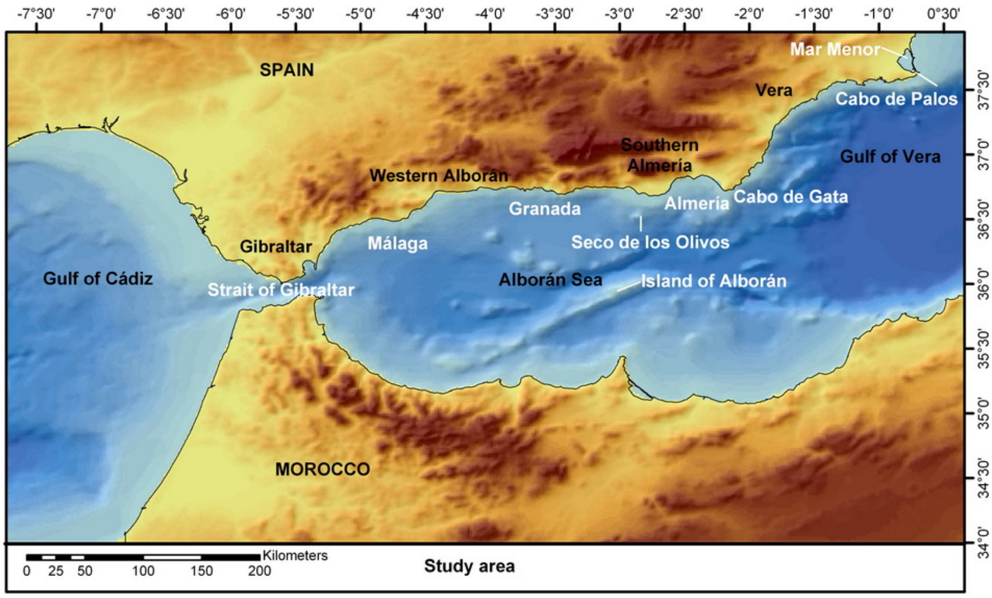

Figure 2.5. Location of several geographic points in the study area.

In the Gulf of Cádiz the dominant winds come from the north (the Azores anticyclone) or from the northwest (with the passage of the cold fronts). Both situations favour the southeast current parallel to the coast. In situations with easterly winds or low pressures over the Gulf of Cádiz, the currents induced by the wind run towards the northwest (Rubín *et al*. 1997).

The topography of the land which surrounds the Alborán Sea has a great effect on the winds, mainly in coastal areas, having a channelling effect. For example, the winds across the Strait of Gibraltar can become very strong.

The predominant winds in the area are westerly and easterly. Winds of lesser intensity from the south-southwest called "leveche" are also present. However, in both cases, the general flow is altered in the western Mediterranean during winter and summer due to the monsoon. During summer, the strong heating of the peninsula encourages the creation of monsoon winds from the Mediterranean Sea towards the land blowing from the east especially during daytime. In winter, however, the sea is much warmer that the land and therefore the monsoon blows from land to sea as a westerly or north-westerly wind. Both monsoons combine with the general isobaric flow (Medina 1974).

The "poniente" winds are westerly, humid and generally associated with low pressure systems to the north and NW of the peninsula. They are more predominant in autumn, winter and spring. These winds last for several days, up to a week or more, and produce a cooling of the sea surface along the Spanish coast (Parrilla and Kinder 1987). In the Alborán Sea, a phenomenon known as "pulsation" takes place (Medina 1974), which consists of the cooling of waters due to the entry of cooler surface waters pushed by winds from the Atlantic. An important effect to consider is the creation of marine currents not pushed by the wind (Medina 1974). Due to the friction of the air against the water surface, the latter is deflected perpendicular to the wind and towards the right in the Northern Hemisphere. Once this current is established it remains at a 45º angle from the wind in the deep open sea and at a smaller angle in shallow waters. Thus, with westerly winds, the surface current induced moves water offshore which is replaced by deeper and denser waters. This superficial water sinks many kilometres away and returns to the coast to close the circuit. A large whirlpool with a horizontal axis is thus formed with a vertical thickness of 200 to 300 m (Medina 1974). The Alborán Sea is well known for the prevalence of up-welling areas resulting from westerly winds.

The "levante" winds are normally easterly or south-easterly winds normally associated with high pressure systems located at the north of the peninsula or even over the Balearic Islands. They are very common in summer, often associated with the establishment of the Azores anticyclone, but can occur at other times of the year associated with cyclonic activity in the western Mediterranean, north of Africa or the Atlantic side of northern Morocco (Parrilla and Kinder 1987). For the same reason described above for westerly winds, when the wind blows from the east in the Alborán sea, there is a transport of surface water towards the coast (to the right of the wind) resulting in an opposite effect to that described above: an up-welling of deeper waters occurs several kilometres away from the coast (from 200 to 300 m depth), and a down-welling of superficial waters occurs next to the coast (Medina 1974).

In addition to these predominant winds, coastal breezes are also very frequent in the Alborán Sea and the Gulf of Vera; these are the result of heating and cooling differences between land and sea. During the day and under the sun, the land heats up more than the sea and since warmer air is lighter, the atmospheric pressure becomes lower on land than at sea and an air flow from sea to land is established (sea breeze). At night, the land cools quicker than the water, and therefore the air blows from land to sea (land breeze). These breezes can be locally very strong.

Winds associated with atmospheric pressure play an important role in the oceanography of the Alborán Sea by increasing or reducing the entry of Atlantic waters. When high pressure systems are present on the western Mediterranean, the sea surface moves down and tends to force the water out across the Strait of Gibraltar, resulting in a reduction in the influence of Atlantic waters (Cheney and Doblar 1979). In contrast, when low pressure systems are present in the western Mediterranean the sea surface becomes higher and the influence of Atlantic waters increases. Similarly, the westerly winds associated with low pressure systems result in an increased flow of Atlantic waters that could even be duplicated when both effects are combined (Lacombe and Tchernia 1972; Cheney and Doblar 1979), whilst the easterly winds associated with high pressures partly slow down the entry of waters from the Atlantic (Parrilla and Kinder 1987).

2.3.3. Oceanography

2.3.3.1. Submarine topography and type of sea bed

Gulf of Cádiz

The Gulf of Cádiz has a wide continental shelf, between 25 and 46 km, with a gentle slope towards higher depths, very far from coast (Figure 2.6).

Alborán Sea

The underwater topography of this region is of great interest and various geological studies have been made. The Alborán Sea has a maximum depth of approximately 1,500 m in the most western area and more than 2,000 m in the eastern basin, with a complex topography. The continental shelf is very narrow, between 2 and 10 km along the Spanish coast and its depth varies between 100 and 150 m. The sea bed is very irregular with big canyons, ridges and sea mounts of various sizes and depths. One of these ridges, which flows in a NE-SW direction, includes the volcanic Alborán Island (600 m x 250 m), which separates the eastern and western basins of the Alborán Sea (Figure 2.5). The western basin is connected to the eastern one through two channels: a deep one between the north of the ridge where Alborán Island is situated and the banks of Djibouti which rise approximately 275 m; and a less deep one to the south of the ridge (Parrilla and Kinder 1987). One of the most important sea mounts in the Alborán Sea is the Seco de los Olivos (Figure 2.5), which rises to around 76 m depth from a surrounding area between 200 and 500 m deep southwest from the Bay of Almería, and is known for its high productivity (Figure 2.6).

In the deep waters of the Alborán Sea the rocky substrate is covered by deposits, which decrease in thickness the closer they get to the continental shelf break where the rocky substrate is uncovered. Alternations of sand and silt are mainly present on the continental shelf. The continental shelf at Almería is mixed; it has sand and coarse gravel which becomes finer towards the shelf break where there is mainly silt. In the inner shelf there are rocky outcrops (Rey and Medialdea 1989).

Gulf of Vera.

The Gulf of Vera reaches depths of 2,500 m at distances of 37 to 75 km from the coast. Its continental shelf is small and irregular and has a mixed composition of silicate and carbonate sediments in the form of sands, gravels and silt on volcanic rock (Rey and Medialdea 1989). The continental slope is steep and only 10km wide. This slope has large morphological irregularities and has deep canyons that travel through the area as well as various spots where there are ridges and sea-mounts (Rey and Medialdea 1989, MOPU 1991, Díaz del Rio 1991) (Figure 2.6). In the area close to Cabo de Gata, the continental margin shows volcanic protrusions which represent old craters surrounded by a group of lava streams that often create wide morphological units (MOPU 1991).

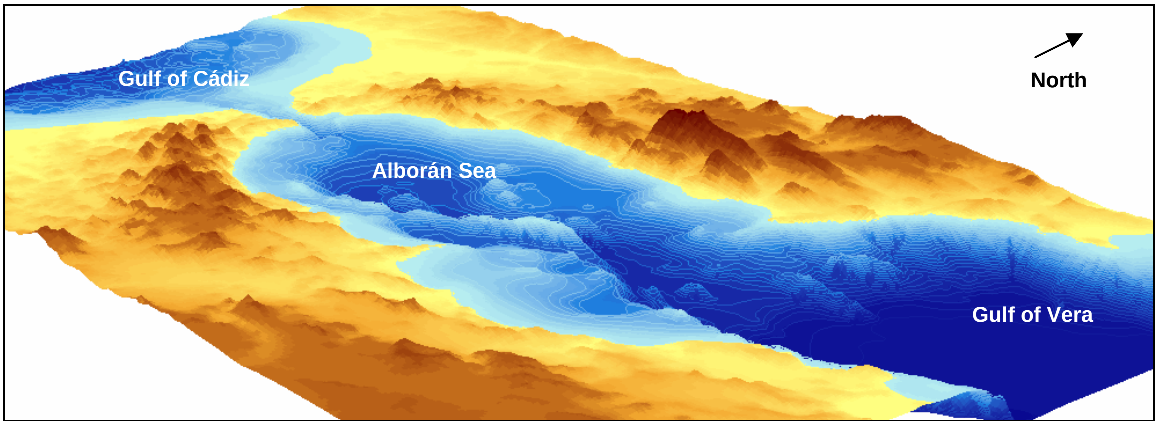

Figure 2.6. Submarine topography of the Alborán Sea, Gulf of Cádiz and Gulf of Vera

2.3.3.2. Physical characteristics

Gulf of Cádiz.

In the Gulf of Cádiz there are superficial Atlantic waters, with a salinity of 36.3 to 36.4 $^o/_{oo}$ at the surface, decreasing slowly with depth, and a surface temperature up to 22º C, also decreasing slowly with depth, except for an almost isothermal mixed superficial layer around 20 m deep. At a given depth, where the temperature reaches 15º and the salinity 36.2 $^o/_{oo}$, the central Atlantic waters layer begins, with a faster decrease of salinity with temperature. Below this, the deep Mediterranean waters layer begins, which comes from the Strait of Gibraltar. The waters over the continental shelf usually have lower temperature and salinity than those in open sea, due to the up-wellings.

Alborán Sea.

The Atlantic water layer in the Alborán Sea, which covers the first 150 m of depth in the middle of the basin and approximately 50 m near the Spanish coast, is almost homohaline with values between 36.2 and 36.5 $^o/_{oo.}$ Between 10 and 100 m depth, there is a minimum salinity value throughout the Alborán Sea generated by evaporation of the surface layer and by the mixture of deeper waters with the more saline Mediterranean water. Below this layer of Atlantic water there is a transition layer of approximately 100 m thickness with a strong salinity gradient. Between 200 and 600 m the gradient is negligible and maximum salinity values are recorded: approximately 38.5 $^o/_{oo}$, which indicates a strong influx of intermediate levantine waters. Below this layer, the salinity decreases slowly and settles at around 38.44 $^o/_{oo}$, which corresponds to that of deep waters (Miller 1983, Parrilla and Kinder 1987).

The temperature gradient of the Atlantic water column varies with seasons. During summer the thermoclines have a strong gradient from almost the surface to approximately 150 m. The thermocline is deeper wherever the Atlantic layer is thicker. In winter the Atlantic water layer is almost isothermal. In the transition area which separates Atlantic and Mediterranean waters, the temperature gradients are high, like those of salinity but at greater depths these gradients decrease substantially. In the layer between 200 and 600 m, associated with the intermediate Levantine waters, the temperature is around 13.2ºC and slowly decreases down to 12.7 – 12.9ºC, the typical temperature of deep Mediterranean waters (Miller 1983, Parrilla and Kinder 1987).

Gulf of Vera.

The Gulf of Vera has the typical seasonal temperature regime of the Mediterranean: cold homothermia in winter and a thermocline in summer. In spring, temperatures in surface waters up to 15 or 20 m deep are 17-18ºC. The thermocline reaches a temperature of approximately 14-15ºC at 30-35 m and slowly decreases down to 100 m to around 13ºC, remaining at this value down to the seabed. During summer a strong temperature gradient can be observed in the water column. Surface temperature is as high as 25-27ºC, and at the thermocline at approximately 20 m the temperature drops to 24ºC, and continues decreasing down to 17-18ºC at 35 m , from where there is a slower decrease down to 13ºC. In autumn there is a warm homothermia between 19 and 20ºC in the first 25-30 m of the water column and then a weak thermocline in which the temperature decreases to 14.5ºC at 50 m and further down more slowly to 13.2ºC at 150 m where the temperature remains constant. In winter there is a cold homothermia with temperatures of 14-15ºC up to approximately 75 m, dropping to 13.7ºC at 100 m and decreasing to 13ºC (Deyá *et al*. 1990).

Salinity measurements in the Gulf of Vera (Deyá *et al*. 1990) show more Atlantic influence (less saline waters) during spring and autumn and less in summer, with an intermediate situation in winter. Typical spring values are 36.14 to 37.00 $^{o}/_{oo}$ down to 25 m, reaching 38.00 $^{o}/_{oo}$ at greater depth, typically Mediterranean. During summer the surface salinity increases up to 37.5 to 38 $^{o}/_{oo}$, with values above 38 $^{o}/_{oo}$ at 60 – 70 m depth. In autumn, the salinity of the first 50 – 70 m decreases to 36.0 – 36.9 $^{o}/_{oo}$, and increases again at greater depths to 38.0 – 38.5 $^{o}/_{oo}$. In winter the surface salinity increases to 37.0 $^{o}/_{oo}$ or a bit more at 50 m, reaching 38.0 – 38.5 $^{o}/_{oo}$ at 100 m and deeper.

Figure 2.7 shows the average weekly sea surface temperature for the study area derived from satellite images for 2000, as an example.

2.3.3.3. Chemical characteristics

Gulf of Cádiz.

There are relatively low levels of nitrates in the surface waters of the Gulf of Cádiz, especially in the proximity of the coast, compared to the waters of the Mediterranean region. The levels of phosphates and silicates in this region are higher than those in the Mediterranean, and the concentration of nutrients is much higher close to shore than in the open sea. In the deeper layers, the concentrations of phosphates and silicates are lower than those of the Mediterranean area (Rubin *et al*. 1997).

Alborán Sea.

Studies of the abundance and distribution of nutrients in the Alborán Sea are scarce. Overall, the vertical distribution of nitrates is very similar in all the oceans, with an increase in concentration from the surface, where it can be almost nil, to deeper waters. However, in Alborán as a result of the divergence processes, high levels of nutrients are detected at sub-surface levels (Rubín *et al*. 1992).

The cruise “Ictio-Alborán 0791” carried out by the Spanish National Institute of Oceanography in July 1991 took measurements of chlorophyll, nitrates and silicates in the northern half area of Alborán. The area of Seco de los Olivos showed one of the highest levels of nutrients and chlorophyll, with maximum chlorophyll values at 25 m and of nitrates and silicates at 50 m (Rubín *et al*. 1992). Chlorophyll values were measured at 10 and 25 m. At 10 m, the highest concentrations were detected close to the Strait, which is a result of a general fertilisation of the euphotic zone generated by the Atlantic water flow and the use of the entering nutrients by the phytoplankton of the area. There is also a higher concentration here than around the south-western area of Málaga bay. In measurements taken at 25 m, three maximum peaks were detected: the Seco de los Olivos, near to the Strait and the Djibouti bank. Nitrates and silicates values were recorded at 25 and 50 m. Maximum nitrate (2-3 μmol/l) and silicate values (1-2 μmol/l) were detected in the Gibraltar and Marbella area at 25 m; silicate values were also high in the Djibouti bank and a positive gradient was detected towards Cabo de Gata. The nitrate gradient from the Strait again shows, the nutrient contribution of incoming Atlantic waters, as well as divergence in the Marbella area. At 50 m, both nitrates and silicates showed maximum concentrations (5-6 μmol/l for nitrates and 3 μmol/l for silicates) close to the coast coinciding with the divergence areas: area of Marbella, Málaga and Motril and also in the Seco de los Olivos. A maximum nitrate concentration was also found at the Djibouti bank.

Gulf of Vera.

In the Gulf of Vera, the observed values of nitrates and of many phosphates are, in general, higher than in other areas of the Mediterranean due to the Atlantic influence. In a study carried out by the Spanish Institute of Oceanography around the area of Garrucha, in the central part of the Gulf, seasonal variations of nutrients concentrations were observed (Deyá *et al*. 1990). In spring, nitrates levels can reach as high as 3 μmol/l just below the surface and 1μmol/l at 25 m in the waters of Villaricos, whilst in summer these concentrations are present in the entire area. In autumn, the nutrient levels in the first 25 meters are lower but from this depth down to 50 m there is an abrupt increase of the concentration up to 4.6 a 6.3 μmol/l, coinciding with high salinity, which suggest the presence of up-welling. In winter the whole photic zone down to 50 m has low nitrate and phosphate levels, similar to the rest of the western Mediterranean at this time of the year, which increase considerably with depth.

Figure 2.8 shows the average monthly chlorophyll concentration for the study area derived from satellite images.

2.3.3.4. Currents and upwellings

As previously described, in the Alborán Sea there is a mixture of Atlantic waters with highly saline Mediterranean waters (Parrilla and Kinder, 1987). Salinity for the entering Atlantic waters increases from 36.2 to 36.5 $^{o}/_{oo}$ during its migration towards the east through the Alborán Sea, being mainly modified by the intermediate Levantine up-welling waters and the Atlantic water which has previously become more saline (Tintoré *et al.* 1988). This modified Atlantic water covers the sea surface down to approximately 150 to 200 m in the centre of the basin and down to 50 m near the Spanish coast, whilst the Levantine intermediate waters are generally between 200 and 600 m (Tintoré *et al.* 1988).

The main surface water current in the Alborán Sea is formed by two adjacent anticyclonic gyres which cover the whole basin and which are known as the Alborán Occidental Gyre and Alborán Oriental Gyre (Arnone and La Violette 1984, La Violette 1986). Once in the Alborán Sea, the main current of modified Atlantic water continues towards the east along the Algerian coast (Millot 1985) (Figure 2.4).

Part of the Atlantic modified water circulates close to the Spanish coast up to Cabo de Gata where it converges with the resident Mediterranean waters of different characteristics which circulates to the east of this cape towards the south-east along the coast, thus resulting in a diversion of the modified Atlantic water to the south-west towards Orán in the Algerian coast (Tintoré *et al.* 1988). This water is partly retained by the oriental gyre of Alborán to continue circulating in an anicyclonic manner, whilst the rest continues towards the east creating the Algerian current. As a result, a very defined front is formed towards the east of the oriental gyre called the Almería-Orán Front formed by the convergence of two very different water masses (Figure 2.4). Typical up-welling-like characteristics and great biological activity has been observed there (Tintoré *et al.* 1988).

The up-wellings are very important mechanisms because they take to the surface deep water masses rich in nutrients, thus fertilising the euphotic zone. Upwellings can be induced by various factors such as vertical circulation, cyclonic circulation regimes or the occurrence of certain type of winds as previously described. Upwellings can be more or less permanent in time or be temporary. Besides the upwellings mentioned at the Almería – Orán Front, the Alborán Sea also has other permanent processes of this type in the north-western sector between the Spanish coasts and the entering Atlantic current, resulting in very fertile areas especially in the areas of Marbella, Málaga and Motril (Rodríguez 1982, Rubín *et al*. 1992). Temporary upwellings can also occur in other spots of the coast when there are strong winds which blow superficial waters to the high sea and cause a surge of cold and salted deep waters (Rodríguez 1982; Medina 1974).

In the Gulf of Vera, that has very different characteristics to the Alborán Sea, the combination of the topography and the interaction of water masses favour, under certain climate conditions, the occurrence of important up-welling areas in the northern area of the gulf next to Cabo Tiñoso, although they have scarcely been studied (Díaz 1991). Deyá *et al.* (1990) suggested the possible presence of up-wellings in the central area of the Gulf, near Garrucha (, which could be favoured by the local marine topography where there are some deep submarine canyons very close to the coast, and also because of the local strong land breezes.

An up-welling is created over the continental shelf of the Gulf of Cádiz due to the persistence of northerly winds (Rubín *et al.* 1997). The previously mentioned up-wellings in Alborán and the Almería-Orán Front can be observed in the satellite images of sea surface temperatures and chlorophyll concentrations (Figures 2.7 and 2.8).

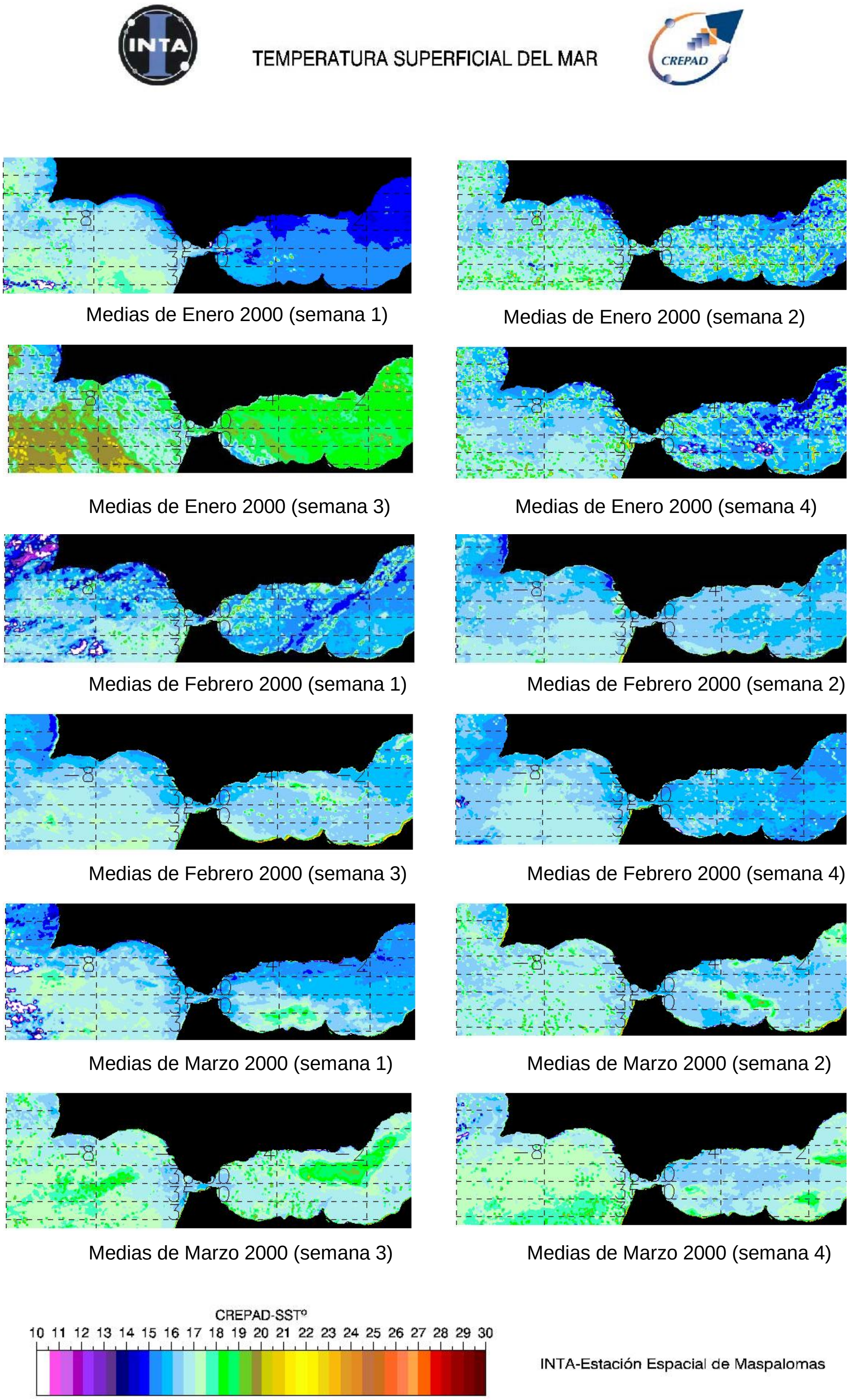

Figure 2.7. Weekly average sst for 2000. January to March.

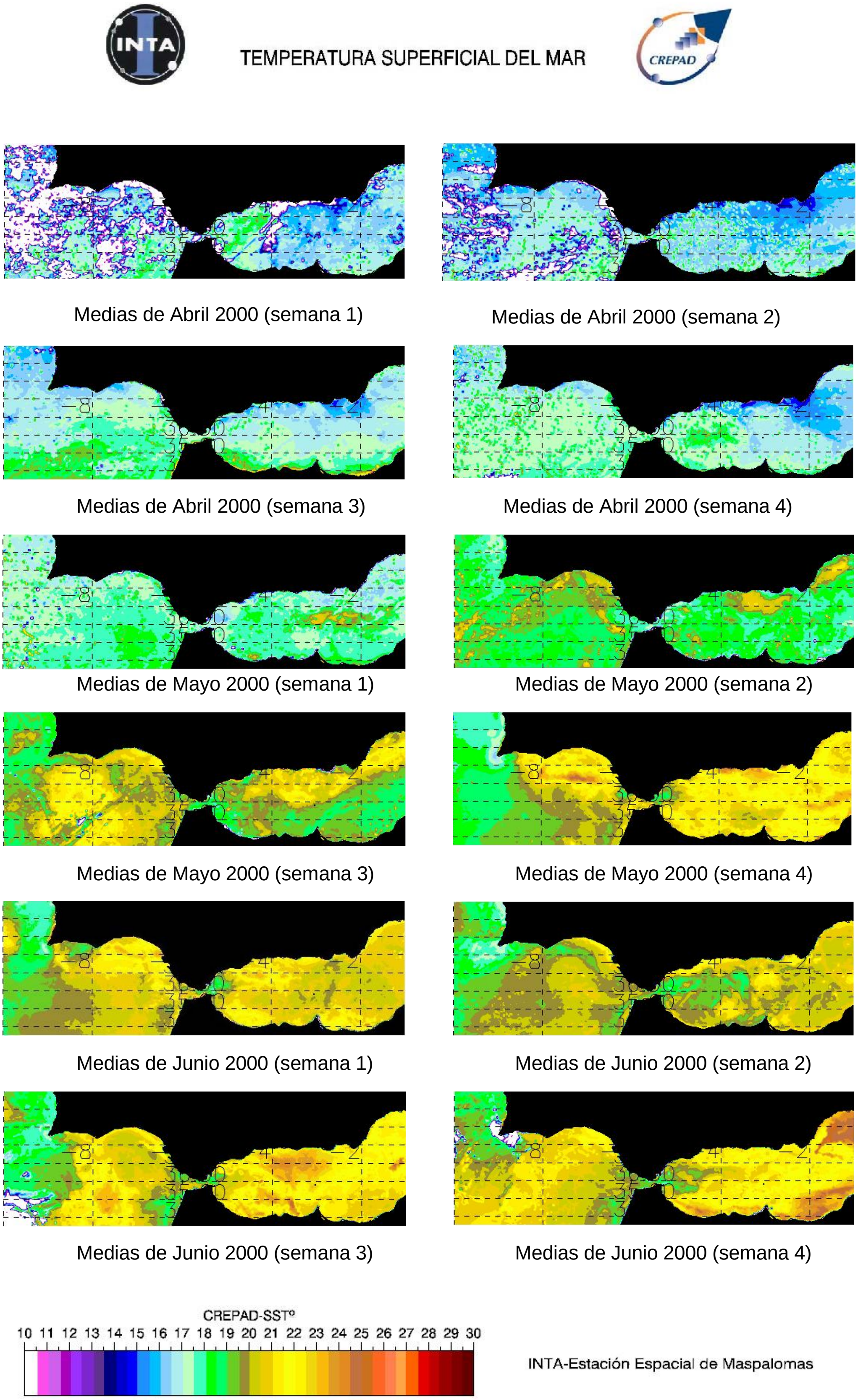

Figure 2.7. (continuation) Weekly average sst for 2000. April to June.

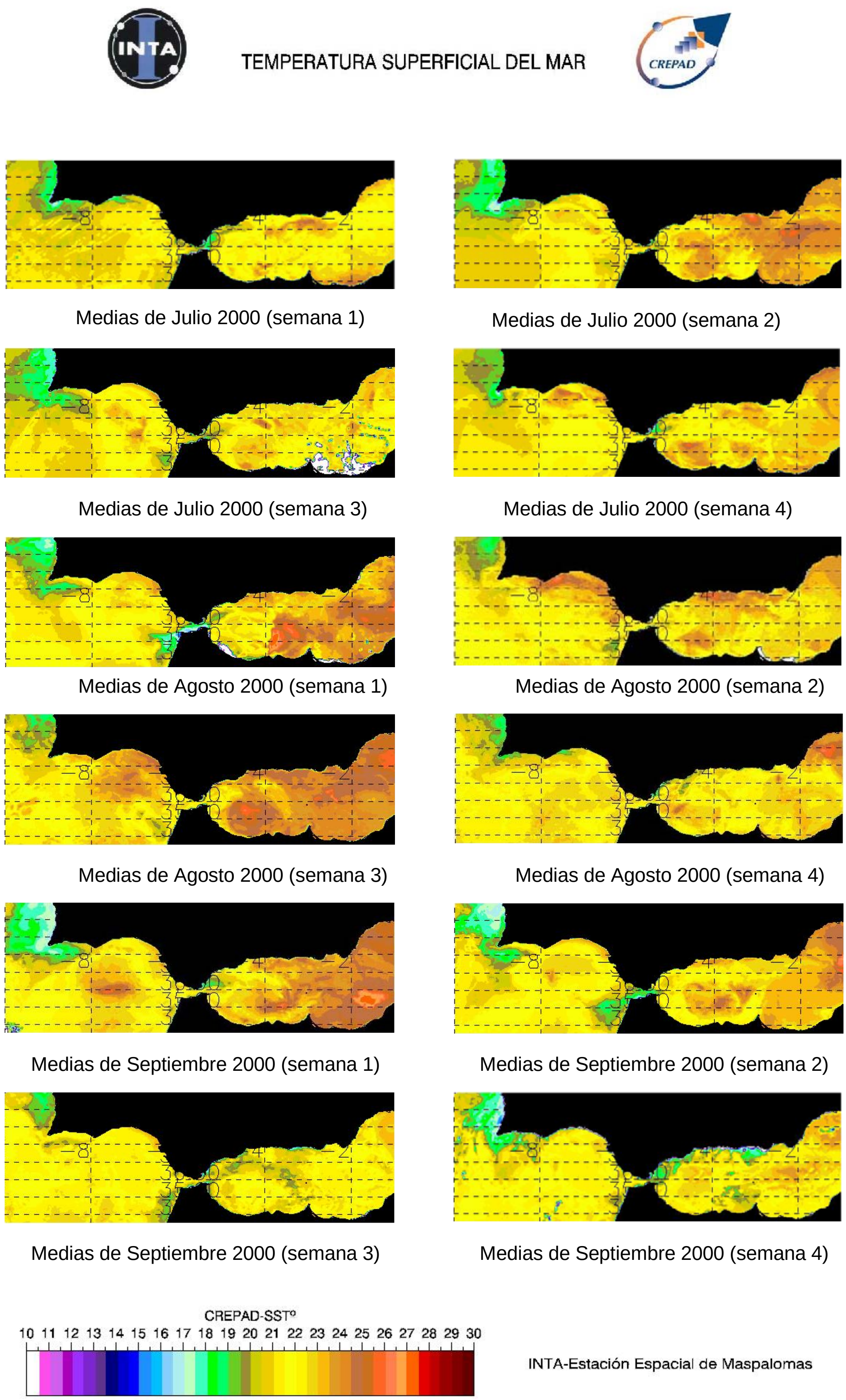

Figure 2.7. (continuation) Weekly average sst for 2000. July to Spetember.

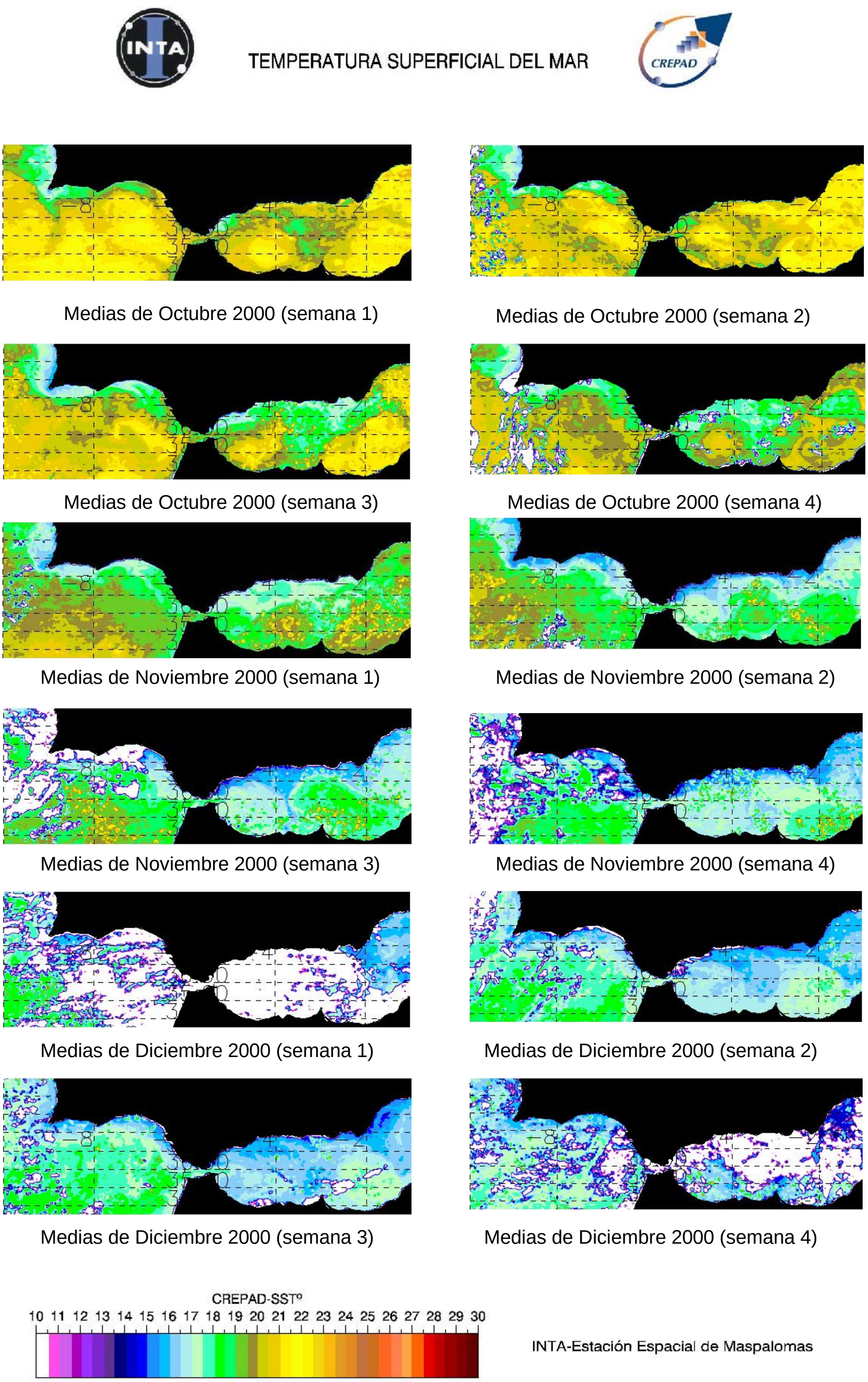

Figure 2.7. (continuation) Weekly average sst for 2000. October to December.

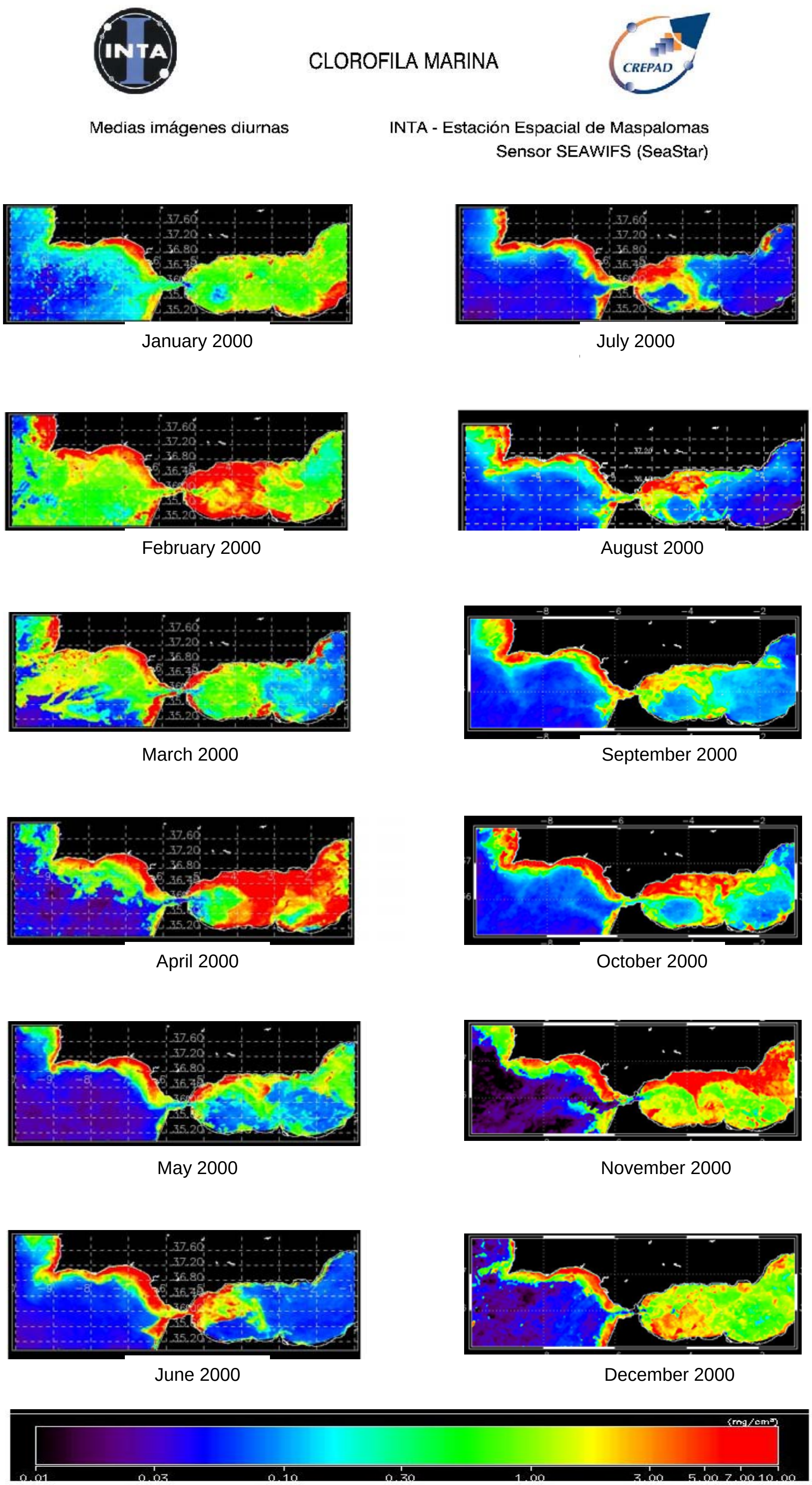

Figure 2.8. Monthly averages of chlorophyll concentration (mg/cm^3) for year 2000

2.3.3.5. Seasonal variations in oceanographic conditions

The mechanism by which the incoming Atlantic water becomes Mediterranean varies according to the season, with two clearly different processes in summer and winter.

During summer, a thermocline is formed between 20 and 40 m in the surface layer with greater Atlantic influence, thus limiting the exchange between this layer and the underlying one, so that the surface layer heats up as a result of the warm and dry weather and there is a greater evaporation thus increasing the salinity. But because of its temperature at approximately 25ºC, this layer does not increase its density therefore remaining in equilibrium. The water located just below the thermocline is still Atlantic, but since it is not affected by the atmosphere it retains minimum salinity levels (Rodríguez 1982).

During the winter months two processes occur which result in an imbalance of the water mass: the cooling of the atmosphere results in a significant heat transfer from the water to the air, and the cold and dry winds of this season favour evaporation. Both the heat loss and the evaporation result in an increase in density of the most superficial and saline layer which then sinks by vertical convection, thus homogenising large water layers and taking oxygen to deeper waters, a very important phenomenon to maintain the deep benthos (Rodríguez 1982). According to Lacombe and Tchernia (1972), this process is quite significant at three points in the Mediterranean and has a great influence in the entire basin: the Aegean and the Rhodes-Cyprus area, the Adriatic and the north-western basin.

2.3.4. BIOTIC CHARACTERISTICS

2.4.1. Plankton

In the Gulf of Cádiz there are three areas with maximum values of mesozooplankton, close to the shore and related to river outlets: one between the mouth of the Guadalquivir river and the mouth of Huelva fiord, another in front of the mouth of the Barbate river, and the third in front of the mouth of the Guadiana river.

Generally speaking the Alborán Sea shows a high species diversity as far as the plankton is concerned with the coexistence of Atlantic and Mediterranean species. Since the primary productivity in the area is high, the zooplanktonic biomass is considered as one of the highest in the Mediterranean (MOPU 1991).

Some studies carried out along the Spanish eastern coast and in Málaga bay show that there are three pulses of primary production: in February, April-May and September. In Málaga bay a winter pulse of phytoplankton has also been described (Margalef 1969; Rodríguez 1979; Jiménez *et al.* 1987).

During the cruise of the Spanish Oceanographic Institute "Ictio-Alborán 0792", the chlorophyll concentrations and phytoplankton of the Alborán Sea were studied (Rodriguez *et al.* 1994). The results from this study enabled the clear differentiation of three areas rich in phytoplankton and two poor areas, in close relation to hydrological processes. The areas with high vegetal biomass are located in the SE and NE of the Strait and in the oriental basin near 3º W, including the area of Almerimar and the Seco de los Olivos. The first of these phytoplankton masses is associated with the Atlantic water flow and areas next to the coast affected by this current, up to 35º30' N and 5º00' W. The second and third ones coincide with the cyclonic circulation areas where there is an up-welling of sub-surface waters. Almería bay also had a significant abundance without an obvious hydrodynamic effect. The really poor areas in phytoplankton are located in the convergence areas of surface waters located in the south-western and south-eastern sectors of the basin. Other measurements such as the carbon concentration or ETS activity (electrons transport system), which is a measurement of the plankton respiratory activity, are also richer in the northern sector of the Alborán Sea versus the poorer southern sector. The spatial distribution of ETS activity differentiates two areas with high values: one in the Strait which enters the Alborán Sea following the oceanic current and the other along the coast between Fuengirola and Almerimar, connecting the eutrophic gyres of the northern region with the higher values registered 35-40 km from the coast. Similarly, the spatial distribution of the bacterioplankton was measured and was closely related to the maximum chlorophyll values: the highest values in the entire basin were located at two points, at 3º00' and 3º50' W respectively. The first one, just south of Almerimar, coincides with the divergence of deep waters, whilst the second one, further south, coincides at the meeting point of the powerful southwest anticyclonic gyre and the oriental cyclonic gyre.

The zooplankton populations in the Alborán Sea show a great species diversity due to the coexistence of Atlantic and Mediterranean waters both in the pelagic and neritic communities. The high primary production of this area results in an average biomass value similar to or higher than the Gulf of Cádiz (Estrada *et al.* 1989). According to Camiñas (1983) in the annual cycle of zooplankton biomass in the north-westerly sector of the Alborán Sea, there are delayed peaks with respect to those of phytoplankton in summer (June - July), autumn (September - October) and spring (March) with the latter one showing the highest biomass. In summer, the highest phytoplankton biomass at the coast appears in the westerly sector (to the west of 4º W) (Rubín 1996). In the waters away from the coast near 36º N, a large zooplankton mass in the westerly sector has also been found during summer, in connection with Atlantic waters, especially in the core of the anticyclonic gyre (Rubín 1996). It is worth highlighting that the areas with maximum abundance of zooplankton biomass can vary considerably between years. It is important to note that the zooplankton has a vertical migration during the day-night cycle: during the day they move to deeper waters and at night they move close to the surface. Approximately four hours after dusk is when the highest plankton concentrations are located at the surface (Lotina 1985a).

The ichthyoplankton is the fraction of the plankton which comprises fish eggs, which drift passively from the moment of the fertilisation. The Spanish Institute of Oceanography (I.E.O.) has carried out a few studies of the ichthyoplankton in the Alborán Sea since 1975. They detected the presence of anchovy eggs in the plankton from May to November in Málaga bay and nearby areas, associated with well-known upwellings (Rodriguez and Rubín 1986). In a study carried out by the I.E.O. in 1991 (Rubín *et al*. 1992), two areas with densities exceeding 2,000 ind/10 m^2 were located: one close to the Strait, determined by the incoming Atlantic waters and another, the most important (with more than 8,000 ind/10 m^2) in the Seco de los Olivos, which is not the result of an accumulation but of *in situ* production, and is the area with the largest ichthyoplankton production of the northern half of the Alborán sea. Rubín and colleagues (1992) also detected three other areas with relatively high egg densities, although below the two previously mentioned areas, with values ranging between 250 and 500 ind/10 m^2: the most important of the three is located south of Cabo de Gata (> 500 ind/10 m^2), probably influenced by the up-welling generated by the Almería - Orán front. The two other areas were located near Málaga and Almuñecar, with the latter one next to an up-welling area. The ichthyoplankton distribution according to species is very uneven. For example, the only significant anchovy eggs accumulation (*Engraulis encrasicolus*) is located near the Strait of Gibraltar, whilst the eggs of gilt sardine or round sardinella (*Sardinella aurita*) have only been detected south of Cabo de Gata (Rubín *et al*. 1992). In the Gulf of Cádiz, the highest densities of icthyoplankton occur in front of Huelva, Chipiona, Cádiz and Barbate.

Fish larvae are also considered as part of the plankton as long as they have no capacity to move consistently against waves and currents and drift with them. The fish larvae concentrations were also studied by Rubín *et al*. (1992), who found three areas of maximum accumulation with densities ranging between 800 and 1,200 ind/10 m^2. The most important one was located approximately at the centre of the western basin of Alborán, with maximum values, another one was just in front of the Strait, immersed in the incoming water current, and the third one was in the divergence area between Málaga and Motril. This distribution also coincides with areas of phytoplankton accumulation at 50 m and with high concentrations of particles and nitrates also at 50 m.

2.4.2. Seaweeds and marine angiosperms

In the Alborán Sea and the Gulf of Vera there are many seaweeds and sea grasses. There are only three species of marine sea grasses in the Mediterranean: *Posidonia oceánica, Cymodocea nodosa* and *Zostera marina*.

Marine sea grasses, but specially *Posidonia oceánica*, have a great ecological value and have been regarded as the "lung of the Mediterranean" being considered as one of the main sources of oxygen. Both leaves and rhizomes are home to many organisms such as: hydrozoa, bryozoa, polychaete, ascidiiae, sponges, epiphyte seaweed, etc., and provide shelter and food to a great variety of fish (Riedl 1986), in addition to being the preferred spawning area of many fishes (Gil de Sola 1993). Unfortunately, *Posidonia* in currently declining in the Mediterranean, although the Cabo de Gata area has the best preserved population of this plant in the Spanish Mediterranean (Gil de Sola 1993). Also the coasts of Granada and surrounding the Island of Alborán (Pinilla 2001) have important populations of sea grasses. The latter area is especially important for several species of seaweeds (Pinilla 2001).

2.4.3. Marine invertebrates

As may be expected, both the Alborán Sea and Cabo de Gata have numerous invertebrate species. Amongst the demersal species the most interesting ones for the present study are the crustaceans (prawns, shrimps, etc.), because they are often part of cetacean diet, or of cetacean prey species' diet, and at times are not only demersal but also pelagic. For example, shrimps (*Alpheus glaber*, *Crangon crangon*), often inhabit muddy or muddy-sandy flats from shallow areas up to 500 m, depending on the species. Prawns from the Pasiphaeidae family (such as *Pasiphaea sivado* and *P. multidentata*) are benthopelagic species which live between 200 and 500 m (sometimes even deeper) (FAO 1987). According to the Spanish Institute of Oceanography the most representative species of the Alborán Sea are the Norway lobster (*Nephorps norvegicus*) and the red prawn (*Aristeus antennatus*) (IGN 1991c).

Other pelagic organisms worth mentioning with a marked seasonal abundance are: cnidaria (such as jelly fish *Velella velella*, *Pelagia noctiluca*, *Rhizostoma pulmo* and *Cotylorhiza tuberculata*), ctenophora and tunicata (salps). Salps (*Salpa máxima*, *Salpa fusiformis*, *Iasis zonaria*, *Thalia democratica*, etc.) tend to form large concentrations, especially from September and October onwards, forming large chains which give the water a jelly appearance (personal observations; Riedl 1986).

2.4.4. Fish and cephalopods

In the Alborán Sea the estimated number of fish species is approximately 300, from which the majority are exploited by man in different ways (MOPU 1991).

Firstly a differentiation should be made between neritic and oceanic species and between demersal or benthic and pelagic (Figure 2.9). The first division refers to the horizontal distribution; neritic species are those living near shore over the continental shelf (from the coastline up to approximately 200 m depth), whilst oceanic species are those which are present beyond the continental shelf. The second division refers to the vertical distribution: demersal or benthonic species are those living close to the sea bottom whilst pelagic live in the water column with no connection to the bottom. According to its depth the latter can be divided into: epipelagic (from the surface to 100 m, including the photic zone), mesopelagic (from 100 m to 1000 m) and bathypelagic (from 1000 m to the bottom). In extremely deep areas we can also have abyssopelagic (deeper than around 4000 m).

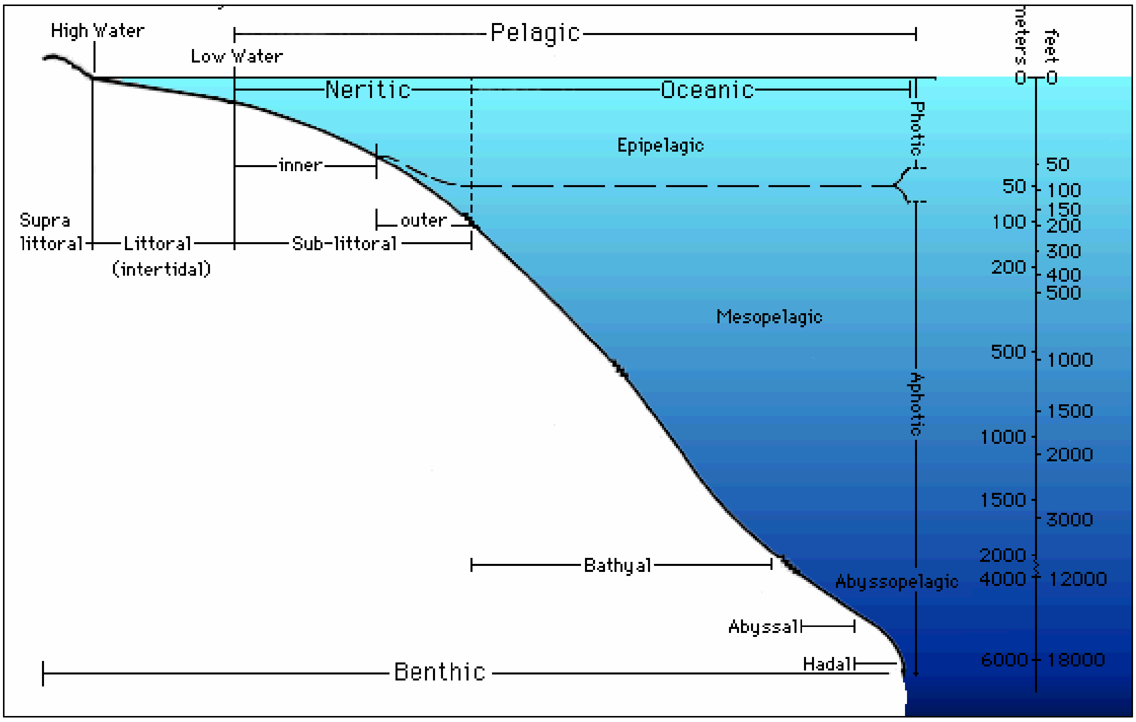

Figure 2.9. Zonation of the marine ecosystem.

2.4.4.1 Demersal fish and cephalopods

The study by Gil de Sola (1993) for the Spanish Institute of Oceanography, gives the following as the most frequent demersal species of the Alborán Sea:

In the littoral areas (up to 50m) demersal species belonging to the sparidae such as bogue (*Boops boops*), white bream (*Diplodus sargus*) and red seabream (*Pagellus bogaraveo*), some labridae and large serranidae, scorpaenidae, bass (*Dicentrarchus labrax*), common sole (*Solea vulgaris*) and otrosturbot (*Scophthalamus rhombus*), mullet (*Mullus surmuletus, Mullus barbatus*), etc. can be found. In littoral areas cephalopods such as the common cuttlefish (*Sepia officinalis*), two species of octopus (*Octopus vulgaris, Eledone cirosa*) and several species of squids (prominent among them being *Loligo vulgaris*) can also be found.

As depth increases, the diversity decreases. Still on the continental shelf but beyond 50 m some common demersal species that can be found are: *Gobius* sp., conger eel (*Conger conger*), hake (*Merluccius merluccius*), red mullets (*Mullus sp.*), flat fish such as soles, megrim, angler fish, etc., horse mackerel (*Trachurus* sp.), and bream (*Pagellus* sp.). Amongst the cephalopods there are cuttlefish (*Sepia elegans*), squids, octopus and flying squids (*Ilex condetii*).

Beyond the continental shelf, in the higher part of the slope (between 200 and 500 m), there are rays (*Raja* spp.), blue sharks (*Prionace glauca*), conger eels, angler fish, hake, blue whiting (*Micromesistius poutassou*), greater forkbeard (*Phycis blenoides*), scaldfish (*Arnoglossus laterna*), and poor cod (*Trisopterus minutus*). Amongst the cephalopods there are flying squids (*Illex condetii* and *Todarodes sagittatus*) and musky octopus (*Eledone moschata*).

On the lower part of the slope, beyond 500 m, there are rays, conger eels, angler fish, blue whiting, hake, greater forkbeard, scaldfish, bream and redfish. Regarding the cephalopods, there are flying squids and musky octopus.

In general, it can be said that the most representative species in the Alborán Sea are the mullet, hake and blue whiting, and in the Gulf of Vera the mullet and to a lesser extent the hake, especially in the southern sector of the gulf (IGN 1991c).

2.4.4.2 Pelagic species

The most important species in the Alborán Sea and in general all over the western Mediterranean belong to four families (Clupeidae, Engraulidae, Scombridae and Carangidae) most of whose species have a commercial value.

The most frequent Clupeidae species in the Alborán Sea are the sardine (*Sardina pilchardus*), the gilt sardine or round sardinella (*Sardinella aurita*) and the sprat (*Clupea spratus*). Anchovies (*Engraulis encrasicholus*) are locally common.

Other species of small fish observed in the Alborán Sea include the argentine (*Argentina sphyraena*), bogue (*Boops boops*), garfish (*Belone belone*), dark-winged flying fish (*Exonautes rondeleti*), horse mackerel (*Trachurus trachurus* and *T. mediterraneus*) and several species of lantern fish (family Myctophidae), in particular *Benthosema glaciale* and *Myctophum punctatum*.

Seasonally abundant are some scombrids such as the Atlantic mackerel (*Scomber scomber*) and the bullet tuna (*Auxis thazard*). The Atlantic bluefin tuna (*Thunnus thynnus*) undertakes yearly migrations between the Atlantic and Mediterranean. Adults enter the Strait of Gibraltar in spring and summer and head towards the spawning area in the Balearic Islands. In autumn a reverse migration takes place and young fish leave towards the Atlantic close to the Spanish coast and the adults closer to the African coast (IGN 1991c). Other species which are also abundant in the area are the sword fish (*Xiphias gladius*), barracuda (*Sphyraena sphyraena*), and the ocean sunfish (*Mola mola*) the latter of no commercial interest.

<u>*The sardine and anchovy*</u>

In this section a special emphasis will be made on the sardines (Clupeidae) and anchovy (Engraulidae) as these probably constitute the most important prey in the diet of the common dolphin.

Sardines (both common sardine and round sardinella) feed on plankton and during their life their nutrition is very similar. Once the larvae have used the reserves of the yolk sac, they start feeding on phytoplankton, but as they grow they also start searching for zooplankton. As adults, the sardine feeds on all types of plankton. The plankton vertical migrations explain why the sardine is closer to the surface at night, in a dispersed manner, and in deeper waters during the day in more o less dense fish schools (Lotina 1985a). At dawn and dusk the sardines exhibit the highest activity although it is thought that it can be dependent on the moon cycle (Lotina 1985b). They are stenothermal, that is, they cannot tolerate sudden changes in temperature although this stenothermia is not regular: at times they prefer warm waters but during the spawning season they look for cooler waters. In fact they start laying eggs when there is a sudden decrease in the temperature and stop the process if the temperature rises. The ideal temperature for the sardines seems to be between 13 ºC and 23 ºC and if not available on the surface they move to deeper and cooler waters (Lotina 1985b). On the other hand, this species forms fish schools at the thermocline level, and always chooses cooler waters. However, salinity rather than temperature is a more influential factor to the sardine in habitat selection, preferring highly saline waters (above 35 $^{o}/_{oo}$) (Lotina 1985b).

Sardines are generally located on the continental shelf and shelf edge, between the surface and 150 m (epipelagic). During the winter breeding period the fish schools move off the shore into deeper waters within the continental shelf where they spend most of the winter period, just before the spawning time, in a hibernation mode during which they scarcely eat whilst they mature. Females lay their eggs at approximately 100 m depth (between 50m and 150 m) in waters between 10 ºC and 17ºC and a salinity of approximately 36 $^{o}/_{oo}$ (Lotina 1985b), but as a result of a drop of oil that they contain, these eggs quickly move towards the surface where they become part of the plankton (ichthyoplankton). Once the larvae grow and reach 2 cm they become young fish and start moving towards the coast reaching coastal waters in spring or during the beginning of the summer (Lotina 1985b). Once spawning is over, adults return to coastal waters in their trophic migration where they find plenty of food and stay in surface waters until the end of autumn or beginning of winter, which is when they once again start their migration for winter breeding.

Sardines are far more abundant in the western Mediterranean basin than in the eastern and they are also abundant in the Adriatic. Two different "breeds" of sardines can be seen in the Mediterranean: the northern one which covers the western area of Italy, France and the northeast Spanish area up to approximately Alicante, including the Balearic Islands, Corsica and the northern half of Sardinia. The southern one covers the Alborán Sea and the Spanish coast up to Alicante, the North African coast up to Tunis, and the southern half of Sardinia, and is slightly smaller than the former. In the adjoining Atlantic area (Gulf of Cádiz) one of the three Atlantic breeds can be found: the southern Atlantic, which has a spawning season at the end of winter (the two Mediterranean breeds spawn during winter) (Lotina 1985b).

During the ECOMED 88 Cruise of the Spanish Institute of Oceanography, it was found that the larger densities of sardines schools in the Alborán Sea were concentrated in three places: in Estepona Bay (close to the Strait of Gibraltar), in Málaga Bay (area of Calaburras - Fuengirola) and between Adra and Almería. In the Gulf of Vera there is only one area with a dense biomass of sardines south of Cabo de Palos (Gil 1992).

Anchovies are usually further away from the coast, but in both species young specimens are normally distributed closer to the coast. Anchovies also move to the high sea during winter and get closer to the coast in spring to spend the summer. However, anchovies unlike the sardines lay their eggs close to the coast (Lotina 1985b).

2.4.4.3 Sharks

The Mediterranean has more than 20 species of sharks, some of which are fairly abundant. Amongst the larger species the most characteristic ones in the Alborán sea are the blue shark (*Galeus glaucus*), the black-mouthed dogfish (*Galeus melastomus*), the porbeagle shark (*Lamna cornubica*), the small spotted dogfish (*Scyliorhinus canicula*) and the tope (*Galeorhinus galeus*). Occasionally there are great whites (*Carcharodon carcharias*), common hammerheads (*Sphyrna zygaena*) and basking sharks (*Cetorhynus maximus*). The Alborán Sea also features several species of rays and sting rays.

2.4.5. Marine turtles

The most frequent turtle in the Mediterranean and therefore in the study area is the loggerhead turtle (*Caretta caretta*) (Camiñas 1996; Tomás 1997), from which an estimated figure of 20,000 are captured each year by the Spanish long lines fleet involved in the fisheries for swordfish in the Western Mediterranean (Aguilar *et al*. 1996). Less frequently, the leatherback turtle can also be seen (*Dermochelys coriacea*) and scarcely the green turtle (*Chelonia mydas*) (Pascual 1985). Photograph 2.1 shows a loggerhead turtle in the study area.

During the years of this study 303 loggerhead turtles were recorded, 3 leatherback turtles and one green turtle, all of them sighted during navigation. Figure 2.10 show the location for all the marine turtle sightings between 1992 and 2004.

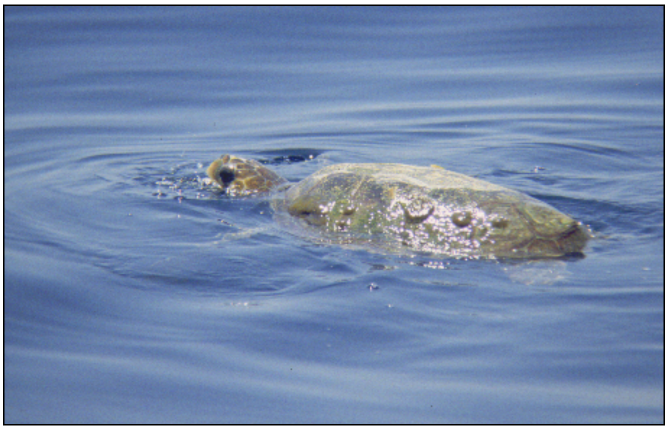

Photo 2.1. Loggerhead turtle basking on the surface

2.4.6. Sea birds

In the Alborán Sea many sea birds can be seen, some are resident with clearly defined nesting areas which can be seen all the year round and others which can only be seen at certain times of the year during their migratory stops. In some cases, some isolated individuals of migratory species can be exceptionally seen year round.

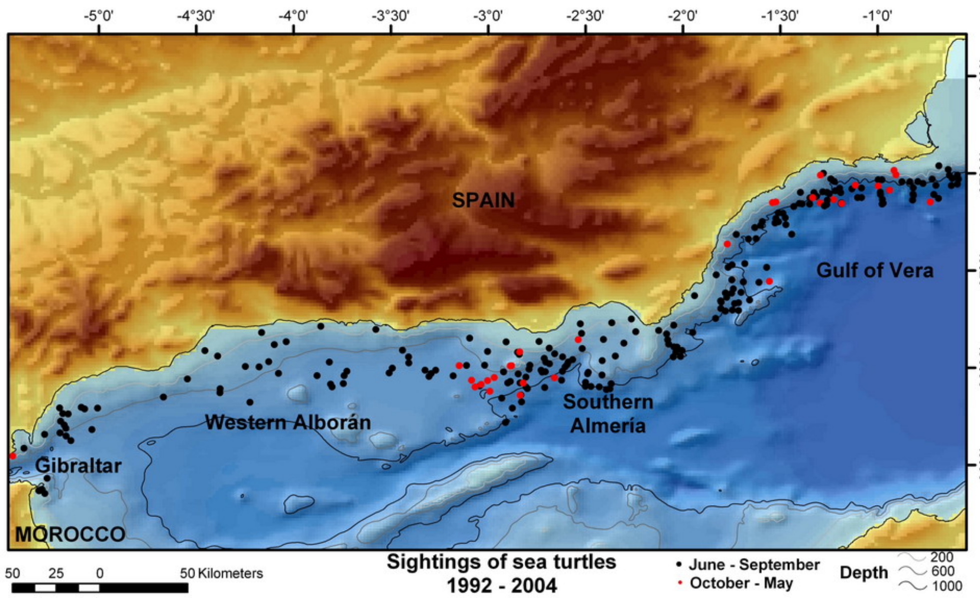

Figure 2.10. Sightings of sea turtles (*Caretta caretta*) in the study area from 1992 to 2004. Red dots indicate sightings in winter. Black dots indicate sightings in summer.

Amongst the sea birds of the area the most representative ones are: the herring gull (*Larus cachinans*; Photo 2.2), Audouin's gull (*Larus Audouinii*; Photo 2.3), Cory's shearwater (*Calonectris diomedea;* Photo 2.4) and storm petrel (*Hydrobates pelagicus;* Photo 2.5), all of which have important nesting areas clearly identified in various areas of the Alborán Sea and the Gulf of Vera (Yus and Cabo 1986; Sánchez and Guardiola 1996).

During summer, large groups of gulls (often more than 100) can be observed including the herring gull and the Audouin's gull, and of Cory's shearwater, often in mixed groups, especially in coastal areas up to a few miles off shore. Gulls are often seen following trawlers. Terns are seen less often, and include the common tern (Photo 2.6), the sandwich tern and the little tern (*Sterna hirundo, S. sandvicensis* and *S. albifrons* respectively). Further away from the coast storm petrels and black terns (*Chlidonias niger)* can be seen less often. When changing from summer to autumn, generally at the beginning of September, others birds can be seen. These are mainly gannets *(Sula bassana*; Photo 2.7) which are present until spring. During spring puffins (*Fratercula arctica*) are often seen flying to the west, as well as groups of manx shearwater (*Puffinus puffinus*), also flying in the same direction. Isolated specimens of great skuas (*Catharacta skua*) and razorbills (*Alca torda*) are also seen. During summer great skuas, isolated puffins and some young gannets can be seen, although not very often.

Photo 2.2. Herring gull

Photo 2.3. Adouin gull

Photo 2.4. Cory's shearwater

Photo 2.5. Storm petrel

Photo 2.6. Common tern

Photo 2.7. Gannet

2.4.7. Cetaceans

As explained in Chapter 1 (Introduction), few data were available on the cetacean populations of the Gulf of Cádiz, Alborán Sea and Gulf of Vera prior to this study. Nevertheless, an exhaustive compilation of existing bibliographic material in relation to strandings and sightings of cetaceans in Andalucía and Murcia was made as background information. A compilation of sighting records from other researchers was also carried out, as well as from opportunistic observers (fishermen, sailors, maritime authorities, etc.) if the information was reliable.

The groups that contributed most of the records were ESPARTE (Sociedad Andaluza de Cetología), SEC (Sociedad Española de Cetáceos), CIRCÉ (Asociación para la Conservación, Información y Estudio sobre los Cetáceos), CEMU (Centro de Estudios Marinos Universitarios), FUNDACIÓN BITÁCORA and GREC (Group de Recherche sur les Cétacés).

2.4.7.1. Strandings

The species recorded stranded most often in the study area are: striped dolphin (*Stenella coeruleoalba*), long-finned pilot whale (*Globicephala melas*), bottlenose dolphin (*Tursips truncatus*), common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), Cuvier's beaked whale (*Ziphius cavirostris*), fin whale (*Balaenoptera physalus*), sperm whale (*Physeter macrocephalus*) and surprisingly a harbour porpoise (*Phocoena phocoena*) in 1981 in Málaga (Casinos and Vericad 1976; Rey and Rey 1979; Rey and Cendrero 1980; Rey and Cendrero 1981; Raga *et al*. 1991; Guirado-Romero 1991; Fernández-Casado *et al*. 1998).

A total of 1130 records have been collected up to 2002. Table 2.1 shows the number of strandings recorded for periods of 10 years (except for the first one which comprises the period between 1753 –first record- to 1960, and the last one which comprises only 2 years) and Table 2.2 shows the percentage of each species for the same periods. Tables 2.3 and 2.4 show the number and percentage, respectively, of strandings by sub-area.

2.4.7.2. Sightings

The most commonly recorded cetacean species in sightings in the study area are: sperm whale (Photos 2.8 and 2.9), fin whale (Photos 2.10 and 2.11), short finned pilot whale (Photos 2.12 and 2.13), common dolphin (Photos 2.14 and 2.15), striped dolphin (Photos 2.16 and 2.17), Risso's dolphin (Photos 2.18 and 2.19), killer whale (*Orcinus orca*) (Photos 2.20 and 2.21) and Cuvier's beaked whale (*Ziphius cavirostris*) (Photos 2.22 and 2.23) (Casinos and Vericad 1976; Rey and Cendrero 1980; Raga *et al.* 1985; Forcada *et al*. 1991; Raga *et al*. 1991; Laurent 1991; Franco and Más 1994; Walmsley 1996; Forcada and Hammond 1998).

A total of 7,153 records have been collected up to 2002. Table 2.5 shows the number of sightings recorded for periods of 10 years (except for the first one which comprises the period between 1894 –first record- to 1960, and the last one which comprises only 2 years) and Table 2.6 shows the percentage of each species for the same periods. Tables 2.7 and 2.8 show the number and percentage, respectively, of sightings by sub-area.

Photo 2.8. Sperm whale

Photo 2.9. Sperm whale

Photo 2.10. Fin whale

Photo 2.11. Fin whale

Photo 2.12. Long-finned pilot whale

Photo 2.13. Long-finned pilot whale

Photo 2.14. Common dolphin

Photo 2.15. Common dolphin

Photo 2.16. Striped dolphin

Photo 2.17. Striped dolphin

Photo 2.18. Risso’s dolphin

Photo 2.19. Risso’s dolphin

Photo 2.20. Orca

Photo 2.21. Orca

Photo 2.22. Cuvier’s beaked whale

Photo 2.23. Possible Cuvier’s beaked whale

Table 2. 1. Number of stranding records in Andalucía and Southern Murcia per periods.

Species	**< 1960**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2002**	**TOT**
Delphinus delphis	1	0	2	24	247	36	310
Stenella coeruleoalba	0	3	16	144	193	24	380
Tursiops truncatus	1	1	5	4	36	28	75
Globicephala melas	1	0	9	24	27	7	68
Grampus griseus	0	0	1	0	10	3	14
Orcinus orca	0	0	0	0	1	0	1
Pseudorca crassidens	4	0	0	0	11	0	15
Physeter macrocephalus	1	0	1	1	5	5	13
Phocoena phocoena	0	0	0	0	4	0	4
Balaenoptera acutorostrata	0	0	0	1	0	0	1
Balaenoptera borealis	0	0	0	1	0	0	1
Balaenoptera edeni	0	0	0	0	1	0	1
Balaenoptera physalus	0	1	0	0	0	0	1
Megaptera novaeangliae	4	0	0	1	9	2	16
Kogia breviceps	0	0	0	0	5	6	11
Kogia simus	0	0	0	1	0	0	1
Mesoplodon europaeus	1	0	0	0	0	1	2
Mesoplodon densirostris	0	0	0	2	2	0	4
Ziphius cavirostris	2	0	1	1	11	2	17
Unidentified dolphin	0	0	4	32	127	32	195
TOTAL	15	5	39	236	689	146	1130

Table 2.2. Percentage of stranding records in Andalucía and Southern Murcia per periods.

Species	**< 1960**	**1961-1970**	**1971-1980**	**1981-1990**	**1991-2000**	**2001-2002**	**TOT**
Delphinus delphis	6.67	0	5.13	10.17	35.85	24.66	27.43
Stenella coeruleoalba	0	60.00	41.03	61.02	28.01	16.44	33.63
Tursiops truncatus	6.67	20.00	12.82	1.69	5.22	19.18	6.64
Globicephala melas	6.67	0	23.08	10.17	3.92	4.79	6.02
Grampus griseus	0	0	2.56	0	1.45	2.05	1.24
Orcinus orca	0	0	0	0.85	0.29	0	0.35
Pseudorca crassidens	6.67	0	0	0	0	0.68	0.18
Physeter macrocephalus	13.33	0	2.56	0.42	1.60	1.37	1.50
Phocoena phocoena	6.67	0	2.56	0.42	0.73	3.42	1.15
Balaenoptera acutorostrata	0	0	0	0	0.73	4.11	0.97
Balaenoptera borealis	0	0	0	0.42	0	0	0.09
Balaenoptera edeni	0	0	0	0	0.15	0	0.09
Balaenoptera physalus	26.67	0	0	0	1.60	0	1.33
Megaptera novaeangliae	0	0	0	0	0.58	0	0.35
Kogia breviceps	0	0	0	0.42	0	0	0.09
Kogia simus	0	0	0	0.42	0	0	0.09
Mesoplodon europaeus	0	0	0	0	0.15	0	0.09
Mesoplodon densirostris	0	20.00	0	0	0	0	0.09
Ziphius cavirostris	26.67	0	0	0.42	1.31	1.37	1.42
Unidentified dolphin	0	0	10.26	13.56	18.43	21.92	17.26
TOTAL	100	100	100	100	100	100	100

Table 2.3. Number of stranding records in Andalucía and Southern Murcia per sub-area. AE = Eastern Almería, AS = Southern Almería, GR = Granada, BMA = Bay of Málaga, BES = Bay of Estepona, SG = Strait of Gibraltar, CA = Atlantic Cádiz, HU = Huelva, ALB = Alborán Sea, exact place not specified, CE = Ceuta, ML = Melilla, MS = Southern Murcia, TOT = Total.

	AE	**AS**	**GR**	**BMA**	**BES**	**SG**	**CA**	**HU**	**ALB**	**CE**	**ML**	**MS**	**TOT**
Delphinus delphis	10	16	20	112	52	62	8	17	3	3	5	2	310
Stenella coeruleoalba	20	39	14	78	42	58	6	18	12	1	1	42	380
Tursiops truncatus	2	2	2	2	4	5	6	43	0	1	0	8	75
Globicephala melas	7	12	4	15	8	6	0	3	0	1	0	7	68
Grampus griseus	1	1	0	3	1	1	1	0	1	0	2	2	14
Orcinus orca	0	0	1	1	2	0	0	0	0	0	0	0	4
Pseudorca crassidens	0	0	0	0	1	1	0	0	0	0	0	0	2
Physeter macrocephalus	1	0	1	3	0	3	1	1	0	1	0	5	17
Phocoena phocoena	0	0	0	1	0	1	4	7	0	0	0	0	13
Balaenoptera acutorostrata	0	0	0	0	1	4	1	4	0	1	0	0	11
Balaenoptera borealis	0	0	0	0	0	0	1	0	0	0	0	0	1
Balaenoptera edeni	0	0	0	0	0	0	0	1	0	0	0	0	1
Balaenoptera physalus	0	2	0	2	0	4	1	4	0	0	1	0	15
Megaptera novaeangliae	0	0	0	0	1	1	0	2	0	0	0	0	4
Kogia breviceps	0	0	0	0	0	0	1	0	0	0	0	0	1
Kogia simus	0	0	0	0	0	0	1	0	0	0	0	0	1
Mesoplodon europaeus	0	0	0	0	0	0	0	1	0	0	0	0	1
Mesoplodon densirostris	0	0	0	0	0	0	0	1	0	0	0	0	1
Ziphius cavirostris	0	5	0	6	3	1	0	1	0	0	0	0	16
Unidentified dolphin	17	46	12	33	29	23	7	20	0	5	1	2	195
TOTAL	58	123	54	256	144	170	38	123	16	13	10	68	1130

Table 2.4. Percentage of stranding records in Andalucía and Southern Murcia per sub-area. AE = Eastern Almería, AS = Southern Almería, GR = Granada, BMA = Bay of Málaga, BES = Bay of Estepona, SG = Strait of Gibraltar, CA = Atlantic Cádiz, HU = Huelva, ALB = Alborán Sea, exact place not specified, CE = Ceuta, ML = Melilla, MS = Southern Murcia, TOT = Total.

	AE	**AS**	**GR**	**BMA**	**BES**	**SG**	**CA**	**HU**	**ALB**	**CE**	**ML**	**MS**	**TOT**
Delphinus delphis	0	2.94	17.24	13.01	37.04	43.75	36.11	36.47	21.05	13.82	18.75	23.08	27.43
Stenella coeruleoalba	85.96	61.76	34.48	31.71	25.93	30.47	29.17	34.12	15.79	14.63	75.00	7.69	33.63
Tursiops truncatus	0	11.76	3.45	1.63	3.70	0.78	2.78	2.94	15.79	34.96	0	7.69	6.64
Globicephala melas	8.77	10.29	12.07	9.76	7.41	5.86	5.56	3.53	0	2.44	0	7.69	6.02
Grampus griseus	1.75	2.94	1.72	0.81	0	1.17	0.69	0.59	2.63	0	6.25	0	1.24
Orcinus orca	0	0	0	0	1.85	0.39	1.39	0	0	0	0	0	0.35
Pseudorca crassidens	0	0	0	0	0	0	0.69	0.59	0	0	0	0	0.18
Physeter macrocephalus	1.75	7.35	1.72	0	1.85	1.17	0	1.76	2.63	0.81	0	7.69	1.50
Phocoena phocoena	0	0	0	0	0	0.39	0	0.59	10.53	5.69	0	0	1.15
Balaenoptera acutorostrata	0	0	0	0	0	0	0.69	2.35	2.63	3.25	0	7.69	0.97
Balaenoptera borealis	0	0	0	0	0	0	0	0	2.63	0	0	0	0.09
Balaenoptera edeni	0	0	0	0	0	0	0	0	0	0.81	0	0	0.09
Balaenoptera physalus	1.75	0	0	1.63	0	0.78	0	2.35	2.63	3.25	0	0	1.33
Megaptera novaeangliae	0	0	0	0	0	0	0.69	0.59	0	1.63	0	0	0.35
Kogia breviceps	0	0	0	0	0	0	0	0	2.63	0	0	0	0.09
Kogia simus	0	0	0	0	0	0	0	0	2.63	0	0	0	0.09
Mesoplodon europaeus	0	0	0	0	0	0	0	0	0	0.81	0	0	0.09
Mesoplodon densirostris	0	0	0	0	0	0	0	0	0	0.81	0	0	0.09
Ziphius cavirostris	0	0	0	4.07	0	2.34	2.08	0.59	0	0.81	0	0	1.42
Unidentified dolphin	0	2.94	29.31	37.40	22.22	12.89	20.14	13.53	18.42	16.26	0	38.46	17.26
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 2.5. Number of sighting records in Andalucía and Southern Murcia per periods.

Species	< 1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2002	TOTAL
Delphinus delphis	5	1	104	124	1312	531	**2077**
Stenella coeruleoalba	0	2	39	67	1249	365	**1722**
Tursiops truncatus	0	0	36	44	500	150	**730**
Globicephala melas	4	0	60	74	650	185	**973**
Grampus griseus	0	0	10	13	88	9	**120**
Orcinus orca	3	0	8	9	17	28	**65**
Pseudorca crassidens	0	1	2	4	1	0	**8**
Physeter macrocephalus	284	2	0	2	87	131	**506**
Phocoena phocoena	0	0	3	2	2	4	**11**
Balaenoptera acutorostrata	0	0	0	0	2	2	**4**
Balaenoptera borealis	102	0	0	0	0	0	**102**
Balaenoptera musculus	5	0	0	0	1	0	**6**
Balaenoptera physalus	210	0	0	1	82	27	**320**
Ziphius cavirostris	1	0	0	1	5	1	**8**
Hiperodoon ampullatus	0	0	0	1	4	0	**5**
Mesoplodon sp.	0	0	0	0	1	1	**2**
Ziphiidae	0	0	0	1	28	4	**33**
Steno bredanensis	0	0	0	3	0	0	**3**
Sin identificar	0	0	51	64	212	131	**458**
TOTAL	**614**	**6**	**313**	**410**	**4241**	**1569**	**7153**

Table 2.6. Percentage of sighting records in Andalucía and Southern Murcia per periods.

Species	< 1960	1961-1970	1971-1980	1981-1990	1991-2000	2001-2002	TOTAL
Delphinus delphis	0.8	16.7	33.2	30.2	30.9	33.8	29.0
Stenella coeruleoalba	0	33.3	12.5	16.3	29.5	23.3	24.1
Tursiops truncatus	0	0	11.5	10.7	11.8	9.6	10.2
Globicephala melas	0.7	0	19.2	18.0	15.3	11.8	13.6
Grampus griseus	0	0	3.2	3.2	2.1	0.6	1.7
Orcinus orca	0.5	0	2.6	2.2	0.4	1.8	0.9
Pseudorca crassidens	0	16.7	0.6	1.0	0	0	0.1
Physeter macrocephalus	46.3	33.3	0	0.5	2.1	8.3	7.1
Phocoena phocoena	0	0	1.0	0.5	0	0.3	0.2
Balaenoptera acutorostrata	0	0	0	0	0	0.1	0.1
Balaenoptera borealis	16.6	0	0	0	0	0	1.4
Balaenoptera musculus	0.8	0	0	0	0	0	0.1
Balaenoptera physalus	34.2	0	0	0.2	1.9	1.7	4.5
Ziphius cavirostris	0.2	0	0	0.2	0.1	0.1	0.1
Hiperodoon ampullatus	0	0	0	0.2	0.1	0	0.1
Mesoplodon sp.	0	0	0	0	0	0.1	0
Ziphiidae	0	0	0	0.2	0.7	0.3	0.5
Steno bredanensis	0	0	0	0.7	0	0	0
Sin identificar	0	0	16.3	15.6	5.0	8.3	6.4
TOTAL	100	100	100	100	100	100	100

Table 2.7. Number of sighting records in Andalucía and Southern Murcia per sub-area. AE = Eastern Almería, AS = Southern Almería, GR = Granada, MA = Málaga, SG = Strait of Gibraltar, CA = Atlantic Cádiz, HU = Huelva, ALB = Alborán Sea, exact place not specified, ALB SW = Southwestern Alboran Sea, ALB SE = Southeastern Alboran Sea, ML = Melilla, IA = Island of Alborán, MS = Southern Murcia, TOT = Total.

	AE	**AS**	**GR**	**MA**	**SG**	**CA**	**HU**	**ALB**	**ALB SW**	**ALB SE**	**ML**	**IA**	**MS**	**TOT**
Delphinus delphis	93	382	81	502	666	104	18	127	26	6	2	0	70	2077
Stenella coeruleoalba	233	435	78	188	540	32	4	53	12	7	0	0	140	1722
Tursiops truncatus	24	173	8	22	345	37	34	35	7	2	0	5	38	730
Globicephala melas	70	213	39	11	484	25	0	97	1	2	0	0	31	973
Grampus griseus	25	34	6	1	0	10	0	21	1	2	0	0	20	120
Orcinus orca	0	0	2	2	51	8	0	2	0	0	0	0	0	65
Pseudorca crassidens	1	0	0	0	3	0	0	4	0	0	0	0	0	8
Physeter macrocephalus	5	16	4	2	469	1	0	0	1	1	0	0	7	506
Phocoena phocoena	0	0	0	0	1	8	2	0	0	0	0	0	0	11
Balaenoptera acutorostrata	0	0	0	2	2	0	0	0	0	0	0	0	0	4
Balaenoptera borealis	0	0	0	0	102	0	0	0	0	0	0	0	0	102
Balaenoptera musculus	0	0	0	0	6	0	0	0	0	0	0	0	0	6
Balaenoptera physalus	7	18	3	38	238	2	0	1	0	0	0	0	13	320
Balaenoptera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ziphius cavirostris	1	2	0	1	0	0	0	2	2	0	0	0	0	8
Hiperodoon ampullatus	0	4	0	0	0	0	0	1	0	0	0	0	0	5
Mesoplodon sp.	0	2	0	0	0	0	0	0	0	0	0	0	0	2
Ziphiidae	2	29	1	0	0	0	0	0	0	0	0	0	1	33
Steno bredanensis	0	0	0	0	3	0	0	0	0	0	0	0	0	3
Sin identificar	42	136	32	65	43	41	4	63	1	2	0	2	27	458
TOTAL	**503**	**1444**	**254**	**834**	**2953**	**268**	**62**	**406**	**51**	**22**	**2**	**7**	**347**	**7153**

Table 2.8. Percentage of sighting records in Andalucía and Southern Murcia per sub-area. AE = Eastern Almería, AS = Southern Almería, GR = Granada, MA = Málaga, SG = Strait of Gibraltar, CA = Atlantic Cádiz, HU = Huelva, ALB = Alborán Sea, exact place not specified, ALB SW = Southwestern Alboran Sea, ALB SE = Southeastern Alboran Sea, ML = Melilla, IA = Island of Alborán, MS = Southern Murcia, TOT = Total.

	AE	**AS**	**GR**	**MA**	**SG**	**CA**	**HU**	**ALB**	**ALB SW**	**ALB SE**	**ML**	**IA**	**MS**	**TOT**
Delphinus delphis	18.5	26.5	31.9	60.2	22.6	38.8	29.0	31.3	51.0	27.3	100	0	20.2	29.0
Stenella coeruleoalba	46.3	30.1	30.7	22.5	18.3	11.9	6.5	13.1	23.5	31.8	0	0	40.3	24.1
Tursiops truncatus	4.8	12.0	3.1	2.6	11.7	13.8	54.8	8.6	13.7	9.1	0	71.4	11.0	10.2
Globicephala melas	13.9	14.8	15.4	1.3	16.4	9.3	0	23.9	2.0	9.1	0	0	8.9	13.6
Grampus griseus	5.0	2.4	2.4	0.1	0	3.7	0	5.2	2.0	9.1	0	0	5.8	1.7
Orcinus orca	0	0	0.8	0.2	1.7	3.0	0	0.5	0	0	0	0	0	0.9
Pseudorca crassidens	0.2	0	0	0	0.1	0	0	1.0	0	0	0	0	0	0.1
Physeter macrocephalus	1.0	1.1	1.6	0.2	15.9	0.4	0	0	2.0	4.5	0	0	2.0	7.1
Phocoena phocoena	0	0	0	0	0	3.0	3.2	0	0	0	0	0	0	0.2
Balaenoptera acutorostrata	0	0	0	0.2	0.1	0	0	0	0	0	0	0	0	0.1
Balaenoptera borealis	0	0	0	0	3.5	0	0	0	0	0	0	0	0	1.4
Balaenoptera musculus	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0.1
Balaenoptera physalus	1.4	1.2	1.2	4.6	8.1	0.7	0	0.2	0	0	0	0	3.7	4.5
Balaenoptera sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ziphius cavirostris	0.2	0.1	0	0.1	0	0	0	0.5	3.9	0	0	0	0	0.1
Hiperodoon ampullatus	0	0.3	0	0	0	0	0	0.2	0	0	0	0	0	0.1
Mesoplodon sp.	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
Ziphiidae	0.4	2.0	0.4	0	0	0	0	0	0	0	0	0	0.3	0.5
Steno bredanensis	0	0	0	0	0.1	0	0	0	0	0	0	0	0	0
Sin identificar	8.3	9.4	12.6	7.8	1.5	15.3	6.5	15.5	2.0	9.1	0	28.6	7.8	6.4
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

2.5. Ecological importance of the area

Based on the information presented in this chapter, the importance of the study area, and in particular the Alborán Sea is quite clear. Some conclusions that can be drawn are:

- The Alborán Sea has very particular oceanographic characteristics, which makes it a transition area between the Atlantic and Mediterranean.
- It is the hydrological motor of the Mediterranean
- It is one of the most productive areas of the Mediterranean
- It is a compulsory route for migrating species between the Atlantic and the Mediterranean
- It has a high diversity of species, both of fauna and flora, due to the entry of Atlantic species

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CHAPTER 3

GENERAL FIELD METHODS

3.1. THE OBSERVATION PLATFORM

The main platform for this study is the research ship *Toftevaag*, a motor-sailer fully equipped for cetacean population studies (Photo 3.1). The *Toftevaag* is a sixty foot gaff-rigged ketch built initially in 1910 for fishing herring in the North Atlantic. In 1989 the ship was restored and converted for its new role as research ship. Equipped with a 120 Hp diesel engine, the *Toftevaag* cruises at an average speed of 5 to 6 knots. It has a crow's nest on the main mast at 12 m height above sea level. Therefore, two observation platforms can be used simultaneously: the crow's nest and deck (2.5 m above sea level) (Photo 3.2). Since 1996, the *Toftevaag* tows an inflatable as an auxiliary dinghy, which is used for tasks such as photo-identification, video filming or biopsy sampling. The ship can accommodate 12 persons.

Photo 3.1. Research vessel *Toftevaag*

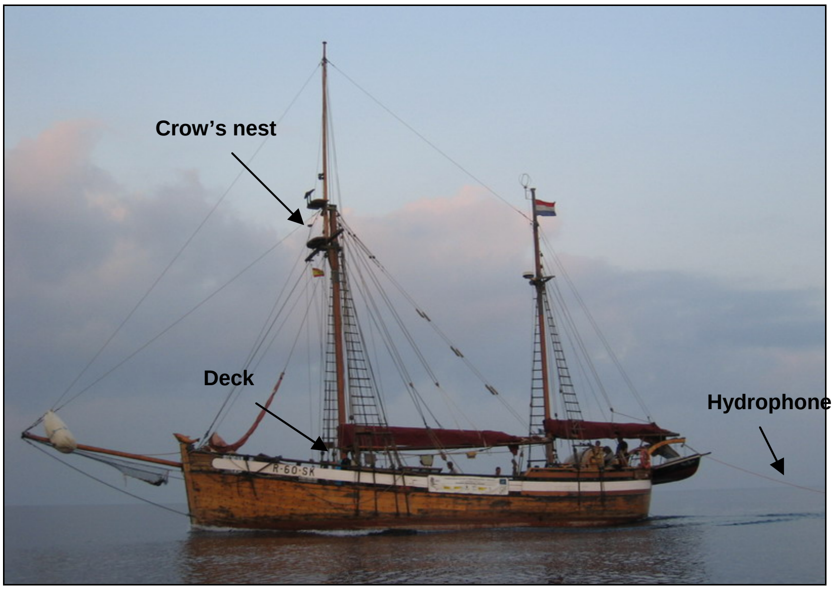


Photo 3.2. Observation platforms on the research vessel *Toftevaag*

In 2003 and 2004 another research ship, the *Else* (Photo 3.3), was used for the area south of Murcia (northern Gulf of Vera). This is a 15 m motor-sailer, also equipped with a crow's nest. In 2001 and 2002, work in the Strait of Gibraltar and the Gulf of Cádiz was complemented with another research boat, the *Elsa*, a 9 m motor boat, with one observation platform at 4m above sea level. These two boats also motor at an average speed of 5 to 6 knots.

Photo 3.3. Research vessel *Else*

Equipment on board.

The research equipment on board Toftevaag included: radar (reaching 30 km), echo-sounder recording on paper (reaching 380 m) until 2000, double frequency echo-sounder (28 KHz and 200 KHz, reaching 2000 m) since 2001, GPS, Hi8 and digital video cameras, underwater housing for the video cameras, analogue photographic cameras (zoom up to 300 mm), digital photographic cameras (zoom up to 300 mm) since 2003, towed hydrophone array (200 Hz to 20 KHz) on a 100 m cable (since 1997) (Photo 3.2), digital DAT recorder for acoustic data (since 1997), binoculars, freezer, digital thermometer, conductivity meter, computers.

Since 1995, the IFAW data logging software LOGGER was used (www.ifaw.org), which recorded the GPS positions and time, through an NMEA cable, every 60 seconds (Figure 3.4). Data on effort (Figure 3.5) cetacean (Figure 3.6) and sea turtle sightings and environmental variables and human activities (Figure 3.7) were also recorded. This software was also used on board the *Else*.

Crew

The crew on board was always composed of 2 to 5 experienced researchers plus 5 to 8 volunteers. Volunteers helped with the watches on deck and with the collection and entry of acoustic, environmental and human activities data. Since 1999, all volunteers came through the Earthwatch Institute.

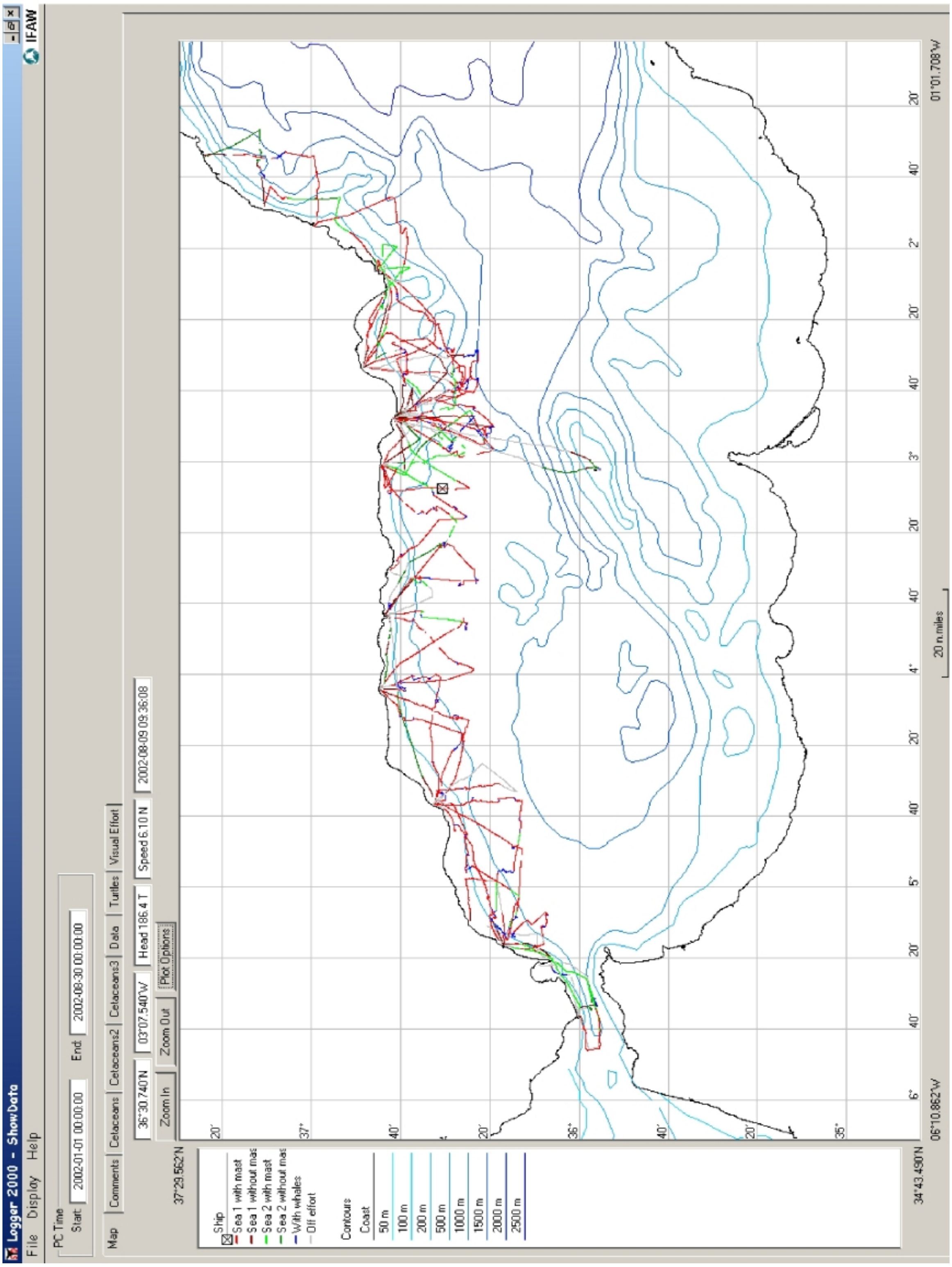


Figure 3.4. Screen of software Logger with the map and the tracks that are being carried out during the survey.

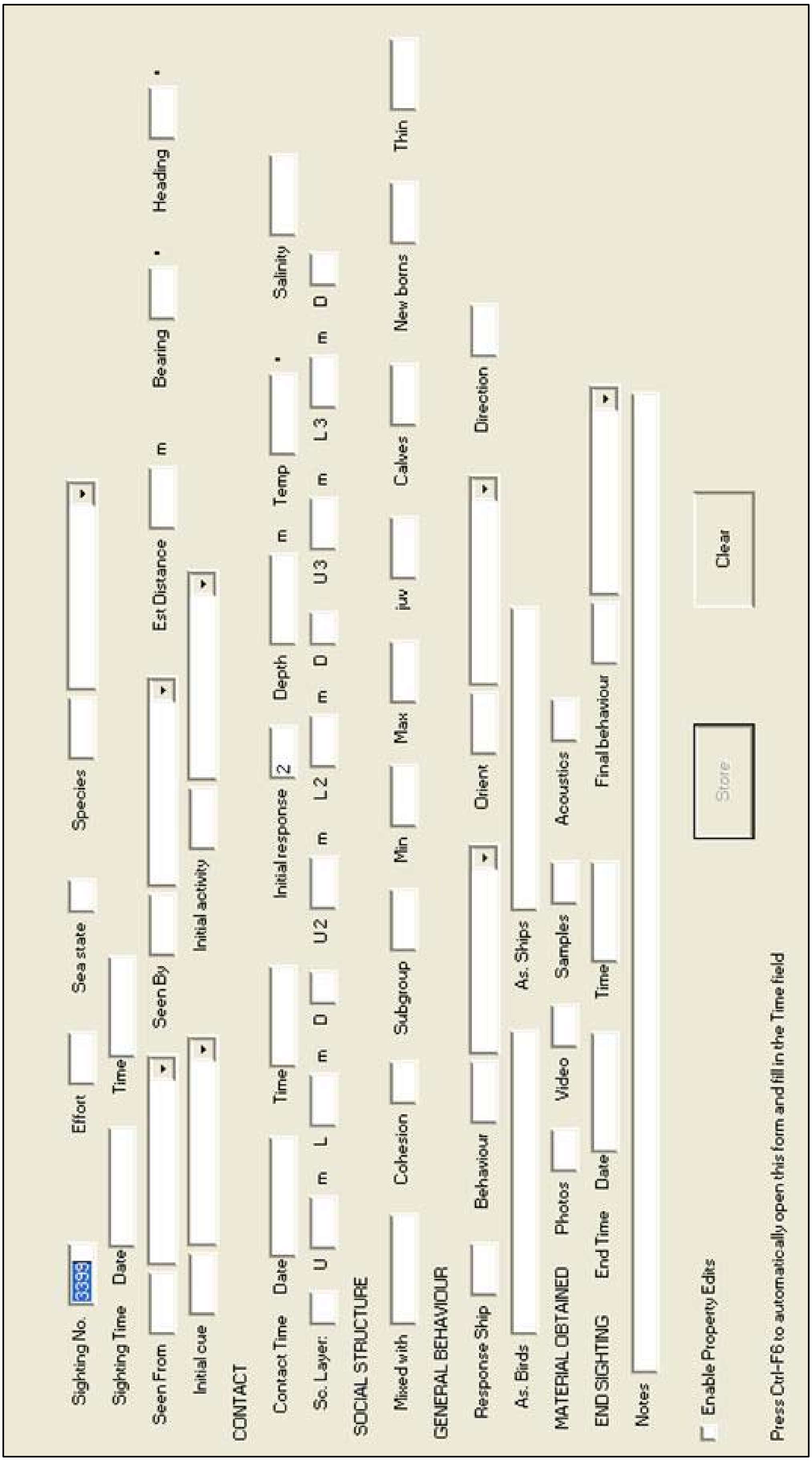


Figure 3.5. Screen of software Logger for sightings data

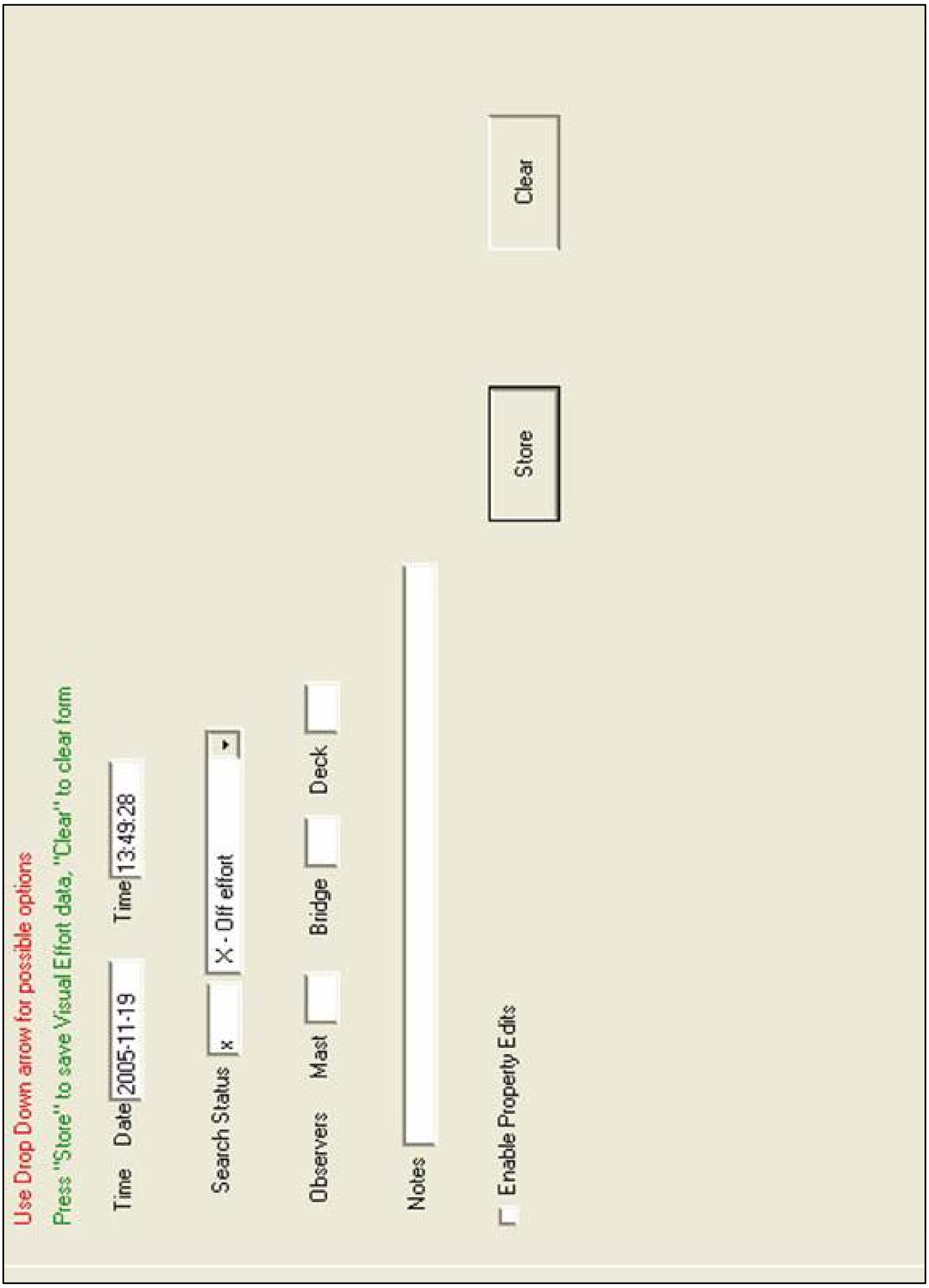


Figure 3.6. Screen of software Logger for searching effort data

Figure 3.7. Screen of software Logger for environmental, acoustic and human activities data

3.2. THE STUDY AREA

The study area has been described in detail in Chapter 2. Table 3.1 shows the amount of effort (kilometres sailed searching for cetaceans) carried out in each of the sub-areas of the study area, per year, totalling 55,000 km of survey in an area of 24,896 km^2. The study area was sampled in January, March, June to September and November from 1999 to 2004. Surveys were also made during March-April, and from June to September from 1992 to 1998.

Table 3.1. Kilometres sailed searching for cetaceans. The surface area is given for each sub-area (in square km).

	Gulf of Vera	**Southern Almería**	**Málaga-Granada**	**Strait of Gibraltar**	**Gulf of Cádiz**	**TOTAL**
Area (km^2)	6165	4234	7589	1258	5651	24896
1992	2254	940				3194
1993	3130					3130
1994	3050					3050
1995	1771	1508				3279
1996	1475	2321				3796
1997	1701	1447				3148
1998	333	2797				3130
1999	174	3181				3355
2000	379	1916	1278	169		3741
2001	360	2275	1391	2312	736	7074
2002	566	1922	1143	1285	1412	6329
2003	2836	1382	1431			5648
2004	2888	1734	1334	143	27	6125
TOTAL	**20916**	**21422**	**6577**	**3909**	**2175**	**54999**

The whole study area was divided, for analytical purposes, into grid cells of 2 by 2 minutes latitude-longitude (12.3 km^2), resulting in 3,416 cells. This cell size was chosen for several reasons: (a) it is small enough to capture much of the variability of the physiography and oceanography of the area, both of which have strong gradients across small distances; (b) it is larger than the available resolution of the oceanographic data and approximately the same size of the minimum resolution available for the physiographic data; (c) a smaller resolution would also result in too many cells and make the analysis too time-consuming; (d) a larger resolution would hide much of the variability, not only in the environmental data, but also on the presence or absence of cetacean species.

3.3 DATA COLLECTION

3.3.1 Survey design

To maintain consistent sighting effort, one trained observer (of a team of five on all ships) occupied each look-out post in one hour shifts during daylight with visibility of over 3 nmi (5.6 km), assisted by 7x50 binoculars, covering the 180º arc ahead of the vessel.

Logistical constraints dictated that transects could not follow a systematic design, and thus equal coverage probability was not achieved across the area. The relatively small vessels used had a slow cruising speed, were very dependent on weather conditions and had to return to port every night. In addition, time was allocated to other activities during encounters, such as photo-identification. These constraints would reduce considerably the effectiveness of a systematically designed survey. Instead, cruise tracks were designed as triangles to cross depth contours and to cover as much of the area as possible (Figure 3.8).

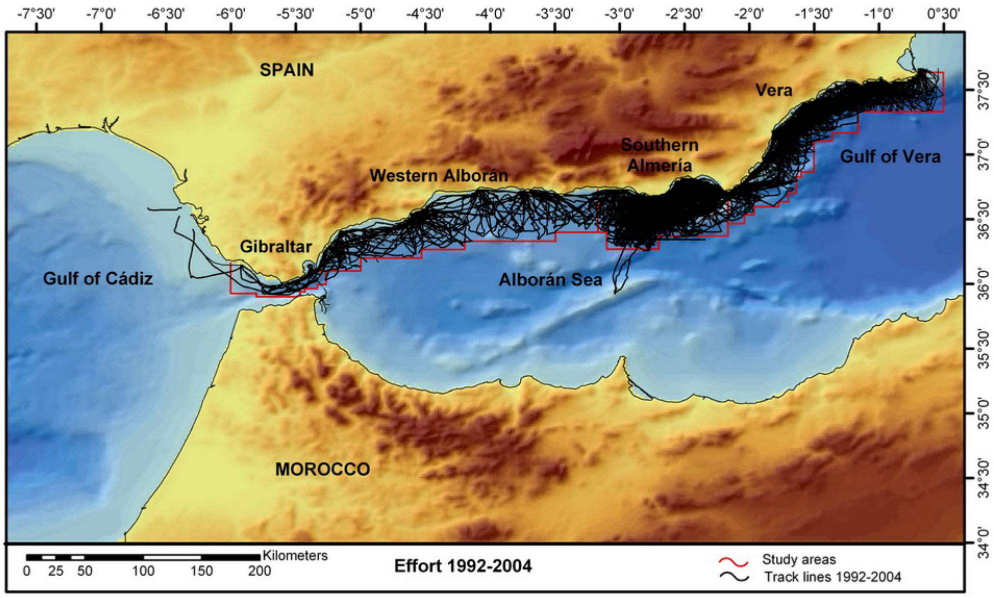


Figure 3.8. Cruise tracks on effort from 1992 to 2004.

3.3.2 Searching effort data

Searching effort was conducted only under adequate sighting conditions (defined as Douglas sea state 2 or lower, equivalent to Beaufort Sea state 2-3, and good visibility) and observers on the lookout posts. Searching effort stopped with sea states of 3 Douglas (Beaufort 3 to 4) or more, and also when animals were encountered (a 'sighting') and recommenced when it was over following a return to the previous course.

Sighting effort was categorized into 'effort types' according to sea state and position of trained observers, because crow's nest observations were cancelled with excessive swell: 1 (sea state 1 Douglas scale and one observer in the crow's nest), 1S (sea state 1 and no crow's nest watch), 2 (sea state 2 with crow's nest watch) and 2S (sea state 2 and no crow's nest watch). Any change of effort type was recorded in the log book and in the Logger software (Figure 3.6).

Almost half of the survey effort was carried out under effort type 1: 47.3%. The remaining effort was distributed as 12.6% for type 2, 20.2% for type 1S and 19.9% for effort 2S.

3.3.3 Sightings data

A 'sighting' was defined as a group of animals seen at the same time, showing similar behavioural characteristics and at distances of less than 1,000m from each other (SEC 1999).

Once an animal or group of animals was detected, immediate 'primary data' were taken: time, position, name of the observer making the sighting, position of the observer (mast or deck), type of effort, angle from the detected group to the trackline, estimated radial distance from the detected group to the ship, species, cue (blow, jump, splash, fin or back, birds, other), initial behaviour (see below), direction of swimming, wind and sea state. Before 2001, angle boards were not used and all angles were rounded in general to the nearest 10º. Since 2001, angles were measured with an angle board on the crow's nest or on the bridge, avoiding any rounding. Distances were always estimated by naked eye. No distance estimation experiments were carried out before or during the surveys.

All detected animals or groups were approached to a distance of 100 m or less, at which point new 'contact data' were recorded: time, position, confirmation of species and group size (see below). If the animals allowed a close approach, the encounter could be prolonged up to several hours to carry out several other tasks (e.g. photo-identification). On leaving the animals, data were recorded again on time, position, wind, sea state and final behaviour, and searching effort started again.

Behaviour was divided into five categories: feeding-foraging (animals observed chasing or eating fish, long synchronized and repeated dives or following trawling fishing boats and repeatedly diving to the level of the trawler net); resting (stationary in one place, almost without any kind of movements); socialising (clear and constant interaction between the animals in the group, normally with much aerial activity and stationary in the area); travelling (moving animals, either on steady course or not, differentiated as travelling slowly (0.1 – 3.7 km/h), travelling moderately (3.8 – 7.4 km/h) and travelling fast (> 7.4 km/h)); and milling (none of the previous categories, usually stationary in the area, with non-synchronized movements and very active).

Group size was assessed several times during the encounter. Animals were counted repeatedly to obtain the best estimate of group size. The number of calves and the estimated number of animals in any subgroups were also recorded. Any changes in group composition (subgroups joining or leaving) were recorded to ensure that the best estimate was of the group initially sighted.

Sightings data were recorded in field notebooks (Figure 3.9) as well as in the program Logger in the computer (Figure 3.5).

3.3.4 Environmental data

During searching on effort, data were recorded every 20 minutes ('sampling stations') on physical and environmental features, such as: depth, sea surface temperature, salinity, presence of other species (sea turtles, birds, sharks, fish, plankton or invertebrate concentrations, etc.) and presence, depth and intensity of scattering layers.

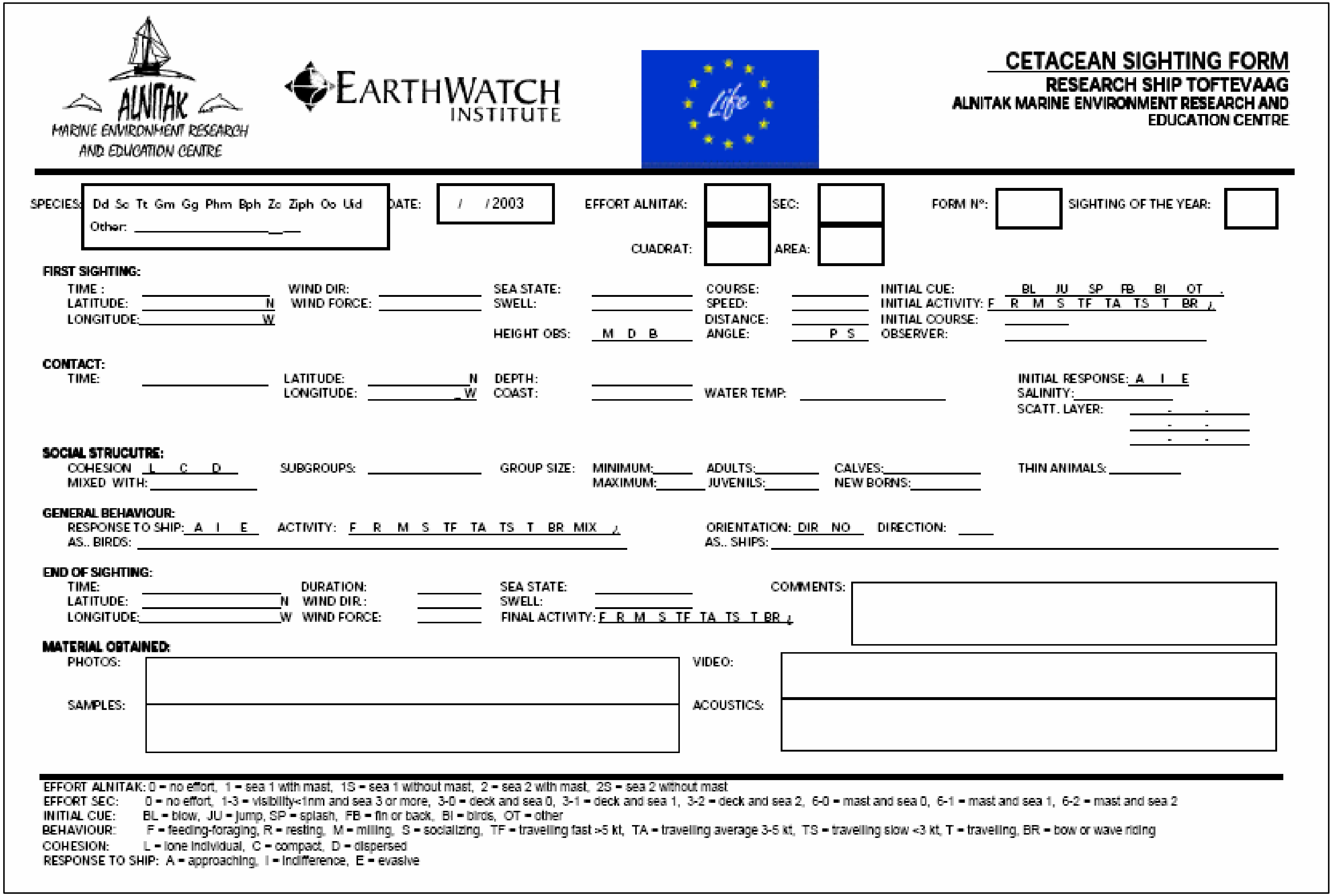
At these sampling stations, the ship's engine was set to neutral (when in a depth of more than 100 m) to listen through the headphones connected to the towed hydrophone. Any cetacean vocalizations (whistles or clicks) were recorded on a scale from 1 to 5 depending on the intensity of the sound perceived (0 when no cetaceans were heard).

Both visual and acoustic data was recorded in field notebooks as well as in the program Logger in the computer (Figure 3.7).

The value of a range of environmental variables was allocated to each grid cell in the study area. These variables can be characterised as geographic, physiographic or oceanographic; they are shown in Tables 3.2 and 3.3. Figures 3.10.a to 3.17 show the geographic distribution of some of the variables. The strong correlation among some of them can be observed.

Table 3.2. Geographic and physiographic variables allocated to grid cells

Type of variable	Variable	Units	Source
Geographic	Latitude	Decimal degrees	Nautical charts of the Spanish Navy Hydrological Institute
	Longitude	Decimal degrees	Nautical charts of the Spanish Navy Hydrological Institute
Physiographic	Depth	Meters	Nautical charts of the Spanish Navy Hydrological Institute + measurements taken with echo-sounder (average of all data points)
	Logarithm of depth		Natural logarithm of depth
	CV of depth	Percentage	Coefficient of variation (SD/Mean) of the data on depth
	Slope	Meters per km	$(Depth_{max} – Depth_{min})$/Distance between $Depth_{max}$ and $Depth_{min}$ (Nautical charts of the Spanish Navy Hydrological Institute)
	Contour index		$100*(Depth_{max} – Depth_{min})/Depth_{max}$
	Distance from coast	Kilometres	ArcView 3.2
	Distance from the 200 m isobath	Kilometres	ArcView 3.2
	Distance from the 1000 m isobath	Kilometres	ArcView 3.2
	Distance from Seco de los Olivos	Kilometres	ArcView 3.2
	Physiography	Sea mount, canyon, escarpment, plain	Nautical charts of the Spanish Navy Hydrological Institute



CETACEAN SIGHTING FORM
RESEARCH SHIP TOFTEVAAG
ALNITAK MARINE ENVIRONMENT RESEARCH AND EDUCATION CENTRE

SPECIES: Dd Sc Tt Gm Gg Phm Bph Zc Ziph Oo Uid
Other:

DATE: / /2003

EFFORT ALNITAK: SEC: CUADRAT: AREA: FORM Nº: SIGHTING OF THE YEAR:

FIRST SIGHTING:
TIME: LATITUDE: N LONGITUDE: W
WIND DIR: WIND FORCE:
SEA STATE: SWELL: HEIGHT OBS: M D B
COURSE: SPEED: DISTANCE: ANGLE: P S
INITIAL CUE: BL JU SP FB BI OT
INITIAL ACTIVITY: F R M S TF TA TS T BR
INITIAL COURSE: OBSERVER:

CONTACT:
TIME: LATITUDE: N LONGITUDE: W
DEPTH: COAST: WATER TEMP:
INITIAL RESPONSE: A I E
SALINITY:
SCATT. LAYER:

SOCIAL STRUCUTRE:
COHESION L C D
MIXED WITH:
SUBGROUPS:
GROUP SIZE: MINIMUM: MAXIMUM:
ADULTS: JUVENILS:
CALVES: NEW BORNS:
THIN ANIMALS:

GENERAL BEHAVIOUR:
RESPONSE TO SHIP: A I E
ACTIVITY: F R M S TF TA TS T BR MIX
AS.. BIRDS:
ORIENTATION: DIR NO DIRECTION:
AS.. SHIPS:

END OF SIGHTING:
TIME: LATITUDE: N LONGITUDE: W
DURATION: WIND DIR: WIND FORCE:
SEA STATE: SWELL: FINAL ACTIVITY: F R M S TF TA TS T BR
COMMENTS:

MATERIAL OBTAINED:
PHOTOS: SAMPLES: VIDEO: ACOUSTICS:

EFFORT ALNITAK: 0 = no effort, 1 = sea 1 with mast, 1S = sea 1 without mast, 2 = sea 2 with mast, 2S = sea 2 without mast
EFFORT SEC: 0 = no effort, 1-3 = visibility<1nm and sea 3 or more, 3-0 = deck and sea 0, 3-1 = deck and sea 1, 3-2 = deck and sea 2, 6-0 = mast and sea 0, 6-1 = mast and sea 1, 6-2 = mast and sea 2
INITIAL CUE: BL = blow, JU = jump, SP = splash, FB = fin or back, BI = birds, OT = other
BEHAVIOUR: F = feeding-foraging, R = resting, M = milling, S = socializing, TF = travelling fast >5 kt, TA = travelling average 3-5 kt, TS = travelling slow <3 kt, T = travelling, BR = bow or wave riding
COHESION: L = lone individual, C = compact, D = dispersed
RESPONSE TO SHIP: A = approaching, I = indifference, E = evasive

Figure 3.9. Sighting form filled in for each sighting.

Table 3.3. Oceanographic variables allocated to grid cells

Type of variable	Variable	Units	Periods	Source
Oceanographic	Average chlorophyll	mg/cm^3	2000-2002 2003-2004 2000-2004 Summer 2000-2002 Summer 2003-2004 Summer 2000-2004 Winter 2000-2002 Winter 2003-2004 Winter 2000-2004	CREPAD (INTA – Instituto Nacional de Técnicas Aeroespaciales): SeaWIFS daily satelite images, 2 km^2 resolution
	Average sea surface temperature 1999	Degrees Celsius	1999 2000-2002 2003-2004 2000-2004 1998-2004 Summer 1999 Summer 2000-2002 Summer 2003-2004 Summer 2000-2004 Summer 1998-2004 Winter 2000-2004 Winter 1998-2004	CREPAD (INTA – Instituto Nacional de Técnicas Aeroespaciales): NOAA AVHRR daily satelite images, 2 km^2 resolution
	Temporal variability of sea surface temperature		1999 2000-2002 2003-2004 2000-2004 1998-2004 Summer 1999 Summer 2000-2002 Summer 2003-2004 Summer 2000-2004 Summer 1998-2004 Winter 2000-2002 Winter 2003-2004 Winter 2000-2004 Winter 1998-2004	Standard deviation of daily sst along the period, from the satellite images
	Encounter rate of total fish		2001-2004 Summer 2001-2004	Number of sampling stations with detection of fish / number of sampling stations
	Encounter rate of demersal fish		2001-2004 Summer 2001-2004	Number of sampling stations with detection of demersal fish / number of sampling stations
	Encounter rate of pelagic fish		2001-2004 Summer 2001-2004	Number of sampling stations with detection of pelagic fish / number of sampling stations

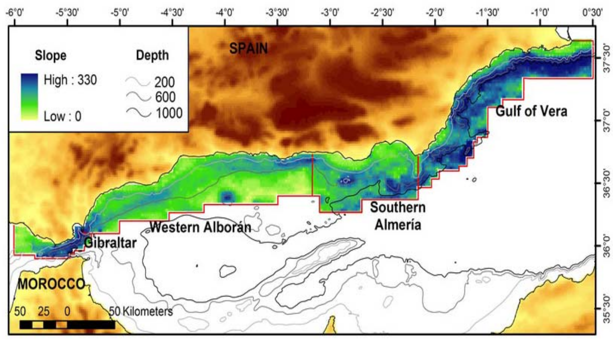


Figure 3.10. Slope

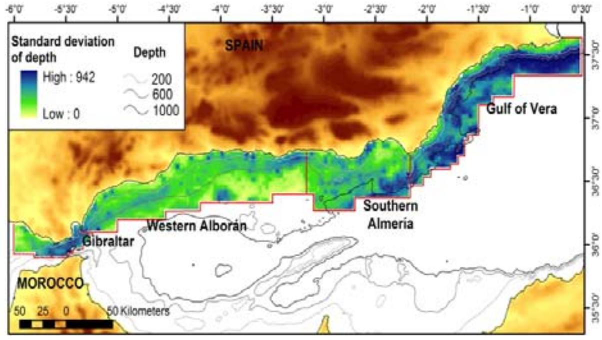


Figure 3.11. Standard deviation of depth

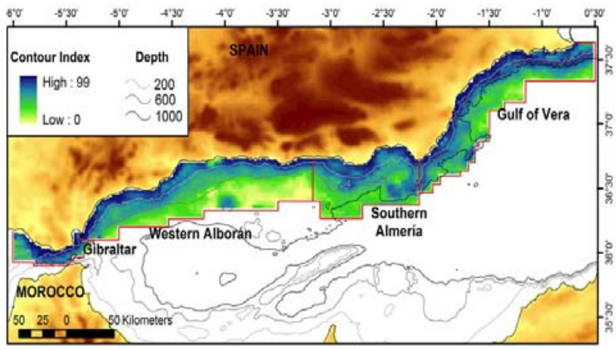


Figure 3.12. Contour Index

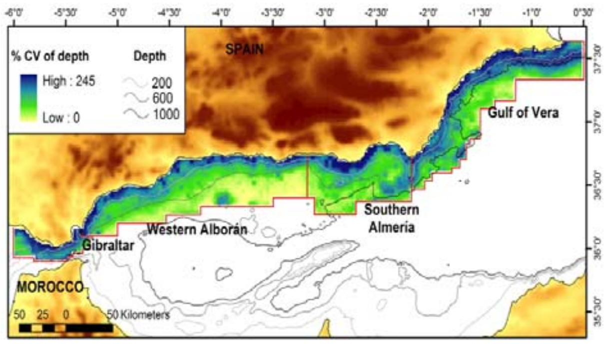


Figure 3.13. Coefficient of variation of depth

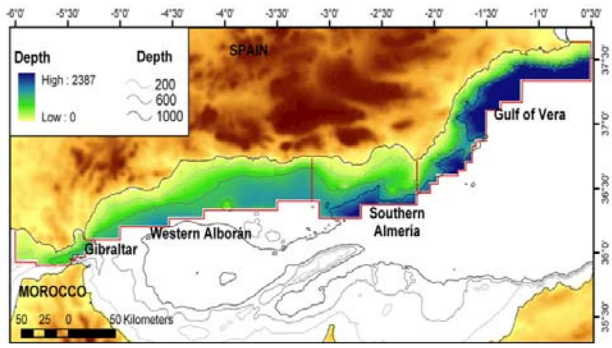


Figure 3.14. Depth

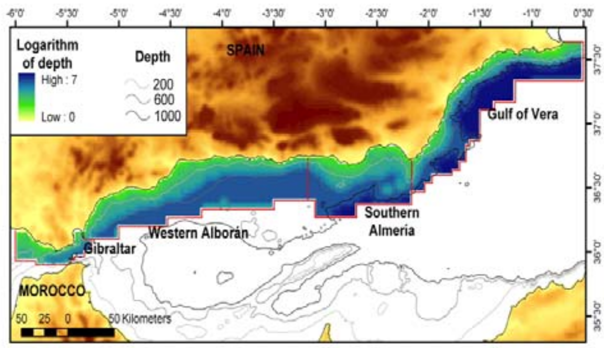


Figure 3.15. Logarithm of depth

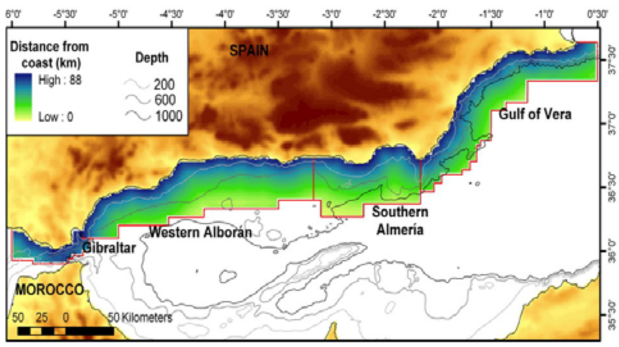


Figure 3.16. Distance from coast

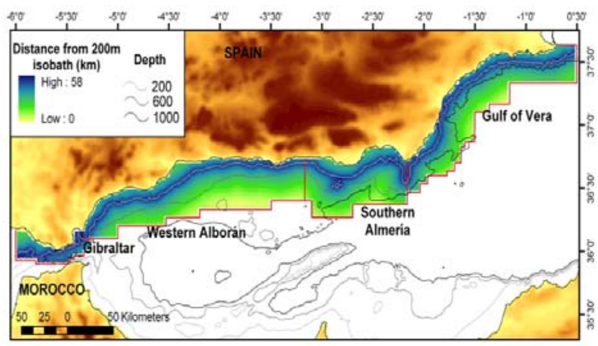


Figure 3.17. Distance from the 200m isobath

3.3.5 Human activity data

At the 'sampling stations', data were also recorded on the presence of ships within a radius of 3 nmi (5.5 km), which is the distance from the observation platform to the horizon. Only those ships for which the complete water line was visible were considered. If in doubt, the radar was used to verify the distance.

The ships were classified into 12 different types: cargo vessels, tankers, ferries, military vessels (including submarines at the surface), sailing boats, motor boats (not included in the previous categories, and including sailing boats that were motoring), trawlers, long-liners, purse-seiners, gill-netters, sport fishing boats, and 'others'.

At the sampling stations, when the ship's engine was set to neutral, data on acoustic pollution were also recorded on a scale from 1 to 5 depending on the intensity of the sound perceived (0 when no sounds were heard). These sounds were mainly from remote ships, although occasionally underwater explosions from military or seismic research vessels were recorded.

Both visual and acoustic data were recorded in field notebooks as well as via program Logger in the computer (Figure 3.7).

Values of some of the anthropogenic variables were allocated to grid cells (Table 3.4). A more detailed description of the visual and acoustic recording of human activities is given in Chapter 4.

Table 3.4. Anthropogenic variables allocated to grid cells.

Type of variable	Variable	Units	Source
Human activities	Trawling area	0-1	Observations at sea
	Encounter rate of trawlers		Number of trawlers encountered / number of sampling stations
	Distance to fishing ports	Kilometres	ArcView 3.2
	Proportion of acoustic detections of ships		Number of acoustic detections / number of sampling stations

3.4 DATA ORGANISATION

Depending on the type of analysis, data were organised in different ways. For Chapter 6 (Modelling habitat preference), effort was expressed as the number of times the research ship passed over a grid cell, and the proportion of positive observations in each cell type was calculated. For Chapters 7 and 8 (Abundance estimation), all on-effort transects were divided into small (average 2.8 km, maximum 4 km) segments between two consecutive sampling stations, in which effort type was constant. It was assumed that there would be little variability in physical and environmental features (bottom physiography, sst, etc.) within each segment. Each segment was assigned to a grid cell based on the mid point of the segment; values of variables in each grid cell were allocated to associated segments.

For some analysis datasets were stratified into years and/or sub-areas, so that each dataset was as homogeneous as possible in terms of effort in the chosen sub-area/s. Years were pooled when necessary to increase sample size. Whenever possible, the stratification was also based on encounter rates, so that consecutive periods with similar encounter rates remained pooled together. The specific datasets used in each case is described in each chapter.

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SEC. 1999. Recopilación, Análisis, Valoración y Elaboración de Protocolos sobre las labores de observación, asistencia a varamientos y recuperación de mamíferos y tortugas marinas de las Aguas Españolas. Technical Report. Sociedad Española de Cetáceos. Available from SEC, Nalón 16. E-28240 Hoyo de Manzanares, Madrid, Spain.

CHAPTER 4

REVIEW OF HUMAN ACTIVITIES POTENTIALLY THREATENING TO CETACEANS IN THE STUDY AREA

4.1 INTRODUCTION

The strategic importance of the study area for man is clear. Its situation in the entrance of the Mediterranean Sea gives the region a great relevance not only in the regional scope, but also on a global scale, since the region constitutes one of the main axes of international marine traffic as well as a politically strategic place.

Therefore, when establishing management measures to maintain a favourable conservation status for the cetacean species and their habitats, the socioeconomic interests of the area should be considered within the framework of the possible designation of protected areas and the establishment of species conservation plans.

The Mediterranean Sea and adjacent Atlantic waters are important to the economy of Andalucía and Murcia. Furthermore, the importance of the region in relation to international politics and economics is also evident. According to forecasts by the European Environment Agency (EEA), the economy of Andalucía will grow strongly in the next few decades. A large part of this growth will occur along the coast, taking advantage of its natural beauty.

Tourism is one of the main human activities directly affecting the conservation of cetaceans and more generally the marine environment. The development of low quality tourism constitutes a potential threat to the most coastal species and their habitats, because it entails a series of impacts in the marine environment. Between 20% and 30% of the hydrocarbon spills, heavy metals and organ-halogenated residuals are discharged into the marine environment through rivers and sewers. The lack of facilities adapted to residual water treatment throughout the coastal area, and in particular in the industrial and mass tourism centres (Huelva, Cádiz, Algeciras, Málaga, Cartagena), has an important impact on the marine environment.

One type of tourism, whale watching, can act negatively on cetaceans, both in the short and the long term, if it is not done in a responsible and sustainable way. Some studies have shown how human presence affects different animals (IFAW 1995), demonstrating that they can be intimidated when there are close approaches, but that they can tolerate, and even habituate to human activities if they are easy to anticipate (Schultz and Bailey 1978; IFAW 1996).

As described in Chapter 2, maritime traffic in the Alborán Sea is very intense, and this results in serious threats for the environment. First, large quantities of potentially dangerous chemicals are transported daily, with a risk of spills if a collision occurs, ot through flushing of deposits and accidental spills. Second, this traffic can cause significant acoustic pollution.

Cetaceans are adapted to the marine environment, where the propagation of sound is far better than that of light. They depend to a large extent on acoustics to orientate themselves and to feed. Social species also use sound for communication. Although there are few studies on the effects and impact of diverse forms of acoustic pollution on cetaceans, it is reasonable to assume that an increase in background noise produced by man will reduce the effectiveness of the use of the sound by cetaceans for feeding, communication and orientation.

Agriculture is one of the main industries in the region. Intensive agriculture entails the use of significant volume of fertilizers and biocides as well as disposable plastic for greenhouses (that frequently ends up at sea), often in the heart of valuable natural sites. Excessive or illegal use of these materials is therefore a potential threat for the marine environment and especially for species like cetaceans that are vulnerable to contamination by persistent pollutants such as organo-halogenated compounds and heavy metals.

Consideration of fisheries is also necessary because although they are less important to the Murcian and Andalusian economies, their impact on the marine environment is especially important. The unsustainable exploitation of fishing resources constitutes one of the main threats to the marine environment in the Spanish Mediterranean. A recent FAO report indicates that the north-east Atlantic, the Mediterranean and the Black Sea are the regions of the world with the greatest need to recover their fish populations (FAO 2004). The shortage of prey, attributable to a large extent to overfishing, without doubt constitutes an important threat both for populations of cetaceans and for the fisheries sector itself.

This review of the human activities potentially threatening to cetaceans in the study area uses two complementary sources of information: official statistical data; and data collected *in situ* during the surveys on diverse human activities and/or their consequences for the marine environment. This is not an in-depth risk analysis, but rather a first description of possible threats or conflicts between the conservation needs of cetaceans and their habitats, and human economic activities.

4.2. DATA COLLECTED DURING THE SURVEYS

Two types of data were collected during the surveys: visual observation of human activities (since 1998), and acoustic detection of man-made background noise (since1997). Sampling was done every 20 minutes throughout 13,800 nautical miles (25,558 kilometres) of survey for the acoustic data and 12,100 nautical miles (22,409 kilometres) for the visual data. The visual and acoustic sampling stations from 1997 to 2004 are shown in Figure 4.1.

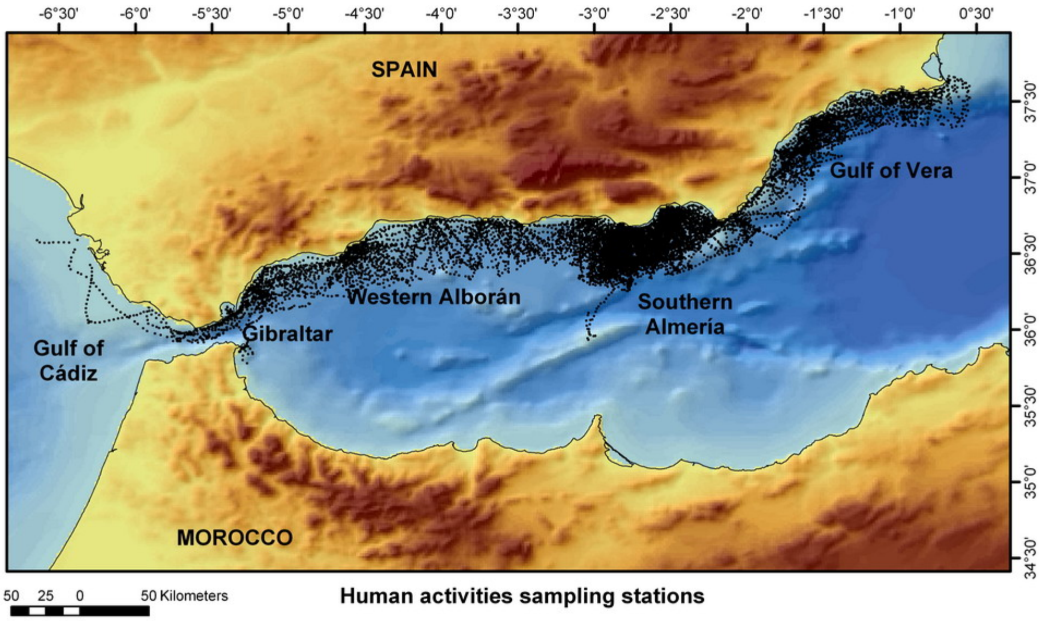

Figure 4.1. Visual and acoustic sampling stations for human activities (1997-2004)

In each sampling station, data were taken on boats within a range of 3 nmi (5.5 kilometres) around the observation platform. Boats were classified into 12 categories: cargo ships, oil tankers, ferries, military ships, sailboats, motor boats, trawlers, longliners, purse seiners, gillnetters, sport fishing and others.

The encounter rate of each category of boat for each grid cell of the study area was calculated by dividing the number of boats detected by the number of sampling stations.

The acoustic samplings, with a duration of one minute each, were made using a towed array hydrophone with two elements BENTHOS AQ4 (range 3Db 200Hz-20KHz). The aim of the acoustic sampling in this study was the detection of sounds of propellers, motors, sonars and underwater explosions. Due to the length of the cable of the hydrophone (100 meters), the acoustic stations were made only in depths of more than one hundred meters and usually outside the traffic separation schemes of the Straits of Gibraltar and Cabo de Gata.

A total of 8,296 acoustic samplings and 9,650 visual samplings were made (Figure 4.1; Table 4.1). There is high density of boats in the study area; 20,748 boats of any type were detected, giving an average of 2.2 boats per sampling station (every 20 minutes). Boats were detected on 65.4% of the visuals samplings, and anthropogenic noise was detected in 49% of the acoustic samplings.

4.3. MARITIME TRAFFIC

4.3.1. Review of situation

It is estimated that between 4,400 to 4,500 oil tankers cross the Strait of Gibraltar each year, in addition to the merchant navy, adding up to a total of 50 MT of oil and refined products, which is one fifth of the world's total (EEA 1999) and makes this waterway the second most transited in the world (de Stephanis *et al*. 2000). According to data from the Tarifa Traffic Control Tower, 83,856 ships were identified in the Strait of Gibraltar in 1999, of which 53,336 were oil tankers and merchant vessels heading E-W, 13,473 were ferries heading N-S and 17,047 were speed boats also heading N-S (de Stephanis *et al*. 2000). These data do not include fishing or pleasure boats. The approximately 50,000 large tonnage boats which navigate E-W also cross the Alborán Sea. According to data from the Almería Traffic Control Tower, in the 24 nm stretch from Cabo de Gata towards the high sea there is a transit of 35,000 boats each year.

To reduce the risk of collision between large boats, the International Maritime Organisation (IMO) recommends the establishment of compulsory maritime routes in these areas of intense traffic, which are known as Traffic Separation Scheme (SST). These devices organise the maritime traffic flow to avoid cross encounters between boats and are also useful to organise traffic in highly dense areas due to fisheries and allow a better functioning of the Lifeguard operations. There are two SST within the study area: one in the Strait of Gibraltar, and another one south of Cabo de Gata. The latter one became active on 20 November 1988.

Observations at sea confirmed the importance of maritime traffic in the region due to the funnel effect for the incoming and outgoing traffic of the Mediterranean Sea. In this section we consider two groups: large tonnage motor boats (merchant ships, oil tankers and ferries) and military and research ships.

Table 4.1. Sampling and detections of human activities

	Samplings	Samplings with detection	% samplings with detection	Number of detections	% of total detections	No. detections per sampling
Acoustics	**8296**	**4062**	**49.00**			
Visual	**9650**	**6309**	**65.40**	**20748**	**100.00**	**3.3**
Large tonnage motor boats		**3796**	**39.34**	**6829**	**32.91**	**1.1**
Cargos		2661	**27.58**	5328	**25.68**	**0.9**
Tankers		496	**5.14**	742	**3.58**	**0.1**
Ferries		639	**6.62**	759	**3.66**	**0.1**
Military ships		184	**1.91**	**167**	**0.80**	**0.03**
Professional fishing		**3502**	**36.29**	**7516**	**36.23**	**1.2**
Trawlers		2438	**25.26**	5352	**25.80**	**0.9**
Longliners		304	**3.15**	487	**2.35**	**0.1**
Gillnetters		660	**6.84**	1580	**7.62**	**0.3**
Purse seiners		100	**1.04**	97	**0.47**	**0.02**
Sport fishing		468	**4.85**	**1309**	**6.31**	**0.2**
Nautical tourism		**3032**	**31.42**	**4302**	**20.73**	**0.7**
Mailing boats		1318	**13.66**	1741	**8.39**	**0.3**
Motor boats		1714	**17.76**	2561	**12.34**	**0.4**
Other		444	**4.60**	**625**	**3.01**	**0.1**

4.3.1.1. Motor boats of large tonnage: merchant ships, oil tankers and ferries

Thirty three percent of all detected ships were large tonnage vessels, second only to professional fishing vessels. Most of the recorded movements corresponded to cargo shipping on direct routes through the Straits on east - west courses. Several ferry lines cut the shipping lines in a more or less perpendicular way (Figure 4.2).

The proportion of cargo ships, oil tankers and ferries altogether recorded throughout the study area is shown in Figure 4.3. The larger proportions occur far from the coast in the Alborán Sea and the Gulf of Vera, especially in the area of Cabo de Gata and Straits of Gibraltar. This corresponds to the maritime traffic main routes of large tonnage vessels that move between the Atlantic and the Mediterranean (in both directions), normally following a route from Cabo de Palos to Cabo de Gata and to Punta Europa (Gibraltar). The highest proportion occurs in the Straits of Gibraltar, mainly due to the funnel effect and also to the presence of the port of Algeciras, one of the main commercial ports of the area, and its petroleum refinery, and to the high concentration of ferries crossing daily between Spain and Morocco, especially during summer (Figure 4.2).

The ferries and fast-ferries in the Straits that link Algeciras, Gibraltar and Tarifa with Ceuta and Tangiers is of special interest due to its potential danger for some species of cetaceans (de Stephanis *et al.* 2000). For example, in August 2002 a ferry between Algeciras and Tangiers collided with a sperm whale of about 15 meters in length, which died after approximately one hour due to the injuries produced by the collision (R. de Stephanis com. pers.). Collisions with small cetaceans have not been detected to date.

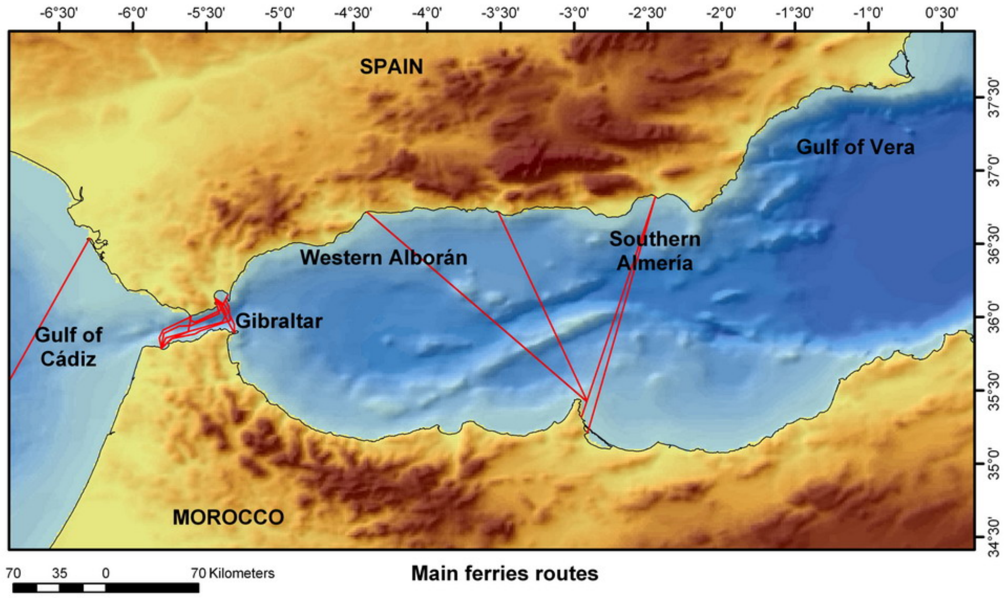

Figure 4.2. Main ferry routes crossing the Alborán Sea and the Strait of Gibraltar.

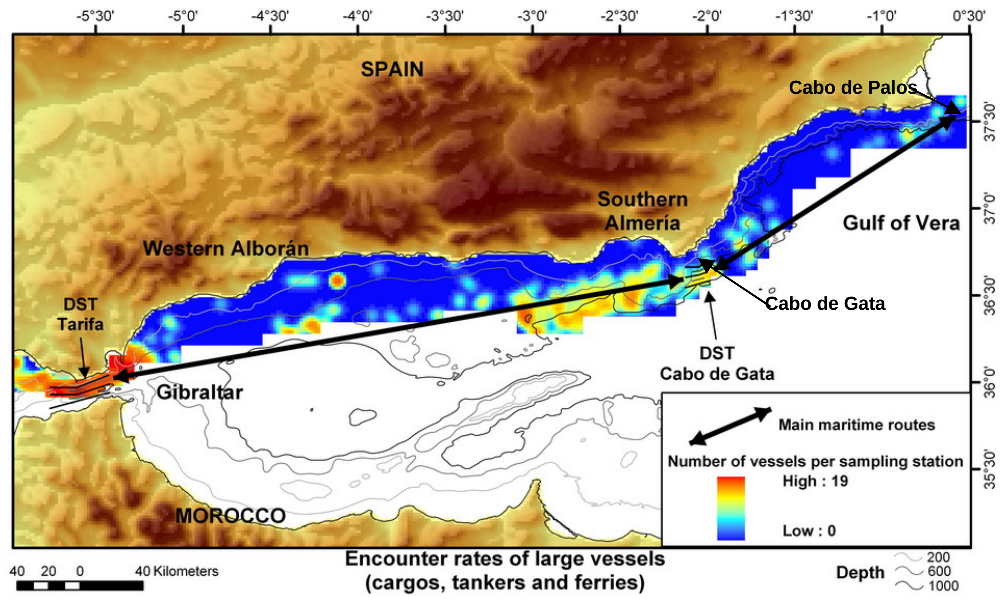

Figure 4.3. Encounter rates of large vessels (cargos, tankers and ferries) in the study area. DST= Traffic Separation Scheme

A total of 8,296 sound recordings were made every 20 minutes (coinciding with visual data collection on human activities). The noise of ship's engines was detected in 4,062 of these recordings, and on 47 occasions powerful underwater sound bursts from military manoeuvres and seismic exploration were heard (see below).

Figure 4.4 shows how acoustic pollution, as recorded, was distributed over the area. This represents background noise only in the range 200Hz to 20KHz, excluding low and frequency sounds. Background low frequency noise must be very high as a result of the omnipresence of large ships in the area. The highest amounts of acoustic pollution occurred in the deepest waters, coinciding with the routes of the large vessels, between Cabo de Palos and Cabo de Gata, and between Cabo de Gata and Gibraltar (Figure 4.3). As expected, the area in and around the Straits itself displays very high levels of acoustic pollution.

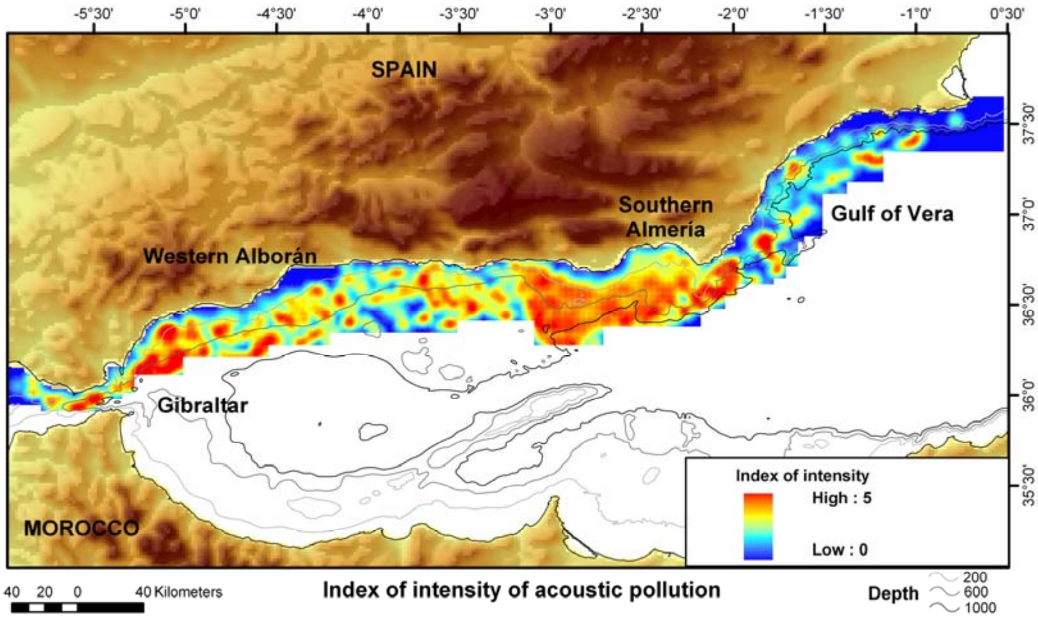

Figure 4.4. Index of intensity of acoustic pollution

Maritime traffic is one of the main anthropogenic sources of sound in the sea. This noise comes from propellers, engines and the friction of the ship hull as it passes through the water. Large oil tankers are one of the main sources of low frequency sound with noise levels of 200 dB at 2Hz recorded at 337 m from one vessel steaming at 17 knots (Gordon and Moscrop 1996). Areas with intensive maritime traffic such as the Alborán Sea and especially the Strait of Gibraltar have a fairly constant high noise level.

Small boats with fast moving propellers that cavitate easily can produce high sound levels at higher frequencies. For example, it has been estimated that at 50 m from a speed boat of 70HP travelling at full power, the sound levels can be approximately 142 dB, in the frequency range 400 – 4000 Hz (Gordon and Moscrop 1996).

4.3.1.2. Military and research vessels

There are four regular areas for target practice or military manoeuvres: Bay of Almería, south of Almería - Island of Alborán, south of Cadiz and south of Cartagena. Both the Spanish Navy and NATO vessels often transit the area undergoing different types of military activity.

Military vessels use a broad range of active sonars. Details on some of this equipment and their sound levels are classified as secret and therefore little is known. However, military vessels carry out frequent training exercises during which they use deep charges, mines, explosions, etc., which result in an important source of noise into the sea (Richardson *et al*.1995).

The most important navy base in the study area is at Cartagena. There are arsenals of weapons, vessels and submarines within this base and the port is frequently used as a stop for other ships and submarines of the NATO fleet (IGN 1996). In addition there are two explosives landfills, one abandoned one south of Punta Europa (Gibraltar), and another one south of Cartagena.

Due to the strategic military interest in the Alborán Sea area and the Strait of Gibraltar, and also due to the proximity of the important navy base at Cartagena, military exercises are fairly frequent, both Spanish and under NATO auspices. These exercises usually include shooting, underwater explosions and the use of powerful sonars. All these are factors to consider when analysing the threats to marine mammals in the area.

The Alborán basin is also subject to seismic surveys for the exploitation of petroleum and gas. Seismic exploration often involves the production of strong pulses of sound, mainly at low frequencies, in the form of serial detonations. These detonation pulses are easily detected more than 100 km away (Richardson *et al*.1995). During summer 2000, the Spanish boat Hespérides carried out seismic research called "TECALB" (Tectonic, Structure and Morphology of the Basins and Margins of the Alborán Sea and South-Baleares) in the Alborán Sea and Gulf of Vera, to record seismic profiles and other geophysical data (Source: Consejo Superior de Investigaciones Científicas). Further explorations have followed. Data gathered during the seismic campaign TECLAB in the Alborán Sea are also being used as a baseline for a new proposal for drilling to the Integrated Ocean Drilling Program (ODP / IODP) in the Western Mediterranean (Source: Consejo Superior de Investigaciones Científicas; www.iodp.org).

4.3.2. Possible threats to cetaceans

4.3.2.1. Toxic pollution

Data from the Cabo de Gata Trafico and Tarifa Trafico control stations and statistics on port movements provide complete information about the volume of ship traffic as well as details on the transit of ships with dangerous cargo, or ferries and fast ferries lines. In addition, the *in situ* observations show the potential risk to species and their habitats. For example, a REPSOL oil tanker ran aground on a beach in the Cabo de Gata - Nijar Natural Park on 10 July 1992. Fortunately it was towed off the next day by two ocean going tugs, thanks to the good sea conditions. This incident is just one example of the potential risk of such intense maritime traffic. According to the European Environment Agency about 2,000 ships pass through the area each day (30% of world-wide traffic) of which between 250 and 300 are tankers (20% of world-wide traffic). According to data from *Lloyds Casualty Reporting Service*, maritime traffic accidents spill between 12 and 13,000 tons of hydrocarbons into the Mediterranean each year.

In addition, there are many fishing and pleasure boats in the area, that use 39 sport harbours and 30 fishing ports in the study area. Marine sport has increased during the last decade, and with it the demand of moorings for sport boats. Sport harbours are sometimes located in places of great ecological value (e.g. Port of Marina del Este, Port of San José) without considering the impact of mechanical destruction of the sea bed, contamination and the effects of changes in currents and sedimentation. There are plans for new sport harbours as well as extension of several existing ones (among them San José, in the heart of the National Park of Cabo de Gata-Níjar). Furthermore, once constructed, the breach of basic norms of protection of the marine environment, such as lack of facilities for the recovery of debris or direct spills of antifouling paint residuals in docks, turn these harbour facilities into important sources of pollution.

Persistent toxic residuals such as organo-halogenated compounds or heavy metals enter the marine trophic web and accumulate in predators like cetaceans.

4.3.2.2. Collision

In most cases the presence of ships does not seem to constitute a collision risk for small dolphins, although it can be for big whales (Panigada *et al*. In preparation).

4.3.2.3. Acoustic pollution

Observations of the most common odontocetes in the region clearly show that they are, to some extent, habituated to the transit of ships because very rarely they were seen to be visibly disturbed by them. But this does not necessarily mean that the ship's noise does not have a negative impact on the populations that inhabit areas of intense traffic. Studies on the effects of acoustic pollution in cetaceans through the analysis of their ears, show that the prolonged exposure to certain frequencies of sounds may cause an erosion in the parts of the internal ear that detect these frequencies, yielding a partial deafness (Ketten 1998).

In the case of certain especially intense sounds (sonars, explosions) the effect on cetaceans can be more damaging. In some cases the intensity of the waves can produce serious injuries or important behavioural changes that can cause the death. This seems to be the case of some military sonars such as LFA (Low Frequency Active Sonar) or others of medium or high frequency, that have caused important mass strandings of beaked whales in several places (Greece, Canary Islands, Madeira, Bahamas) (Frantzis 1998; IWC 2001; Jepson *et al*. 2003) giving rise to a vigorous debate about its use (Gordon *et al*. 2003).

4.4. TOURISM

4.4.1. Review of situation

4.4.1.1. Tourism along the coast

Spain is one of the leading tourist destinations in the world. According to data from the WTO (World Tourism Organisation) more than 23 millions tourists came to Spain in 1980 (8,46% of the world's total), second only to France, whilst in 1992 it moved to the third place, behind France and the United States, with almost 40 millions of visitors (8,23% of the world's total). If day visitors are also considered, the total number of entries in Spain in 1992 was greater than 55 million people, and >57 million in 1993. In Spain, the main tourist attractions are the coasts and beaches, and there is a strong seasonality with a larger number of visitors concentrated in the summer months (IGN 1994). In the study area, tourism varies by area; it is less in Almería and Cádiz (including Strait of Gibraltar) than in Murcia, Granada and Málaga, where there is a mass tourism (EEA 1999).

4.4.1.2. Leisure craft (sail and motor boats)

Yachts in transit travel East - West, generally without course variations. On some occasions small course alterations were observed for the observation of cetaceans, and generally approaches to the animals were correct (at slow speed and without sudden changes of course). Nevertheless, the chasing of dolphins with speedboats and ski-jets were observed on several occasions (Punta Calaburras, Fuengirola and Estepona).

Most boats of this type occurred along the tourist coasts of Malaga and Estepona (mainly local tourism and yachts in transit), in the Straits of Gibraltar (mainly whale-watching) and, to a lesser extent, in the area of Cabo de Gata in Almeria (mainly yachts in transit) (Figure 4.5).

4.4.1.3. Whale watching

‘Whale-watching’ is a relatively recent activity in Andalusia. Two main nuclei exist at the moment: Fuengirola and Benalmádena (common dolphin) and the Straits of Gibraltar (common, striped and bottlenose dolphins, pilot whale, sperm whale and orca).

Whale watching is now an important tourist and recreational activity. In involves environmental education, investigation and other socioeconomic aspects such as the creation of employment. Whale watching started in San Diego, United States, in the 1950s and has been increasing world-wide since 1991, when the number of people was slightly more than 4 million per year, increasing to 5.4 million in 1994, up to 9 million in 1998.

Whale watching activities have increased a lot in recent years in the western sector of the Alborán Sea and especially in the Strait of Gibraltar. In 1999, there were 5 boats dedicated to this activity in the area of the Strait (de Stephanis *et al.* 2000). In 2002 there were 13 with a capacity for 611 tourists, and the ‘whale-watching’ area started to extend to the port of Estepona, Fuengirola and Benalmádena, with some other boats operating from these ports.

Whale watching in the Straits can be divided in three categories, based on the target cetacean species and the sighting area: a) Bay of Algeciras for common and striped dolphins; b) central area of the Straits for pilot whales, bottlenose, striped and common dolphins and sperm whales; and c) southwest of the Straits dedicated to the observation of the interactions between orcas and the tuna fisheries.

Observations made during the sampling stations in the waters off Tarifa showed an appropriate approach of the whale-watching boats to sperm whales and pilot whales (slow speed, no sudden changes in course, and avoiding harassment and crowding of boats). Nevertheless, the main location of this activity to the south of Tarifa coincides with the TSS for regulation of marine traffic in the Straits. Manoeuvres by these whale-watching boats as well as by the local fishing boats are made regularly in a way that could be dangerous in this important traffic scheme for merchant ships. The control station of Tarifa Tráfico does its best to control this situation also showing great interest in the presence of cetaceans in the area, and collaborating with the traditional fishing of Tarifa and the whale-watching companies of Tarifa and Algeciras.

4.4.2. Possible threats to cetaceans

Mass tourism along the Andalusian coast creates several problems for the marine environment. The most important is that waste water treatments plants in the places that takes most tourists during the summer are not fully prepared. The majority of waste water produced during the summer is released straight into the sea through outfalls, contributing to the water pollution and having potentially important effects on cetacean health.

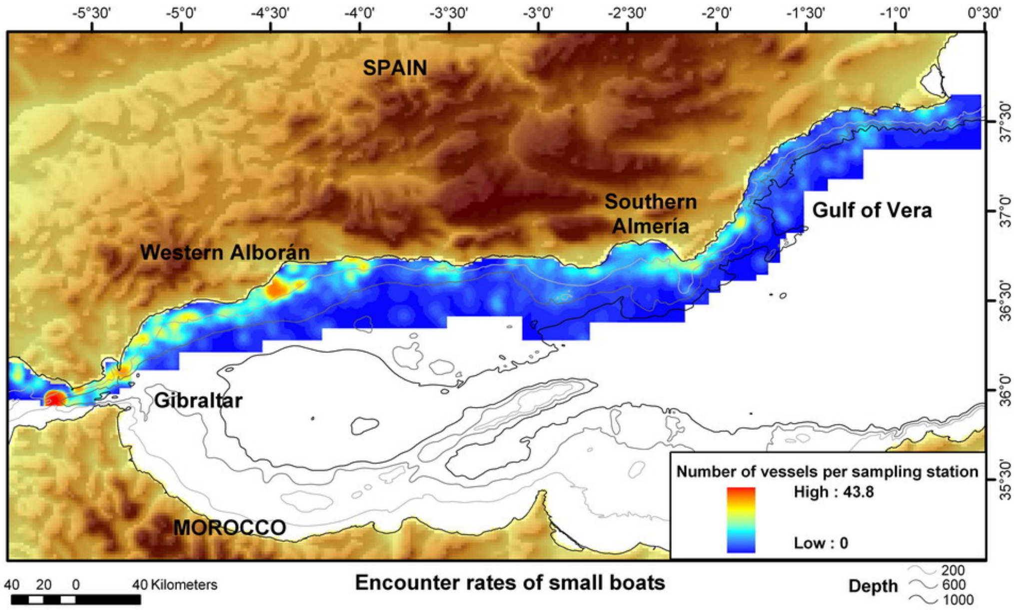

Figure 4.5. Encounter rates of leisure sailing and motor boats

Recreational navigation should not in principle constitute a threat for cetaceans and their habitats. Observations at sea show, however, that irresponsible behaviour can produce an important risk for cetaceans and the marine environment, and for navigation in general (e.g. anchorage in marine prairies of phanerogams, spills or garbage thrown into the sea and persecution of cetaceans with jet-skis and speed boats). In all recorded cases of persecutions or harassment of cetaceans, they could be linked directly to boats or rental jet-skis in zones of tourist affluence (Estepona, Fuengirola, Benalmádena). Harassment can produce alterations in the behaviour of the animals, stress and exclusion from the area if disturbance is persistent.

Studies on the effect of whale-watching activities on cetaceans (Schultz and Bailey 1978; IFAW 1995; IFAW 1996), together with experience in the Canary Islands, highlight the necessity for a regulation of the activity. The whale-watching companies in Tarifa voluntarily established a code of conduct in 2001 in accordance with that approved by the Government of the Canary Islands in 1995, and modified in 2000. This regulation requires: a) the obligatory of specific authorization to develop this activity; b) a Code of Conduct based on the development of non-intrusive activities, avoiding bothering or harming the animals, establishing a maximum approach distance, making the correct manoeuvre without harassing the animals, and not crowding boats together; and c) taking a guide specialising in cetacean observation, among other factors. However, this agreement could fail due to increasing competition, and to the arrival of new platforms, both in established places and in potentially exploitable ones. It is anticipated that a Royal Decree of the Ministry of Environment that regulates these activities will get final approval shortly. This Decree will be a basic framework that must then be implemented by the Regional Governments.

4.5. FISHERIES

4.5.1. Review of situation

Direct observations at sea complement official statistical data that for various reasons do not always reflect reality. These direct observations contribute important information on illegal fishing activities such as trawling in waters less than fifty meters deep or prohibited fisheries in waters of the EC.

At first sight, it could be thought that fisheries is one of the main industries in Andalucía, but the apparent importance of the fishing sector is due more to its social root than to its contribution to the regional economy, which does not exceed 1%. In spite of this, commercial fishing is one of the human activities with the greatest impact on the marine environment.

Andalusian fisheries have been in crisis for years and are maintained mainly thanks to subsidies from the European Union. There is no obvious solution to this problem. In Andalusia there are about 17,000 registered professional fishermen. However, these data as well as the registry of boats and the technical characteristics of the fleet are very far from reality. The statistical data have therefore a limited utility for the analysis of the present situation of commercial fisheries and their impact on the marine environment. Data on fish landings and registry of the fleet are also difficult to analyze because of movements of the fleets from one port to another.

Fishing is extensive across the whole study area. The total fishing fleet based at ports in the Strait of Gibraltar (not considering the Morocco fleet) is 750 boats, which mainly use long lines, gillnets and maze nets. There is no trawling in this area. The most common fishing methods in the Alborán Sea are trawling and long lining followed by bottom gill netting and purse-seining. In the Strait of Gibraltar, the Seco de los Olivos and near Málaga there is intense sport fishing.

The preferred target species in the Alborán Sea is the sardine, which constitutes the main catch in Málaga and Almería. Other important species are garfish, mackerel, anchovy, blue whiting, plain bonito, prawns and octopus amongst others.

In 2000, the Spanish Oceanography Institute carried out a review of the historic catches of small pelagic fish in the Spanish Mediterranean between 1945 and 1997 (Giráldez and Abad 2000). According to this report, sardines catches have decreased in the South-Mediterranean region (Cabo de Gata to Strait of Gibraltar), but increased in the levantine region (Cabo de la Nao to Cabo de Gata) and in the north (border with France to Cabo de la Nao). However, during the 1990s there was a widespread decrease in sardine catches in the three regions. There was a big decrease in anchovy catches in 1985, following a few years of intensive fishing, and there has been no recovery since then. In the northern region, catches increased significantly from 1966, but are currently very low. The two previous species are caught by purse-seiners. The horse mackerel, another important small pelagic species, is caught both by trawling and purse-seining. In all regions there was a very sharp increase in the catches of the two mackerel species (*Trachurus trachurus* and *T. mediterraneus*) between 1950 and 1955, which subsequently decreased to very low levels, especially in the South-Mediterranean region in 1985. Catches of Atlantic mackerel show large oscillations without a specific pattern, but currently there are low catches in all regions. The catches of gilt sardine are small, but have increased in the Eastern Spanish region during the last decade.

Giráldez and Abad 2000 also state that there are 136 purse-seine boats of which 91% are smaller than 40 gross tonnes, with the average tonnage being 18.1 tonnes, in the South-Mediterranean region. There has been a 41% decrease in the number of boats over 18 years (in 1980 a total of 231 boats were recorded), especially of the large tonnage boats, mainly due to the decrease in the anchovy catches. The sardine is caught in the whole area, especially from Almería, Adra and Málaga, which are the three most important ports.But this species is not so important from the economic point of view, and the main target of the purse-seine netting fleet is the anchovy, due to its high price. Currently, the only anchovy fishing ground in the north of the Alborán Sea is Málaga bay, where 85% of the total is taken. There is another important fishing ground in the southern area along the coasts of the Morocco, to which the Spanish fleet has no access since 1984.

The data collected at the sampling stations showed the main fishing areas of the fleets working during day light. However, they do not reflect the fishing grounds of some important activities such as purse seining small pelagic fish that operate at night with the aid of lights. The fishing boats traffic concentrates in waters of the continental shelf and its slope, consisting mainly on small boats of between five (gill-netters) and thirty meters (trawlers and longliners). In deeper waters longliners of the Spanish fleet as well as foreign fishing boats were observed (factory ships, tuna fishing boats, etc.).

Observations at sea show also some quite worrisome aspects of the reality of the fisheries in waters of Andalusia and Murcia. Landings of fish outside the market is habitual throughout the coast. There is a complete lack of control in ports like Almerimar, where the fleets of Adra and Almería can operate without any supervision. Trawling during prohibited times has also been observed regularly throughout the study. This is of particular concern when it happens in especially vulnerable areas of high ecological value, such as the surroundings of the Island of Alborán, the waters of Cabo de Gata - Nijar Natural Park or in waters less than fifty meters deep with sea grass prairies near Almería, Granada and Malaga.

4.5.1.1. Trawling

Trawlers (Photo 4.1. and 4.2.) were the most abundant fishing vessels in the study area (Table 4.1), especially in the coastal zones off Southern Almería (between the western half of the bay and Adra, including the surroundings of the Seco de los Olivos), in front of Estepona, the coastal zone of Granada and the bay of Málaga, and in front of Garrucha and Carboneras in the Gulf of Vera (Figure 4.6). Trawling does not occur in the Straits of Gibraltar.

Photo 4.1. Trawler trawling

Photo 4.2. Trawler hauling the net

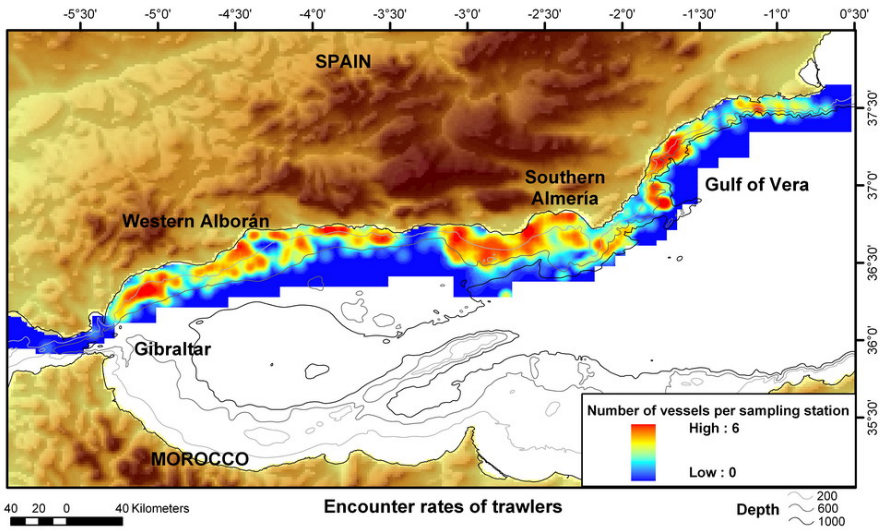

Figure 4.6. Encounter rates of trawling fishing boats

Although trawling is only legal in depths of more than fifty meters, frequent trawls in shallower depths were observed, even in especially vulnerable zones like the prairies of *Posidonia oceanica* of Cabo de Gata, Almería bay and the coastal zone of Granada. Trawlers were also observed working in non-permitted hours and days. There is an important volume of plastic debris gathered from the sea floor by the trawlers, which is generally thrown back to the sea.

4.5.1.2. Long lines

The longlining fishing boats (Photo 4.4) were observed mainly in the Gulf of Vera (and especially off Carboneras, the main longlining port of the region), in the Strait of Gibraltar and in the region of Seco de los Olivos and other areas off Southern Almería (Figure 4.7). Andalusia has an important surface longlining fleet for swordfish, but a section of this fleet regularly fishes in other regions (e.g. Balearic Sea and international waters), which may explain the relatively low number of observations recorded during the sampling stations.

Photo 4.4. Long liner with the buoys on the aft

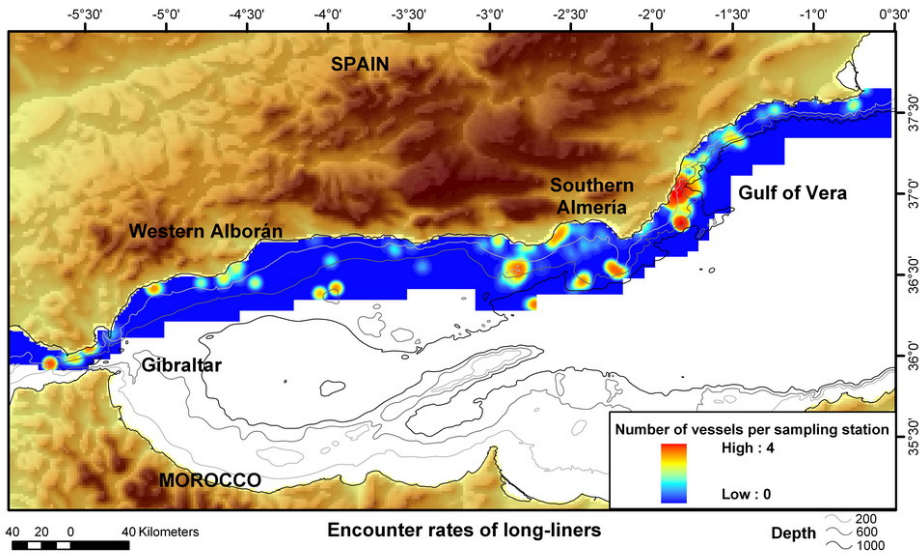

Figure 4.7. Encounter rates of long-lining fishing boats

<u>Tuna targeted fishing in the Strait of Gibraltar</u>

In the Strait of Gibraltar there is a fishery targeting bluefin tuna (*Thunnus thynnus*). The vessels are small fishing boats from Morocco using hand lines and larger ships from Spain using a modified type of long line (Photo 4.5). The bluefin tuna is also caught in the southern area of Almería using a hand line between May and August (IGN 1991c).

Photo 4.5. Tuna fishing boat from Morocco using hand lines. In the background are Spanish tuna fishing vessels. Strait of Gibraltar.

4.5.1.3. Gill-netting

Gillnetting is a passive fishing method, used closer to the shore, in which fish are trapped in a vertically anchored net, either on the sea bed (bottom set gillnet) or at the surface (driftnet). In the latter case the net can move as a result of the tides and currents.

<u>Bottom gillnets</u>

Bottom gill-netters (Photos 4.6 and 4.7) were observed mainly in the Gulf of Cádiz, and also along the coasts of Fuengirola, Gulf of Vera (especially between Carboneras and Garrucha) and off Southern Almería (especially between the port of Almerimar and Seco de los Olivos) (Figure 4.8).

Photo 4.6. Gill netter

Photo 4.7. Gill netter hauling the net

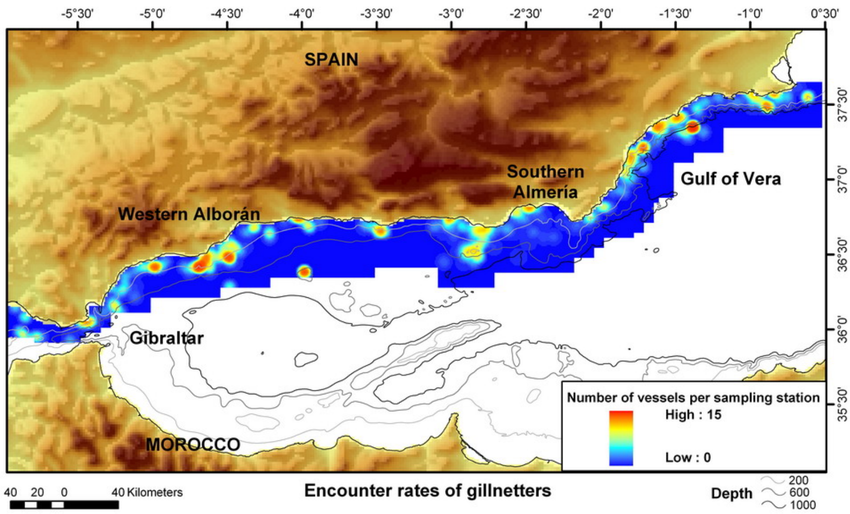

Figure 4.8. Encounter rates of gill-netting fishing boats

Drift nets

Drift nets in the Mediterranean have mostly been used to catch swordfish, although they have also been (and still are) used to target other pelagic species such as bluefin tuna, bonito, bullet tuna and several species of pelagic sharks. In 1992, the European Community prohibited driftnet fishing in the Mediterranean with nets longer than 2.5 km (European Regulation EC No 345/92), as did the General Fisheries Commission for the Mediterranean (GFCM) in 1997 under binding Resolution 97/1. A total ban on driftnet fishing - irrespective of net size - on large pelagic species by EU fleets within and outside Community waters in the Mediterranean entered into force on 1 January 2002 (European Regulation EC No. 1239/98). Despite this ban, driftnets continue to be used in the Mediterranean For example, a study carried out by WWF and AZIR in 2002 and 2003 in Morocco showed the important driftnet fleet in this country and the associated by-catch of cetaceans (Tudela *et al*. 2005).

Photos 4.8 and 4.9 show a large piece of driftnet that came close to the coast of Almería. In this mess of net there were many sunfish, a swordfish, several other species of fish and a juvenile striped dolphin.

Photo 4.8. Drift net with sunfish

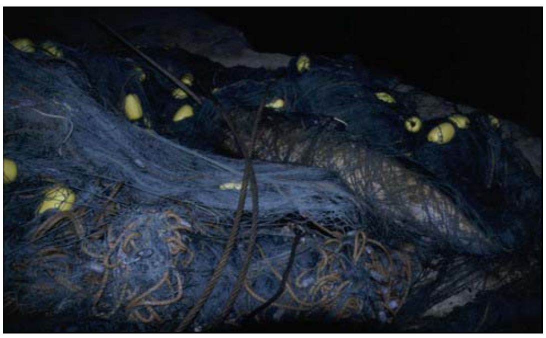

Photo 4.9. Drift net with a swordfish

4.5.1.4. Purse seiners

In the study area, the purse seine is mainly used for small epipelagic fish like sardines and anchovies (Photo 4.10 and 4.11).

Photo 4.10. Purse seiner

Photo 4.11. Purse seiner hauling the net

There were almost no recorded observations of this fishery during the on effort transects because it operates at night. According to the data on this fishery published by the Spanish Institute of Oceanography (Abad and Giráldez 1997), the main fishing grounds in the study area are the coastal waters of Almería bay, Málaga bay and Estepona.

Personal comments from fishermen point at an important crisis in this fishery throughout the last decade due first to the closing of the Moroccan grounds and second to the shortage of sardine and anchovy. According to the fishermen from Almería, other species of small pelagic fish of little or no commercial value such as the round sardinella (*Sardinella aurita*) or the needle fish (*Belone belone*) could have taken advantage of the decline in sardine and anchovy. In recent years, the commercial capture of these species has increased for food for the aquaculture farms for tuna fattening.

4.5.1.5. Fishing with traps

<u>*Trap baskets*</u>

Baited trap baskets and pots are placed on the sea bed to trap fish or shrimps (Photo 4.12). The use of trap baskets has been observed mainly in Almería and Águilas (Murcia). According to personal comments from fishermen as well as from a study done by Greenpeace in 1991 (X. Pastor, com. pers.), the use of dolphin blubber as bait for this type of trap was common, especially in the Gulf of Vera, until a few years ago.

Photo 4.12. Trap fishing boat

<u>*Maze nets*</u>

Maze nets are arranged in such a way to create a maze from which fish are unable to escape, and are mainly used for tuna fish. There is a fishery for blufin tuna using mainly maze nets during July and August on both sides of the Strait of Gibraltar (IGN 1991c) (Photos 4.13 and 4.14).

Photo 4.13. Maze net in Barbate

Photo 4.14. Maze net in Barbate

4.5.1.6. Sport fishing

The sport fishermen concentrate their activity in particular areas relatively near their home ports, such as the Seco de los Olivos, the coast of Motril, Calaburras and off Benalmádena, el Placer de las Bóvedas and in the fishing grounds of the Straits (Figure 4.9). There has been an important increase in this activity during recent years in various places along the coast of Andalusia.

The target species of most sport fishing are the swordfish (*Xiphias gladius*) and the blue fin tuna (*Thunnus thynnus*). Sport fishing is responsible for a large number of captures of tunas around the Strait of Gibraltar (Photo 4.15).

More than 100 small sport fishing boats have been recorded in a single sampling station (radius of 5.5 km), especially in Seco de los Olivos. As for other activities identified as possible threats, sport fishing becomes a potential risk when it is undertaken in an uncontrolled or illegal form, because it can contribute markedly to the overexploitation of endangered species in the Mediterranean.

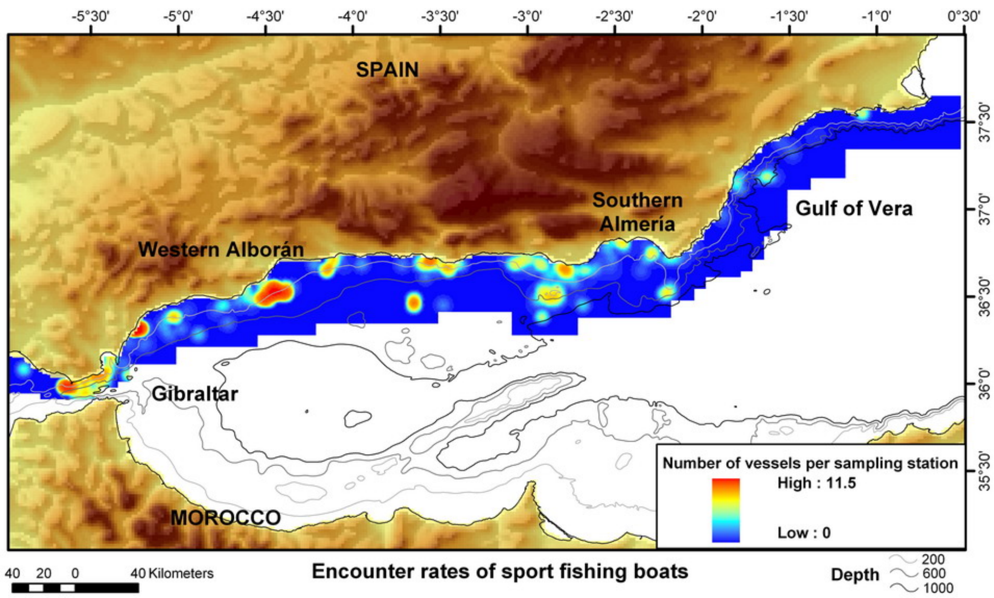

Figure 4.9. Encounter rates of sport fishing boats

Photo 4.15. Large tuna captured by a sport fishing boat near the Strait of Gibraltar.

4.5.1.7. Aquaculture

Aquaculture is increasing along the Andalusian and especially the Murcian coasts in recent years. The main target species is the gilthead seabream followed by far by the European seabass, *Mugilidae* and the sole, although tuna fattening farms are also being developed. Prawn and shrimp fattening and the culture of giant oyster and clam are also important. Aquaculture farms are found especially in the area off Southern Murcia, and off the ports of Carboneras, Almería, Aguadulce and Benalmádena.

4.5.2. Possible threats to cetaceans

4.5.2.1. Accidental captures or by-catch

The accidental capture of non target species or "by-catch" is one of the biggest problems associated with fisheries. In spite of its important impact on the marine environment, this problem is generally not considered until it affects "emblematic" species like cetaceans or marine turtles.

In the study area the loggerhead turtle (*Caretta caretta*) is by-caught by surface longlining, with an annual accidental capture of more than 20,000 turtles in the Spanish Mediterranean. Most cases of accidental capture of cetaceans are anecdotal along the coasts of Andalusia and Murcia. Reported cases of entanglement in surface longlines, in purse seines or gillnets, or catches in trawl nets are very few in this area.

The accidental capture of 3 species of cetaceans in the Spanish swordfish and tuna longlining fleet in the Mediterranean was observed in a study carried out by the I.E.O. (Valeiras and Camiñas 2002): striped dolphin (7 individuals), Risso's dolphin (7 individuals) and unidentified beaked whale (1 individual), during 798 sets. The rate of accidental capture was between 0.001 and 0.008 cetaceans per 1,000 hooks depending on the type of line (4 types studied); surface longlining for swordfish had the maximum rate of accidental capture, whereas no captures were detected in stone-ball longlining (semipelagic). Most of these cetaceans were entangled in the line, 2 died by asphyxia and 3 were caught when biting the baited hook. Therefore, longlining represents a risk for cetaceans, especially those of oceanic habits, although it does not seem to be, by the rate of captures, a serious threat for the populations.

This it is not the case for accidental captures of cetaceans in pelagic driftnets. These nets, prohibited in Spain since 1988 and in European waters since 2001, are used by various foreign fleets in the Alborán Sea, especially from Morocco (Tudela *et al*. 2005). To ascertain its biodiversity impact, 369 fishing operations (4,140 km of driftnets set) made by the driftnet fleet targeting swordfish based in Al Hoceima (Alborán Sea) were monitored. An estimated by-catch of around 3,000 common and striped dolphins (approximately 50% each species) occurs in the Alborán Sea. As a result of the publication of this study, Moroccan authorities openly recognized the problem and announced the launching of a phase-out plan for the fleet, to be completely eradicated in four-years time.

In April and May of 2002 several strandings of sperm whale, striped and bottlenose dolphins and pilot whales entangled in pieces of driftnets were recorded. Simultaneously there were many complains by the fishermen brotherhood of Adra (Almería) for the presence of driftnets around the Island of Alborán. The observations made *in situ* allowed verifying the presence of boats registered in Morocco fishing with driftnets only two miles from the island, inside the fishing reserve.

Gillnetting can have significant by-catches of bottlenose dolphin and harbour porpoise in other regions (Bearzi 2002; Cox *et al*. 2003; Forcada et al. 2004; Larsen 2004; Vinther and Larsen 2004). The results of this study showed interactions between bottlenose dolphins and gillnets in the region of Murcia, with only one entanglement recorded.

4.5.2.2. Direct captures

Direct captures of small cetaceans and in particular of bottlenose and common dolphins were, until recently, regular in some fishing ports of the region (Adra, Almería, Carboneras, Garrucha). Dolphins were captured by means of harpoon, and their blubber was used as bait in trap baskets. Although it is probable that some fishermen continue this activity, everything indicates that it has been abandoned during the last decade, mainly due to the presence of our research boat, according to direct comments from fishermen. During the period 1999 - 2004 there has been only a single record of deliberate capture by the Cantabrian tuna fishing fleet boats in the Straits of Gibraltar in winter 2001.

4.5.2.3. Competition for resources

The harvest of fishing resources constitutes one of the main threats to cetaceans.

For most coastal species such as the bottlenose and the common dolphin, direct competition with fisheries probably exists because these species feed mainly on commercially harvested species of the continental shelf and shelf edge. In the case of the common dolphin, this competition may have increased to a great extent during recent years with the intense exploitation of round sardinella, a species of little commercial value that is being captured now to supply the tuna fattening farms. In some regions (Almería - Murcia), the purse seine fleet works mainly for the tuna fattening farms and/or aquaculture companies through collaborative agreements.

Bottlenose dolphins, and rarely common dolphins, could be observed in several occasions taking advantage of the trawl fishing. The bottlenose dolphin is a species widely known by its frequent interactions with fisheries, especially with trawling and gillnets. In our area, interactions are recorded mainly with trawling: dolphins follow the trawlers when these are working, and make frequent immersions at the level of the net. This feeding strategy, habitual in bottlenose dolphins in the Mediterranean Sea and other regions (e.g. Fortuna *et al.* 1996; Bearzi and Notarbartolo di Sciara 1997; Fertl and Leatherwood 1997; Chilvers and Corkeron 2001), does not apparently entail any negative effect for the fishermen.

This type of interaction between bottlenose dolphins and the trawling was also observed in a study carried out by the I.E.O., highlighting in addition that fishermen suggest that these dolphins are beneficial for the fishing, since the catches of hake seem to increase when they follow the net. In fact, a larger capture of hake was observed in the same trawling area when bottlenose dolphins were following the boats (Abad *et al.* 2001). This could be because dolphins follow boats that are or located over good fishing areas or because the presence of dolphins generates a cornering of fish towards the net.

The results of this study did not show significant number of cases of interaction between bottlenose dolphins and gillnets in the region. Nevertheless, personal comments from fishermen in several ports refer to damage of gillnets by bottlenose dolphins when they use these nets to corner prey.

For the majority of the other cetacean species present in the region, direct competition probably does not exist because they feed mainly on cephalopods or fish of little or null commercial value.

4.5.2.4. Mechanical destruction of the sea floor

Trawling is the main method of fishing over the continental shelf over most of the study area. Due to the over-exploitation of resources, mainly demersal fish and red prawn, the catches of these fisheries at the moment are very limited in volume and especially in value. Nevertheless, instead of reducing its effort to allow a regeneration of stocks, the fleet has increased its hours of trawling or fishes in waters less than fifty meters deep, despite being prohibited.

The main impact of this fishery is the mechanical destruction of the sea floor and especially of prey aggregating benthic habitats. The net, its cables and the doors that keep the net open are dragged over the sea bed causing the destruction of fragile habitats like the marine prairies of phanerogams and resulting in erosion of the sea bed. Fishing effort is practically continuous throughout the day.

This has an indirect but potentially important effect on populations of cetaceans because it affects the survival of the prey on which they feed, *inter alia* by destroying the habitat of the juveniles of these prey.

4. 6. INDUSTRIAL AND URBAN WASTE

4.6.1. Review of situation

4.6.1.1. Energy centres

Land-based centres which produce or use potentially hazardous toxic or harmful chemicals are important because although there is no disposal at sea, they can be a threat to the marine ecosystem if they produce accidental spills or through the constant emission of by-products or wastes. Such is the case of energy producing centres. In the case of energy centres associated with sea ports there is the added problem of transporting these dangerous substances (hydrocarbons and gas) to and from these ports, therefore increasing the risk of spills in the area.

Within the Gulf of Vera there are 3 important energy centres: the oil refinery at Escombreras (Cartagena), the Thermal Oil-Gas Station at Escombreras, and the Thermal Coal Station at Carboneras (Almería). In the Alborán Sea area there is a Thermal Oil-Gas Station in Almería and another one in Málaga. In Málaga there is also an installation for the production of manufactured gas. In the Strait of Gibraltar there is a large accumulation of energy centres, especially on the outskirts of Algeciras. In the City of Ceuta there is a Thermal Oil-Gas Station, whilst in Algeciras there is a Thermal Coal Station and an Oil-Gas Station, an oil refinery and two self-producing Thermal Stations (IGN 1991a).

4.6.1.2. River contributions

There are very few rivers in the study area and have all low flow rates. In many cases, they are dry most of the year, but sometimes intense and continuous rain results in large floods. This is the case for the dry riverbeds ("ramblas").

In the Gulf of Vera only the river Almanzora is noteworthy, described by the General Direction of Hydraulic Works as a river with medium contamination according to the I.C.G or General Quality Index (IGN 1991b). In Alborán, 3 rivers should be mentioned: the Guadalhorce in Málaga with high levels of contamination, the Andarax in Almería also with high contamination, and finally the Guadalfeo, a river with medium contamination in Motril. The mouth of the three most westerly rivers (of Gibraltar-Estepona, Málaga and Motril), coincides with the three areas of the coast that have the highest coliform and heavy metals concentration according to the General Secretary of the Environment (IGN 1991b).

4.6.1.3. Agricultural fertilisers and pesticides

Agriculture is an important source of water contamination. Through mechanisms such as the floods produced by rainfall or normal water currents and the transport of sediments, large quantities of phosphorous, nitrogen, pesticides, metals, pathogens, salts and trace elements are transported directly to the sea.

The entry into the sea sediments of substances such as nitrogen, phosphorous and organic carbon, as a result of fertilisers, can result in the eutrophication of certain areas. Eutrophication phenomena have been detected along the coasts of Málaga (UNEP/FAO/WHO 1996).

Pesticides from agriculture are an important contaminating source in the Mediterranean, with the added problem that they are difficult to degrade (EEA 1999). Pesticides and their derivatives, and specially PCBs (polychlorinated biphenyls) are bioaccumulative and are associated with degenerative diseases with immunodeficiency and reproductive impairment. As an example, in the epizootic of striped dolphins which occurred in 1991 in the western Mediterranean, high levels of PCBs were recorded in necropsies, which were linked to a possible immunodeficiency of the animals made easier through infection by morvillivirus (Borrell and Aguilar 1991).

Problems with fertiliser and pesticides from agriculture are more intense in Almería than in other areas of the study area mainly due to intensive greenhouse agriculture, which has grown exponentially during recent decades, as can be seen in the satellite images of Almería taken in 1974 and 30 years later in 2004 (Photos 4.16 and 4.17).

Photo 4.16. Satellite image of Almería in 1974. The white colour on the top is snow.

Photo 4.17. Satellite image of Almería in 2004. The white colour on land represents the greenhouses.

4.6.1.4. Quality of water and contamination levels

In 1984, UNEP presented a study on the contaminants of the Mediterranean based on land sources (UNEP 1984). This study divided the Mediterranean basin into 10 geographical areas. The so called area I includes the Alborán Sea and Gulf of Vera to Cabo de Palos, which corresponds to our study area. According to this study, this area was much less contaminated than the adjacent areas II (north-western basin, between the Valencia and Balearic coast, to Corsica, France and Italy) and III (south of Baleares to Africa and Sardinia).

According to data of the European Environment Agency (EEA 1999) and Greenpeace (Greenpeace 2002) there are 82 submarine outfalls in Andalusia of which the majority release untreated waters. There are about 2,000 other points of release including 47 industrial outfalls. The main industrial nuclei of the region are in Huelva, Cádiz, Algeciras, Málaga, Motril and Cartagena, but there are also other important sources of pollution such as commercial ports and marinas, industries located right at the border of the sea (thermal power station at Carboneras, cement industry at Carboneras, co-generation centre in Villaricos, petroleum refineries in Algeciras and Escombreras, Cartagena), beaches regenerated with sands loaded with heavy metals (Carchuna - Granada) and areas of intensive agriculture with important use of biocides, fertilizers and plastics (Almería).

During 1981 and 1982, the Spanish Institute of Oceanography carried out a study on the concentrations of cadmium, lead and zinc in the surface waters of the Alborán Sea (Guerrero 1986). It was found that these concentrations were slightly higher in stations closer to the coast, but in general, similarly to the conclusions of the UNEP, they were significantly lower than those of other Mediterranean areas.

In the northern sector of the Gulf of Vera, the city of Cartagena is heavily industrialised; Portman bay had intense mining activity until the beginning of the 1990s. Both these places have had high marine contamination in the region as highlighted by some studies by the Spanish Institute of Oceanography (Guerrero *et al*. 1989; Guerrero and Rodríguez 1990).

The presence of solid debris was recorded during surveys. In most cases they consisted of small plastic bags, but all type of debris were observed: bottles, feminine hygienic towels, small pieces of plastic, enormous garbage bags (full and possibly thrown into the sea by large vessels), cans, mattresses, wooden boxes, etc. The volume of debris was especially high in frontal zones of currents as well as along the main transit routes of merchant ships and ferries.

Hydrocarbon spills were frequently recorded along the main transit routes of merchant ships. Some of these bilge cleaning operations were directly observed (for example, 8 km south of the valuable marine area of the Punta Entinas - Sabinar SAC (SAC ES6110009)). Bilge cleaning by merchant ships and tank cleaning by oil tankers is regularly conducted, generally at night.

4.6.2. Potential threats to cetaceans

Contamination of the trophic web constitutes a major threat to cetaceans. But the dimension and dynamics of the oceans make the control and elimination of persistent polluting agents, such as plastic bags, organ-chlorate compounds and heavy metals, very difficult. Although once in the marine environment these polluting agents can spread, their effects are usually more concentrated around their areas of origin: the ports, outfalls and river mouths of the populated and industrialized regions. The impacts of this type of contamination are difficult to establish.

Plastic bags and other plastic residues remain in the water column for years before being deposited at the bottom of the sea. This debris may be ingested by cetaceans and marine turtles, in some cases causing death. Persistent toxic residuals may cause important health problems in cetaceans.

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CHAPTER 5

DISTRIBUTION OF CETACEANS OFF SOUTHERN ALMERÍA

Cañadas, A., R. Sagarminaga and S. García-Tiscar. 2002. Cetacean distribution related with depth and slope in the Mediterranean waters off Southern Spain. Deep Sea Research I 49: 2053-2073.

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Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain

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Abstract

The northeastern section of the Alboran Sea is currently under consideration as a Special Area for Conservation under the European Union's Habitat Directive. Within this framework, the present study focuses on the distribution of cetaceans in this area and is part of the Spanish Ministry of the Environment's "Program for the Identification of Areas of Special Interest for the Conservation of Cetaceans in the Spanish Mediterranean". Shipboard visual surveys were conducted in 1992 and from 1995 to 2001 in the north-eastern Alboran Sea, covering 14,409 km. A total of 1,134 sightings of cetaceans were made. From the data collected, the distribution of seven species of odontocete was examined with respect to two physiographic variables, water depth and slope. Analyses of χ^2 and fitting of GLMs demonstrated significant differences in distribution for all species, mainly with respect to depth. Kruskal–Wallis tests, factor analysis and discriminant function analysis showed that the species could be classified in two major groups, shallow-waters (short-beaked common dolphin and bottlenose dolphin) and deep-waters (striped dolphin, Risso's dolphin, long-finned pilot whale, sperm whale and beaked whale), respectively. Preferred habitats in terms of water depth were areas deeper than 600 m for the deep-water group, and the shallower ranges from shore to 400 m for the other. The distribution of cetaceans was further matched with that of their most common prey in order to establish which habitats could be considered important for their feeding. The resulting analysis highlighted two areas in the region as important habitats for the conservation of the most vulnerable species in the Mediterranean, the bottlenose and the common dolphin.
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Keywords: Environmental factors; Cetaceans; Conservation; Physiography; Habitat; Mediterranean Sea; Distribution; Dolphins; Protected areas

1. Introduction

The primary influence of the physical environment over cetacean distribution is probably the aggregation of prey species (Rubin, 1994; Baumgartner, 1997; Davis et al., 1998). Studies in the Gulf of Mexico (Mullin et al., 1994; Baumgartner, 1997; Davis et al., 1998), eastern NorthPacific

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(Hui, 1979, 1985; Perrin et al., 1985; Taylor, 1992), and North Atlantic (Scott et al., 1985; Kenney and Winn, 1987; Forcada et al., 1990; Hooker et al., 1999) have suggested the possibility of defining habitat in terms of physiography for several species of cetaceans. In the case of benthic or demersal prey species, physiography plays a very important role in limiting distribution directly by depth, slope, and type of substrate (Gil de Sola, 1993). For other species of cetacean prey, such as pelagic fish or cephalopods, physiography could play a more indirect role through mechanisms such as topographically induced up-welling of nutrients (Guerra, 1992; Rubin, 1997), increased primary production, and aggregation of zoo-plankton due to the enhanced secondary production or convergence of surface waters (Rubin et al., 1992; Rubin, 1994).

The present study is part of the Spanish Ministry of the Environment's "Program for the Identification of Areas of Special Interest for the Conservation of Cetaceans in the Spanish Mediterranean". It takes a first step in analyzing the importance of the physiography of the northeastern Alboran basin for several species of cetaceans within the context of national and international biodiversity conservation frameworks (European Union's Habitats Directive, the Bonn Convention's ACCOBAMS agreement and the Barcelona Convention).

This study focused primarily on two delphinids, the bottlenose dolphin (*Tursiops truncatus*) and the short-beaked common dolphin (*Delphinus delphis*) considered to be declining in the Mediterranean biogeographical region (Pelegrí, 1980; Viale, 1980, 1993; Laurent, 1991; Aguilar, 1991; Notarbartolo di Sciara, 1993; Gannier, 1995), both being included in Spain's National Endangered Species Act as vulnerable (BOE, 2000) and the bottlenose being included in the European Union's Habitats Directive Annex I. Other species included in this study are striped dolphin (*Stenella coeruleoalba*), long-finned pilot whale (*Globicephala melas*), sperm whale (*Physeter macrocephalus*), Risso's dolphin (*Grampus griseus*), and beaked whales of the Ziphiidae family.

The research site was the northeastern Alboran Sea (Fig. 1), a region that stands out in the Mediterranean as especially important for these two target species. Common dolphins, at present found only in small groups in the southern part of the central Mediterranean basin (Lauriano and Notarbartolo di Sciara, 1995; Notarbartolo di Sciara et al., 1993, Politi, 1998; UNEP, 1998), are abundant only in the Alboran Sea, where the population is estimated to be 15,072 (95% CI = 7,337 and 30,960) (Forcada and Hammond, 1998). Moreover the region has also been highlighted as especially important for the long-finned pilot whale (Cañadas and Sagarminaga, 2000).

The Alboran Sea has been defined as the transition zone between the Mediterranean Sea and the Atlantic Ocean (Rodríguez, 1982). Parallel to its importance for maintaining a possible gene flow between Mediterranean and Atlantic populations (Natoli et al., 2001), the Alboran Sea plays a vital role in the oceanography of the Mediterranean basin. The important circulation pattern of the Atlantic surface water in the Alboran Sea is often referred to as the hydrologic motor of the western Mediterranean basin (Rodríguez, 1982) and makes this area one of the most productive regions of the Mediterranean (Rubin et al., 1992). The research area, in the northeastern section of the Alboran Sea, has a relatively narrow continental shelf, somewhat wider within the large bay of Almería. The shelf edge starts its drop at around 150 m. There is great variability in the slope of the shelf edge, from very steep escarpments to gently sloping plains. The abyssal plain is very narrow because of the presence of ridges and volcanic mountains such as those giving rise to the island of Alboran (Parrilla and Kinder, 1987) (Fig. 1). The particular physiography of the Alboran basin directs the currents (Parrilla and Kinder, 1987), which, favored by atmospheric and meteorological conditions (Cheney and Doblar, 1979), give rise to processes of convergence and divergence of water masses creating areas of enhanced productivity (Rubín et al., 1992).

2. Methodology

Transects did not follow a systematic design with random probability sampling, but were

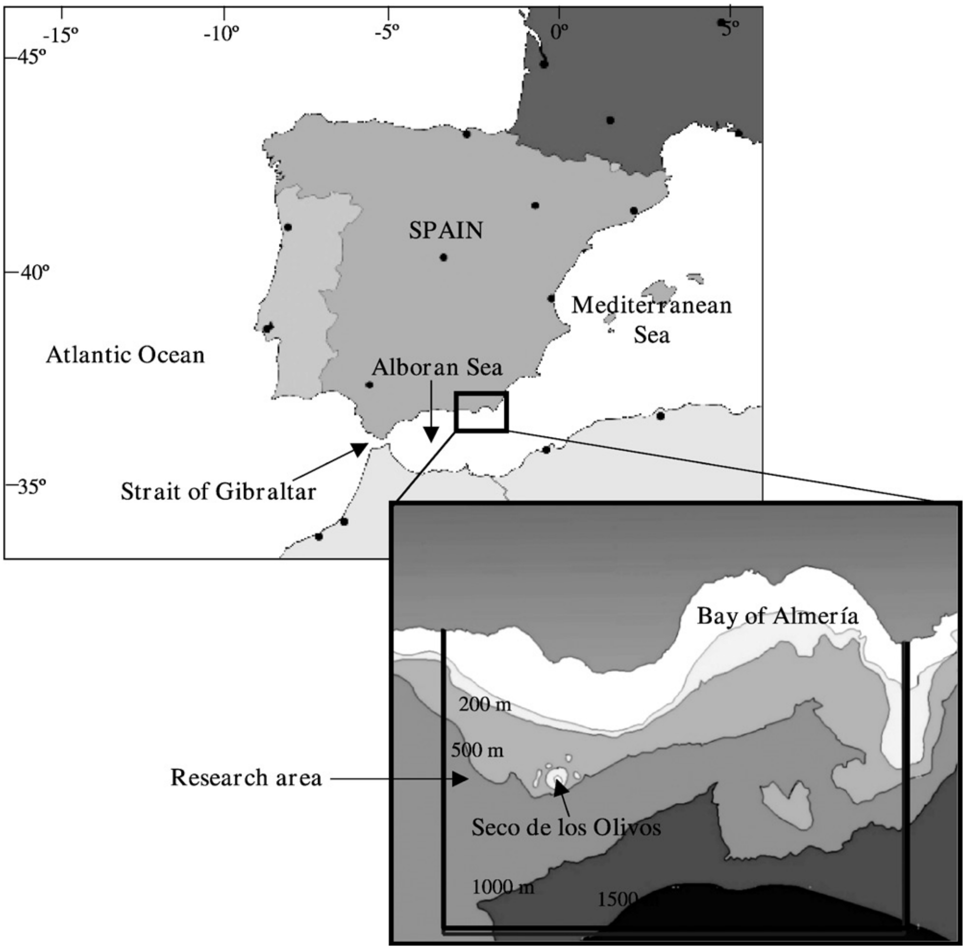

Fig. 1. Research area.

designed as triangles to cross depth contours as perpendicularly as possible and to cover as much as the area as possible, although it was not covered homogeneously (Fig. 2). Searching effort stopped at sighting and started again when the sighting was ended, with a return to the course previously established. A 'sighting' was defined as a group of animals of the same species seen at the same time showing similar behavioral characteristics and at distances of less than 1500 m from each other (SEC, 1999).

The survey transects (Fig. 2) were conducted from the Alnitak research motorsailer "Toftevaag", sampling the study area throughout the months of April, June, July, August and September in 1992 and from 1995 until 2001. Surveys were also made during the month of November in 1999, 2000 and 2001 and January in 2001. The observation platform had two searching platforms (crow's nest and deck) with an eye height of 12 and 2.5 m, respectively, above sea level. To maintain consistent sighting effort, one trained observer (of a team of five) occupied the look-out posts in one hour shifts during daylight with visibility of over 3 nmi (5.6 km), assisted with 7×50 binoculars, covering 180° ahead the vessel. Volunteers participating in this research (mostly untrained) contributed 2.1% of the total observations made from an additional look-out post on deck. Sighting effort was measured as the number of miles traveled with

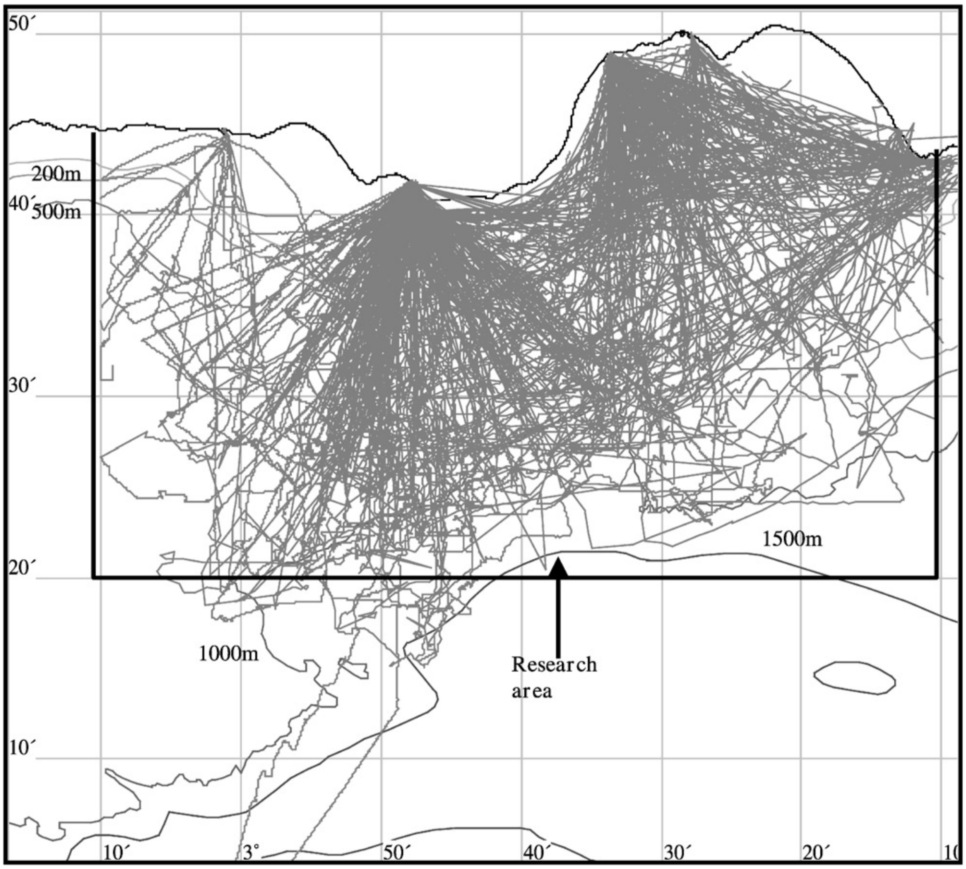

Fig. 2. Map showing the shipboard transects carried out from 1992 to 2001 in the research region onboard the research vessel *Toftevaag*.

adequate sighting conditions (i.e. with sea state Douglas 0 to 2 and good visibility) and observers on the lookout posts. Sighting effort stopped with sea states of 3 Douglas or more (the approximate equivalence to Beaufort wind force scale in offshore, current-free conditions, of 3 Douglas is Beaufort 3 to 4). Four categories of sighting effort were considered according to sea state and position of trained observers, as crow's nest watch was canceled with excessive swell: 1 (sea state 1 in Douglas scale and one observer in the crow's nest), 1S (sea state 1 and no crow's nest watch), 2 (sea state 2 with crow's nest watch) and 2S (sea state 2 and no crow's nest watch). The geographic position of the ship was continuously recorded by the ship's computer from a GPS navigation system using Logger, the IFAW Data Logging Software (NMEA data automatically recorded every minute in a database). Data concerning time, species, number of individuals, behavior, and other relevant data during sightings were recorded together with other complementary environmental data.

The research area was divided into 548 quadrats with a cell resolution of 2 min latitude by 2 minutes longitude each. Encounter rate for each species was calculated for each quadrat as the number of sightings per mile searched. That is $100 \times (n/L)$ where n is the number of sightings and L the number of miles of sighting effort. Here, we analyze only occurrence, so the number of individuals in each sighting is not considered.

Encounter rate was stratified by type of sighting effort, as this factor can greatly affect the detectability of the animals.

2.1. Physiographical features

Two features were measured for describing the physiography: depth and slope. Mean depth and slope were calculated for each quadrat. Depth was derived from the nautical charts of the "Instituto Hidrográfico de la Marina" (Spain). Mean depth was calculated as the average of the maximum and the minimum depth recorded in each quadrat. Slope was calculated as $(D_{max} - D_{min})/\mathrm{DI}$ where D_{max} the maximum depth in the quadrat, D_{max} is the minimum depth in the quadrat, and DI the distance in meters between the points of maximum and minimum depth of the quadrat, and expressed in units of meters per km. Depth and slope, were not correlated (Pearson $r = 0.0408$).

2.2. Analysis

To determine if the different species of cetaceans were distributed non-uniformly with respect to depth and slope, two techniques were used: a chi-square analysis of a bivariate contingency table and a Generalized Linear Model (GLM). Results from the bivariate contingency table were used to assess which depth/slope ranges could be considered as preferred by the different species, if any.

For the chi-square analysis, the expected frequencies were obtained (after Hui, 1979) as: $E_i = (n \times L_i)/L_T$, where E_i = expected number of sightings in class i, n is the total number of sightings, L_i is the amount of effort in class i, and L_T the total effort. Cetaceans found off-effort or during other sightings were not included in the analysis. For depth and slope five and four classes, respectively, were arbitrarily defined: depth 0–200, 201–400, 401–600, 601–1000 and 1001–1600 m; slope 0–20.0, 20.1–40.0, 40.1–80.0 and 80.1–220 m km^{-1}. Nevertheless, for some species some classes had to be pooled to avoid small sample size. This classification was defined in order to have enough sample size in each of the classes, given the restriction in chi-square tests that requires that all expected frequencies exceed 5 (Sokal and Rohlf, 2000).

For the GLMs, each quadrat was classified by depth and slope. As there was no restriction similar to that of chi-square tests regarding sample size in each class, a more detailed classification was used here. Fifteen depth ranges at 100 m intervals (except for the first two: 0–50 and 51–100 m, and the deepest one: 1300–1600 m) and 16 slope ranges at 5 m km^{-1} intervals up to 50 m km^{-1} and at larger intervals in the steeper areas (because of the smaller number of quadrats falling in these classes) were arbitrarily chosen. This gave 240 possible combinations, of which only 77 were found in the survey, hereafter referred to as 'physiographic types'. The response variable was the encounter rate, which was calculated for each species for each of the 77 physiographic types. Given the nature of the response variable, with value '0' for the encounter rate in many classes and decreasing frequencies of increasing encounter rates, the Poisson distribution and the log link function were chosen. Data were visually inspected, through the construction of univariate scattergrams of encounter rate against depth or slope, to get an idea of what would be likely to be important in the full model and to assess if quadratic or cubic functions should be included (Figs. 3 and 4). An interaction term between depth and slope was also included. The best model was selected with a stepwise method, using AIC (Akaike Information Criterion) as selection criteria.

To test whether different species could be differentiated based on physiographic variables, several techniques were used. Factor analysis based on principal components was conducted to explore the spatial coincidence between species, using a matrix of encounter rates for all species in each of the 77 physiographic types. Discriminant function analysis was used to test the significance of both depth and slope in differentiating species or groups of species.

All analyses were performed on two different data sets, one using only effort type 1 (the best sighting conditions) and the other one using the four effort types pooled together. In all cases results were very similar for both datasets. Therefore we present here the results obtained with the analysis considering the four effort types pooled together to increase sample size. On 66 occasions,

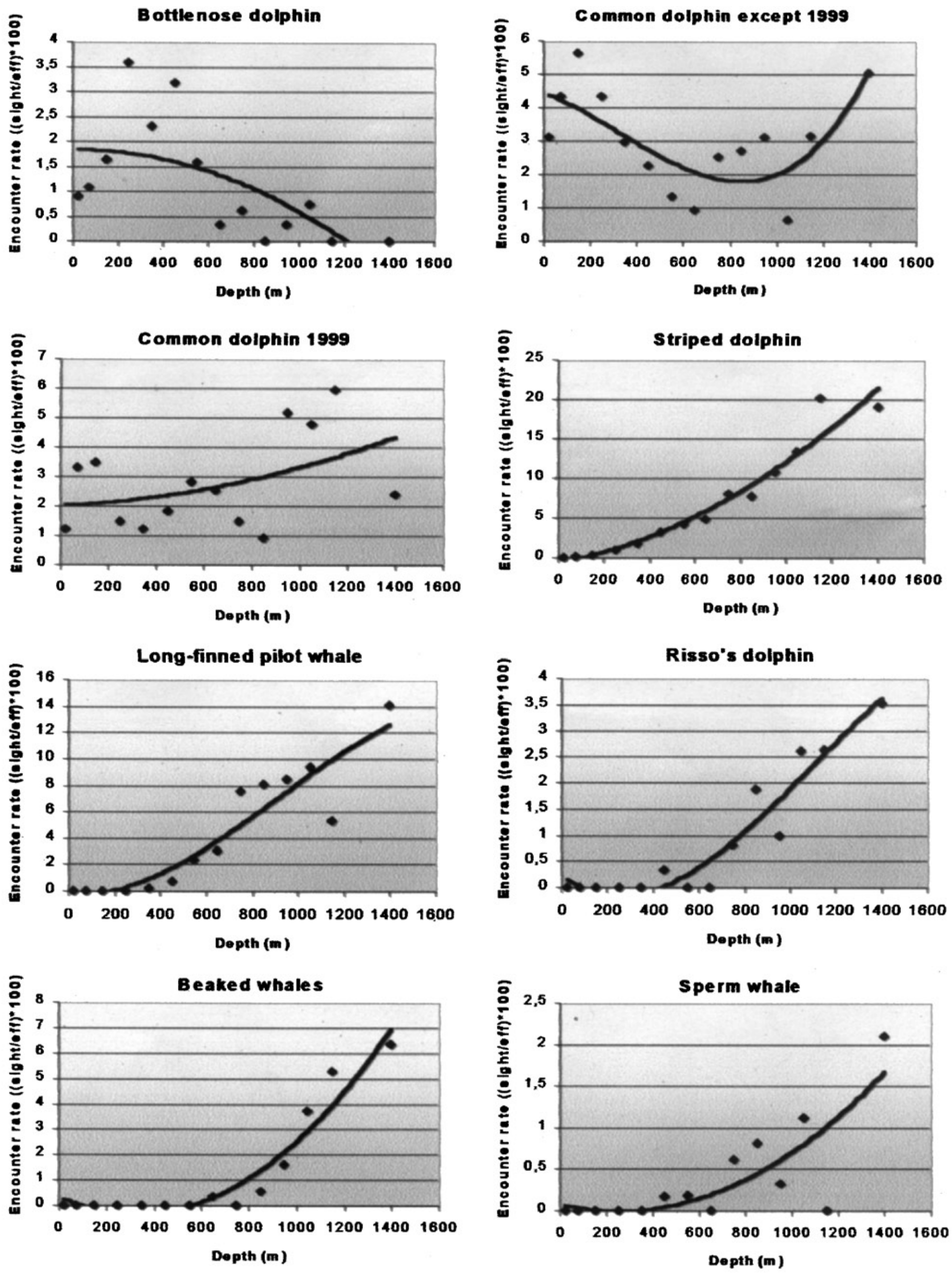

Fig. 3. Scattergram plots of encounter rates vs. depth ranges for the eight groups of species. Quadratic or cubic functions have been fitted to the scattergrams as suggested by the GLMs.

mixed groups of two species were encountered, mainly mixed groups of striped and common dolphins, but also a few of pilot whales with common dolphins or bottlenose dolphins.

In 1999, an important shift in the distribution of common dolphins was observed by the authors in the research area (unpublished data). This shift was not observed in other species. As a result, for

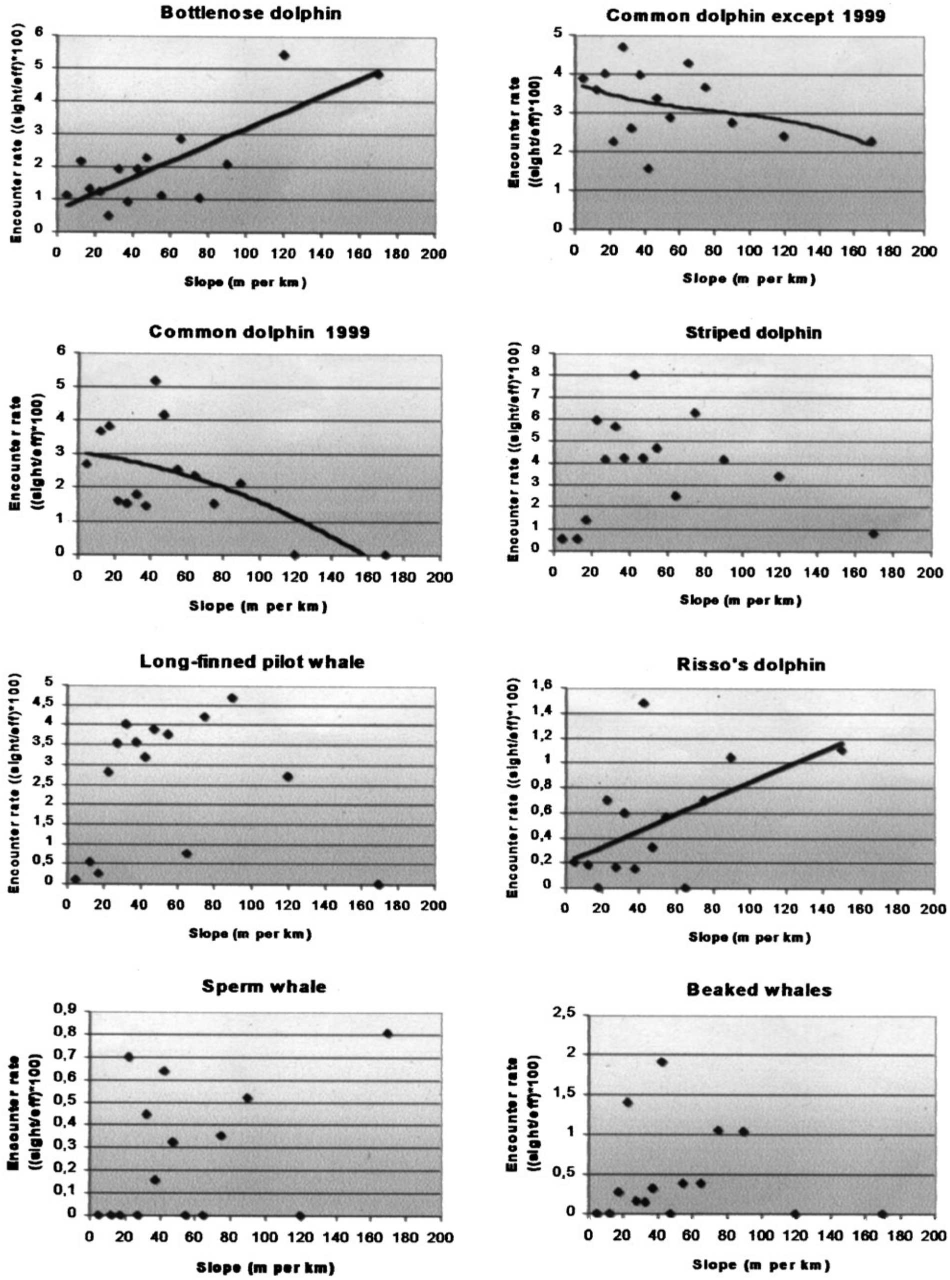

Fig. 4. Scattergram plots of encounter rates vs. slope ranges for the eight groups of species. Linear or quadratic functions have been fitted to the scattergrams as suggested by the GLMs.

all analysis, the sightings of common dolphins were separated into two groups: 1999 alone and all other years with the exception of 1999 (Dde99 and Dde9201, respectively, hereafter). In 42 common dolphins sightings, feeding behaviour could be assessed (feeding behaviour being defined as the observation of dolphins chasing and eating fish on surface, either by direct visual observation or by underwater video filming of the animals).

3. Results

The shipboard surveys covered a total of 7780 nmi (14,409 km) with adequate sighting effort (conducted in sea states of less than 3 Douglas) from 1992 until 2001 (with the exception of 1993 and 1994, see Fig. 2). During this period, cetaceans were sighted 1134 times, of which 105 sightings were of baleen whales or unidentified species of small dolphins, giving 1029 sightings of identified odontocetes. Mean depths and slopes for encounters for monospecific groups are given in Table 1.

3.1. *Tursiops truncatus*

One of the most coastal species encountered was the bottlenose dolphin, showing a clear distribution throughout both the continental shelf and shelf edge. From 1992 to 2001 on effort 132 groups were encountered, seven sightings were classified as mixed groups with pilot whales. The GLM analysis selected a model with depth, slope, a quadratic function for depth, and the interaction between depth and slope (see Table 2). Bottlenose dolphins showed a clear preference for steep areas between 200 and 400 m, and avoided depths over 600 m, with a highly significant difference ($\chi^2 = 87.2$, $n = 125$, df = 9, $p \ll 0.001$).

3.2. *Delphinus delphis*

On effort 313 sightings of this species were made; 53 were mixed groups of common and striped dolphins, five were common dolphin with pilot whales and one with Risso's dolphin. Data were pooled for all years, 1999 alone (Dde99) and all years without 1999 (Dde9201) (Tables 1). A significant difference was found for depth between Dde99 and Dde9201 ($U = 2731$, $p < 0.0001$), but not for slope. When the year 1999 was analyzed, four variables were selected in the GLM: slope, its

Table 1
Descriptive statistics of the distribution by depth (a) and slope (b) for the seven cetacean species or group of species, ordered by increasing means

	N	Mean	Lower CI −95%	Upper CI +95%	Median	Min.	Max.	Stand. dev.	Stand. error
(a) Depth									
Common dolphin (except 1999)	212	287.1	247.3	326.9	188.5	25	1300	294.02	20.19
Bottlenose dolphin	125	288.5	252.2	324.8	250	12	1300	205.04	18.34
Common dolphin (total)	254	338.6	296.8	380.5	199	25	1300	338.38	21.23
Common dolphin (1999)	42	598.6	466.9	730.3	625	35	1200	422.7	65.2
Striped dolphin	270	844.0	808.0	880.1	895	69	1600	300.86	18.31
Long-finned pilot whale	171	894.2	858.4	930.0	900	380	1550	237.23	18.14
Sperm whales	15	932.7	783.0	1082.3	950	400	1400	270.20	69.76
Risso's dolphin	31	987.1	909.2	1065.0	1000	600	1500	212.32	38.13
Beaked whales	33	1099.4	1042.2	1156.6	1050	700	1450	161.38	28.09
(b) Slope									
Common dolphin (1999)	42	33.6	27.1	40.0	33.2	3.7	86.4	20.73	3.20
Common dolphin (total)	254	33.8	30.6	36.9	26.1	3.7	183.2	25.43	1.60
Common dolphin (except 1999)	212	33.8	30.3	37.4	25.7	3.7	183.2	26.3	1.81
Striped dolphin	270	42.5	39.5	45.5	37.6	3.7	203.7	25.06	1.52
Beaked whales	33	43.8	35.0	52.7	41.0	15.1	127.6	24.83	4.32
Long-finned pilot whale	171	44.2	40.8	47.6	37.8	5.4	131.7	22.56	1.72
Sperm whales	15	48.8	28.2	69.4	38.9	21.6	166.0	37.15	9.59
Bottlenose dolphin	125	49.7	42.0	57.4	36.7	5.4	193.0	43.35	3.88
Risso's dolphin	31	54.4	38.1	70.7	42.1	8.1	203.7	44.37	7.97

Table 2
Variables in Generalized Linear Models (GLM) showing the estimate and the significance values (p) derived from the chi-square test (df = 1)

	Sco Estimate	Ttr Estimate	Gme Estimate	Ggr Estimate	Ziph Estimate	Dde99 Estimate	Dde9201 Estimate
Intercept	−2.00197	−1.08961	−10.50201	−6.60846	−4.99479	1.41761	1.77740
DEPTH	0.00786	0.01077	0.03479	0.01697	0.01143		−0.00434
SLOPE	—	0.02010	—	−0.11619	—	−0.04391	—
DEPTH*SLOPE	—	−4.120E−05	—	−7.271E−06	—	0.00012	—
DEPTHˆ2	−3.321E−06	−1.903E−05	−3.095E−05	0.00152	−5.584E−06	−2.054E−06	7.122E−06
SLOPEˆ2	—	—	—	—	—	−0.00060	—
DEPTHˆ3	—	—	8.9119E−09	−5.025E−06	—	—	−3.146E−09
SLOPEˆ3	—	—	—	—	—	—	—
AIC	343.92	211.22	301.02	175.4	118.08	457.78	456.6
	Sco *p*	Ttr *p*	Gme *P*	Ggr *p*	Ziph *p*	Dde99 *p*	Dde9201 *p*
Intercept	0.0008	0.0337	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
DEPTH	<0.0001	0.0019	<0.0001	<0.0001	<0.0001	—	0.0012
SLOPE	—	0.0017	—	<0.0001	—	0.0002	—
DEPTH*SLOPE	—	0.0181	—	<0.0001	—	<0.0001	—
DEPTHˆ2	<0.0001	0.0084	0.0002	0.0001	<0.0001	<0.0001	0.0024
SLOPEˆ2	—	—	—	—	—	<0.0001	—
DEPTHˆ3	—	—	0.0034	0.0037	—	—	0.0063
SLOPEˆ3	—	—	—	—	—	—	—

Ttr = bottlenose dolphin, Sco = striped dolphin, Gme = long-finned pilot whale, Ggr = Risso's dolphin, Ziph = beaked whales, Dde99 = common dolphin in 1999, Dde9201 = common dolphin from 1992 to 2001 except 1999. AIC = Akaike Information Criterion.

quadratic function, the quadratic function of depth and the interaction between depth and slope (Table 2), although the model did not fit very well according to the plots of residuals. This year, common dolphins showed a preference for the deepest areas with intermediate slopes (40–80 m km^{-1}), especially above 600 m ($\chi^2 = 22.0$, $n = 42$, df = 6, $p < 0.005$). When the period from 1992 to 2001 excluding 1999 (Dde9201) was considered, the GLM incorporated the depth and its quadratic and cubic function (Table 2). During this period, common dolphins showed a preference for areas with depths between 1 and 400 m (especially below 200 m) and slopes between 0 and 40 m km^{-1} ($\chi^2 = 39.2$, $n = 212$, df = 9, $p < 0.001$).

The feeding behaviour was significantly more often observed in shallow waters between 1 and 200 m than in the other areas ($\chi^2 = 28.4$, $n = 42$, df = 3, $p < 0.001$). In some of these sightings prey species were identified (garfish—*Belone belone,* gilt sardine—*Sardinella aurita,* flying fish—*Exonautes rondeleti*). At the same time, much larger group sizes were observed in shallower waters than in deeper waters ($x = 117.7$, sd = 137.31, $n = 188$ for areas of 1–400 m vs. $x = 40.0$, sd = 57.04, $n = 119$ for areas deeper than 400 m).

3.3. *Stenella coeruleoalba*

On effort 324 groups of striped dolphins were seen. The variables that showed significant GLM fits were depth and its quadratic function (Table 2). The striped dolphin was not uniformly distributed through all the physiographic types considered ($\chi^2 = 487.0$, $n = 270$, df = 12, $p \ll 0.001$). This species was very rarely found on continental shelf waters (only five sightings of monospecific groups), showing instead a preference for waters of more than 600 m (with increasing encounter rates for increasing depths) with intermediate slopes (between 20 and 80 m km^{-1}).

3.4. *Globicephala melas*

The long-finned pilot whale, of which one hundred and eighty-three groups were encountered on effort (12 in association with either common or bottlenose dolphins), showed a very widespread distribution throughout pelagic waters. The GLM model selected depth and its quadratic and cubic functions (Table 2). The preferred physiographic types for this species were areas with depths greater than 600 m and intermediate slopes between 20 and 80 m km^{-1} ($\chi^2 = 397.0$, $n = 171$, df = 9, $p \ll 0.001$).

3.5. *Grampus griseus*

Risso's dolphin was only encountered 31 times. Five variables were selected in the GLM: depth, its quadratic and cubic functions, slope, and the interaction between depth and slope (Table 2), although the model didn't seem to fit very well, according to the plots of residuals, maybe because of the small sample size. This species was not distributed uniformly through all the physiographic types, preferring areas with depths over 600 meters (with no sightings below 400 m) and, within these, the steepest ones (more than 40 m km^{-1}) ($\chi^2 = 90.0$, $n = 31$, df = 4, $p \ll 0.001$).

3.6. *Ziphiidae*

Beaked whales were only encountered 33 times. The only terms included in the GLM were depth and its quadratic function (Table 2). This group showed a strong preference for deep and steep areas of more than 600 m depth and slopes of more than 40 m km^{-1} ($\chi^2 = 107.3$, $n = 33$, df = 4, $p \ll 0.001$).

3.7. *Physeter macrocephalus*

The small sample size of sightings of this species ($n = 15$) constituted a difficulty when the chi-square test and the GLM were applied, but the encounter rates in the scattergram showed a preferential depth of more than 700 m and no patterns regarding slope (Figs. 3 and 4).

3.8. *Comparison among species*

A Kruskal–Wallis one-way ANOVA was used to compare the distribution among the different species (in monospecific groups). Common dolphins were introduced as two separate groups: Dde99 and Dde9201. Highly significant differences were found for both variables, although the statistic was much higher for depth than for slope (depth: $k = 456.26$, $n = 896$, $p < 0.0001$; slope: $k = 45.39$, $n = 896$, $p < 0.00001$). A chi-square test of medians showed highly significant differences among the species regarding depth ($\chi^2 = 354.48$, $n = 896$, df = 7, $p < 0.0001$); species fell into two groups: common (Dde9201) and bottlenose dolphins in one group and all the others in another. The first group were found in shallower water while the second group were found in deeper water. For Dde99, the observed values were equal to expected. The chi-square test of medians for slope also showed highly significant differences among the species ($\chi^2 = 21.65$, $n = 896$, df = 7, $p = 0.0029$). As for depth, common dolphins (Dde9201) had more observed values than expected lower than the overall median, and Dde99 equal number. Bottlenose dolphins and sperm whales had observed values equal to expected.

Factor analysis was used to classify the associations between species using both variables at the same time. The factor loadings (Table 3) showed

Table 3
The factor loading for the seven types of cetacean groups from the factor analysis

	Factor 1	Factor 2
Bottlenose dolphin	0.3859	−0.4186
Striped dolphin	*−0.8365	0.2434
Long-finned pilot whale	*−0.7873	0.3336
Risso's dolphin	*−0.7455	0.1037
Sperm whale	−0.6916	−0.3724
Beaked whales	*−0.8314	−0.1699
Common dolphin (1999)	−0.4893	−0.6488
Common dolphin (except 1999)	−0.0206	0.5425
Expl.Var	3.4335	1.2393

Expl. Var. is the variance explained by a factor. Marked loadings are >0.7.

that striped dolphins, pilot whales, Risso's dolphins and beaked whales load strongly and are associated with the first factor, with sperm whales very closely related. In the second factor none of the species loaded more than 0.7, although it was dominated by 1999 common dolphins. Both bottlenose dolphins and common dolphins excluding 1999 were far from the first group in the first factor. In a plot of the factor loadings (Factor 1 vs. Factor 2, Fig. 5), three groups can be clearly distinguished: striped dolphins, pilot whales, Risso's dolphins, beaked whales and sperm whales in one group, common dolphins excluding 1999 in a second group, and bottlenose dolphins in a third group. Common dolphins in 1999 appear close to the first group.

The stepwise discriminant analysis selected both depth (Wilk's $\lambda = 0.962$, $p < 0.000001$) and slope (Wilk's $\lambda = 0.474$, $p = 0.00004$) as explanatory variables in the distinction among the 8 monospecific groups considered. The percentage of correctly predicted classifications for the model was high only for two species: striped and common dolphins excluding 1999 (Table 4). Bottlenose dolphins were classified mainly as common dolphins. Common dolphins in 1999 were mainly classified as striped dolphins. The other four species, pilot whales, Risso's dolphins, sperm whales and beaked whales were classified almost completely as striped dolphins. Hence, the results of the discriminant analysis for the species suggested that at least two groups could be differentiated. One group consisting of striped dolphins, pilot whales, Risso's dolphins, sperm whales and beaked whales, with little differentiation within it, and another one consisting of common dolphins (Dde9201) and possibly bottlenose dolphins. The situation of common dolphins in 1999 remained unclear, with 43% of the cases assigned as common dolphins and 57% as striped dolphins.

Based on all the previous results, from the Kruskal–Wallis analysis of variance, the factor analysis and the discriminant analysis, a clear

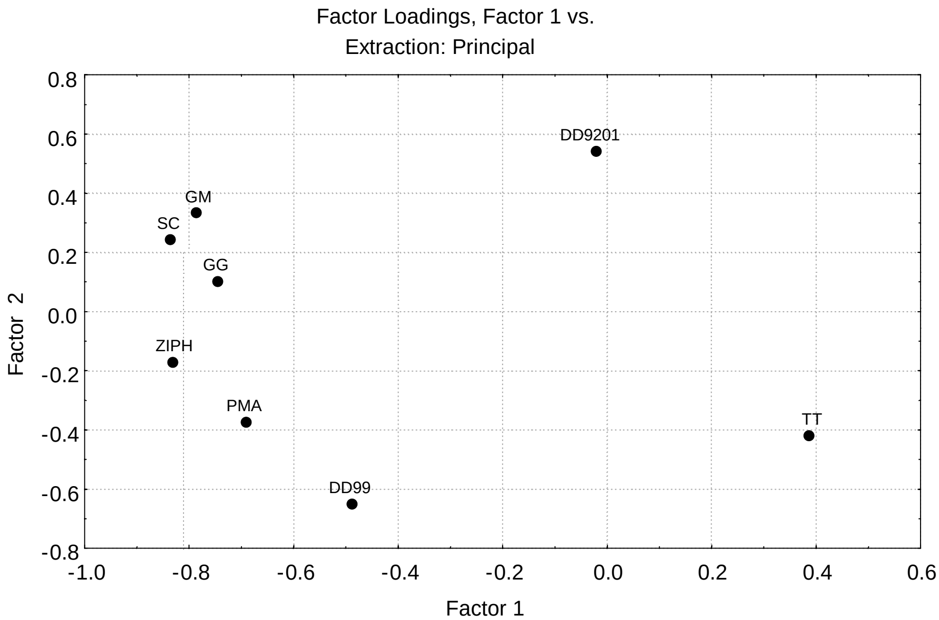

Fig. 5. Plot of factor loadings (Factor 1 vs. Factor 2) from the factor analysis for eight groups of species: TT, bottlenose dolphin; DD9201, common dolphin (except 1999); DD99, common dolphin in 1999; GM, long-finned pilot whale; SC, striped dolphin; GG, Risso's dolphin; ZIPH, beaked whale; PMA, sperm whale.

Table 4
Classification matrix of the discriminant function analysis for seven groups of species, with two variables in the model (depth and slope). Wilk's Lambda: 0.46697, $p<0.0000$

	Percent correct	Ttr	Dde9201	Dde99	Sco	Gme	Ggr	Ziph
Bottlenose dolphin	15.2	19	92	0	14	0	0	0
Common d. (except 1999)	77.4	13	164	0	35	0	0	0
Common dolphin (1999)	0.0	0	18	0	24	0	0	0
Striped dolphin	83.7	9	34	0	226	1	0	0
Long-finned pilot whale	0.0	3	6	0	162	0	0	0
Risso's dolphin	0.0	1	0	0	29	0	0	0
Beaked whale	0.0	0	0	0	31	0	0	0
Sperm whale	0.0	1	1	0	13	0	0	0
Total	45.6	46	315	0	534	1	0	0

Observed classifications in rows, predicted classifications in columns.

Table 5
Descriptive statistics of the distribution by depth (a) and slope (b) for the two groups

	N	Mean	Lower CI −95%	Upper CI +95%	Median	Min.	Max.	Stand. dev.	Stand. error
(a) Depth									
Shallow-waters group	379	322.1	291.6	352.6	230	12	1300	301.64	15.49
Deep-waters group	516	885.9	862.1	909.7	900	69	1600	275.03	12.11
(b) Slope									
Shallow-waters group	379	39.0	35.7	42.4	31.0	3.7	193.0	33.25	1.71
Deep-waters group	516	43.9	41.7	46.2	38.7	3.7	203.7	25.99	1.14

Shallow-waters (SW): common and bottlenose dolphins and DW (deep-waters (DW): striped and Risso's dolphins, long-finned pilot whales, sperm whales and beaked whales.

distinction between common and bottlenose dolphins in one (or two) group and striped and Risso's dolphins, pilot whales, beaked whales and sperm whales in the second group is apparent. We named these groups as shallow-water (SW) and deep-water (DW) groups, respectively, because, according to the results, the first two species seemed to prefer shallow waters while the second group seemed to prefer deeper waters than the first one.

The mean depth and slope for both groups are shown in Table 5. Highly significant differences were found between the two groups of SW and DW, in terms of both depth and slope when a univariate Mann–Whitney U test was performed (depth: $U = 19,821$, $n = 896$, $p<0.00001$; slope: $U = 77,090$, $n = 896$, $p<0.00001$). A discriminant function analysis was used to explore the difference between these two groups (Table 6). Since the common dolphin distribution in 1999 was different from that observed in other years, the discriminant analysis was performed in two ways: including Dde99 in the SW group, and excluding it. In the first case, only depth was included in the model (depth: Wilk's $\lambda = 0.993$, $p<0.000001$; slope: Wilk's $\lambda = 0.514$, $p = 0.333$), and a high percentage of the cases were correctly classified (82.1% of the SW and 88.0% of the DW). When common dolphins of 1999 were excluded, again only depth was significant and included in the model (depth: Wilk's $\lambda = 0.995$, $p<0.000001$; slope: Wilk's $\lambda = 0.461$, $p = 0.154$), and the percentage of correctly predicted classifications increased (84.9% of the SW and 89.6% of the DW).

Differences were observed within both groups. The distribution of bottlenose and common

Table 6
Classification matrix of the discriminant function analysis for the two groups of species (SW = shallow-waters group, and DW = deep-waters group), with two variables in the model (depth and slope)

	Percent correct	SW	DW
(a) Including common dolphins in 1999, Wilk's Lambda: 0.5131, $p<0.0000$.			
SW	82.1	311	68
DW	88.0	62	455
Total	85.5	373	523
(b) not including common dolphins in 1999, Wilk's Lambda: 0.4599, $p<0.0000$			
SW	84.9	286	51
DW	89.6	54	463
Total	87.7	340	514

Observed classifications in rows, predicted classifications in columns.

dolphins (1999 excluded) within the SW group, was significantly different both for depth and slope (depth: $U = 11{,}134.5$, $n = 337$, $p = 0.014$; slope: $U = 10{,}425.5$, $n = 337$, $p = 0.0011$). Within the DW group also highly significant differences were obtained but only for depth (depth: $K = 32.29$, $n = 517$, $p<0.00001$; slope: $K = 1.43$, $n = 517$, $p = 0.839$). The chi-square test of medians showed that striped dolphins and pilot whales had more observations than expected lower than the overall median, as opposed to the other 3 species, both for depth and slope. To analyze the differences found within the DW group, pairwise t-tests were carried out for depth. The following pairs of species were different: striped dolphins–beaked whales ($t = -4.535$, $n = 301$, $p<0.00001$), striped dolphins—Risso's dolphins ($t = -2.408$, $n = 300$, $p = 0.016$), long-finned pilot whales–beaked whales ($t = -4.496$, $n = 202$, $p<0.00001$), sperm whales—beaked whales ($t = -2.585$, $n = 46$, $p = 0.013$) and Risso's-dolphins—beaked whales ($t = -2.399$, $n = 61$, $p = 0.019$).

4. Discussion

This study of seven odontocetes in the north-eastern section of the Alboran Sea indicates that local physiography can play a significant role in their distribution. Depth was the variable with the strongest influence, although slope also played a role for some species. Two distinct groups of species were identified according to their different distribution with respect to depth. Striped dolphins, Risso's dolphins, pilot whales, beaked whales and sperm whales, all had a preference for deep waters. Common and bottlenose dolphins were more frequently found in shallower waters. These groups were not homogeneous, however; differences found between and within them are discussed below.

Davis et al. (2001) classified cetacean species in the Gulf of Mexico in 4 categories based on diverse criteria, including diving ability, depth preference, phylogenetic relationship and dietary preference. One of their categories, 'squid-eaters', included pilot whales, Risso's dolphin and beaked whales. Sperm whales were assigned to a unique category because of their large body size, and striped dolphins were assigned to the group of oceanic stenellids with preference for deep waters.

The most obvious characteristic common to all species in the DW group was their feeding habits. The five species included in this group have been frequently reported as teutophagic (Mercer, 1975; Clarke and Pascoe, 1985; Würtz et al., 1992; Blanco et al., 1995; Kenney et al., 1995; Santos et al., 1996; Gannon et al., 1997; Pauly et al., 1998; Blanco and Raga, 2000), although some species like striped dolphins have a wider spectrum of target prey. Likewise, and in contrast with the DW group, common and bottlenose dolphins (SW group), despite being considered as very opportunistic species with a wide range of target preys (Cockcroft and Ross, 1990; Klinowska, 1991; Young and Cockcroft, 1994; Reynolds et al., 2000), have shown in many dietary studies to have preference for fish over squid (Barros and Odell, 1990; Young and Cockcroft, 1994; Kenney et al., 1995; Cordeiro, 1996; Salomón, 1997). Hence, the classification of odontocetes in the Alboran Sea according to their depth preference seems to match a broad classification according to feeding habits.

4.1. Shallow-water group

The Mediterranean Sea is currently experiencing many human environmental pressures such as over-exploitation of fish resources and pollution of different sorts. Until recently, most of these environmental pressures have affected primarily the coastal waters of the continental shelf and shelf edge, where human activity is most concentrated (EEA, 1999). It is therefore not surprising that the two species that appear to be declining during the last decades in the Mediterranean are the common and the bottlenose dolphin that inhabit these waters.

4.1.1. Bottlenose dolphin

The quadrats showing a mean depth of 200 to 400 m and very high slope values, where the highest encounter rates of bottlenose dolphins were found, are those surrounding the "Seco de los Olivos" sea mount (Fig. 1). This is an important area of upwelling induced by several very steep underwater volcanic mountains rising up to 70 m in an area of 200 to 500 m, which has been highlighted for having the highest concentrations of ichthyoplankton of the northern half of the Alboran Sea (Rubín et al., 1992). Bottlenose dolphins were often observed surrounding these submarine mountains (Fayos et al., 2000), an area also heavily exploited by local fishermen. In general, bottlenose dolphins are widely considered as benthic or demersal feeders (Gunter, 1942; Tomilin, 1957; Evans, 1980; Barros and Odell, 1990). Although there are no studies regarding the diet of this species in the research area, a stomach content study was carried out in Valencia, around 400 km to the north-east along the Spanish coast (Salomón, 1997). In this study, 95.8% of the stomach contents was composed of fish, and 87.5% was composed of neritic-benthonic/demersal prey items (hake, *Merluccius merluccius*, being the main prey) while only 12.5% was composed of pelagic prey. In the Ligurian Sea (north-western Mediterranean Sea) and in Portugal and Galicia (north-west Spain), fish constituted between 85% and 99% of the contents, with blue whiting (*Micromesistius poutasou*), hake, some demersal Trichiuridae and conger (*Conger conger*) as main prey (Relini et al., 1994; Santos et al., 1996; Silva and Sequeira, 1997). These prey species have a distribution primarily confined close to the sea floor, around depths of 100 to 600 meters and especially at the steeper shelf edge (FAO, 1987). Thus, the area of "Seco de los Olivos" has ideal conditions for the presence of the bottlenose dolphin's favorite prey. High numbers of these species of fish (*M. poutassou*, *M. merluccius*, *T. trachurus*, *G. argenteus*, *Mullus* spp., etc.) have been found over the continental shelf and continental slope (0–500 m) of the northern Alboran Sea (Gil de Sola, 1994). Hence, habitats such as the shelf or shelf edge waters around the north-eastern Alboran Sea and shelf slopes as that of "Seco de los Olivos" seem to be largely used by bottlenose dolphin, and illustrate the importance of local physiography for this species. These areas will be considered as priority for protection within the Project for the Identification of Areas of Special Interest for the Conservation of Cetacean in the Mediterranean Spanish Waters set up by the Spanish Ministry for the Environment.

Our results show this species to be one of the two most coastal of all odontocetes in the research area; nevertheless, they occur in higher numbers in intermediate depths, beyond the continental shelf, more in accordance with the offshore ecotype of bottlenose dolphin (Ross, 1984; Hersh and Duffield, 1990; Kenney, 1990; Peddemors, 1999). This agrees with a recent study on phylogeography that shows the Mediterranean bottlenose dolphins to be more closely related to the offshore than to the inshore genotype (Natoli and Hoelzel, 2000).

The existence of different, loosely defined 'ecotypes' of such a cosmopolitan species as the bottlenose dolphins makes the attempts of comparison of the distribution of different populations difficult. The findings of this study agree with observations made on the same species in some areas like the Gulf of Mexico (Davis et al., 1998; Baumgartner et al., 2001) and South Africa (Peddemors, 1999) but differ from observations in other areas like the northeastern coast of the United States (Kenney, 1990). In other areas of the Mediterranean Sea the distribution by depth of this species shows great variation, e.g. northwestern Sardinia (Lauriano, 1997), Balearic Islands and Gulf of Vera (personal observations of the authors) and the Strait of Gibraltar (de Stephanis, com. pers.). However, these data are not corrected for sighting effort. Bottlenose dolphins probably take advantage, in each area, of the features that favor the aggregation of locally abundant prey species that can vary from region to region.

4.1.2. Common dolphins

There is no information on the diet of this species in the research area or other parts of the Spanish Mediterranean coast. Nevertheless, according to other studies around the world, this species appears to be an opportunistic feeder (Klinowska, 1991; Young and Cockcroft, 1994; Gannier, 1995, targeting mainly small, neritic, epipelagic fish, especially of the Clupeidae family and some of the Gadidae family, as well as a small amount of cephalopods (Young and Cockcroft, 1994; Kenney et al., 1995; Cordeiro, 1996; Santos et al., 1996).

Several species of small pelagic fish included in the diet of this species are seasonally very abundant along several parts of the continental shelf and upper slope of the Alboran region, and the continental shelf waters of the Alboran area are important breeding sites for some fishes, especially for the Clupeidae and Engraulidae families (Rodríguez, 1990; Rubin et al., 1992; Gil, 1992; Rubín, 1994). In fact, the western section of the Bay of Almería has one of the highest densities of sardines along the Spanish Mediterranean coast (Gil, 1992). In addition, gilt sardines (*Sardinella aurita*) and needle-fish (*Belone belone*) constitute an important by-catch of the local purse seining fleet (Abad et al., 1991, 1992; personal communication of local fishermen). This could explain why this region appeared to be heavily used by common dolphins (higher encounter rates, larger group sizes and observations of feeding behaviour). The combination of certain physiographic characteristics in conjunction with winds and currents can result in the existence of locally high productivity related to physiography (Medina, 1974; Rubín et al., 1992). The local physiography of the north-eastern Alboran Sea therefore appears to play an important role in concentrating the prey of common dolphin.

Moreover, a previous study on the movement patterns and orientation of common and bottlenose dolphins in the research region found common dolphins to be oriented in the same direction as the depth contours in the range between 1 and 300 m depth in the western section of the Bay of Almería (Fayos et al., 2000). As in the case of bottlenose dolphins, these areas will be considered as priority for protection within the Project set up by the Spanish Ministry for the Environment for this purpose.

Fig. 3 shows a slight bimodality in the plot of encounter rate vs. depth. An apparent bimodality in distribution by depth of common dolphins has been suggested before for the north-east Atlantic (Forcada et al., 1990; López, A. com. pers.), although no clear evidence exists for this. It has been suggested that this apparent bimodality could mean the co-existence of two sympatric populations, one neritic and one pelagic (Forcada et al., 1990), but it could also be due to age/sex segregation. Further research is needed to address this issue.

Common dolphins are present along most coasts world-wide in temperate, tropical and subtropical areas, mainly over the continental shelf, although they can be found in all depth ranges (Evans, 1994; Forcada and Hammond, 1998; Peddemors, 1999) and our results agree with this. On the other hand, it has been indicated that this species preferentially travels over underwater escarpments (Hui, 1979, 1985; Selzer and Payne, 1988; Evans, 1994), which does not seem to be the case in the north-eastern Alboran Sea. Hui (1979) suggested that common dolphins prefer prominent underwater topography because these features promote upwelling and therefore primary and secondary production, which in turn would attract great numbers of anchovies, part of the diet of these dolphins. In the case of the Alboran Sea, primary production is higher in coastal areas due to the particular oceanographic dynamics of the region, and sardines (probably more important in the diet of common dolphins in this area because its biomass is much higher than that of anchovies) are very abundant in those coastal regions over the continental shelf (Abad et al., 1991, 1992; Gil, 1992), which could explain the lack of specific preference for steep areas shown by this study.

During the summer of 1999, a pronounced drop in sea surface temperature (SST) was recorded coinciding in time with the breeding season of the sardine along the southern coast of Almería. The temperature dropped drastically in a few days (a result of an unusually strong westerly wind), to temperatures 8–10°C lower than the normal summer SST (15–16°C versus 23–26°C) (personal observations of the authors). Several inquiries among fishermen in the area revealed that during the summer of 1999 the sardine catch dropped to a minimum along the coasts whereas sardine predators such as the horse mackerel (*Trachururs trachurus*) and mackerel (*Scomber scomber*) increased. The unusual abundance of such predators or the sudden sea surface temperature drop, which could lead to the death of most of the sardine larvae and juveniles, could explain the scarcity of sardines along the Andalusian coast during the summer of 1999. The scarcity of sardines and the cooler sea surface temperature coincided also with a displacement in the distribution of the common dolphins during that summer towards deeper areas. Hence, sightings of common dolphins in deep waters, where the most abundant small delphinid is the striped dolphin, increased considerably as did the number of mixed groups of both species (34.6% in 1999 against an average of 17% for the other years—ranging from 0 to 26%) (García et al., 2000; personal observations of the authors). The fact that the GLM did not fit very well for Dde99 was likely a combination of small sample size and that there were variables other than physiography influencing their distribution to a greater extent.

4.2. Deep-water group

The other species considered in this study have very different feeding habits from the two previous ones. The striped dolphin is considered to have opportunistic feeding habits but seems to prefer some oceanic epi or meso-pelagic fish, mainly of the Gadidae family, Myctophidae family, and others, but especially several species of oceanic meso-pelagic cephalopods that mainly inhabit oceanic waters (Blanco et al., 1995; Kenney et al., 1995; Santos et al., 1996; Pauly et al., 1998). The long-finned pilot whale, considered to be predominantly a squid-eater (Mercer, 1975; Kenney et al., 1995; Gannon et al., 1997; Pauly et al., 1998), feeds not only on cephalopods but also occasionally on some pelagic fish (Desportes and Mouritsen, 1993; Santos et al., 1996; Pauly et al., 1998).

Risso's dolphins are known to be exclusively teutophagic (Clarke and Pascoe, 1985; Würtz et al., 1992; Kenney et al., 1995), and their most common prey species are from the Histioteuthidae, Ommastrephidae, and Sepiidae families (Gannier, 1995; Santos et al., 1996). Species of the family Ziphiidae appear to feed also only on cephalopods, and their most common prey species are from the family Histioteuthidae (Kenney et al., 1995; Santos et al., 1996; Blanco and Raga, 2000), which are oceanic and meso or bathypelagic inhabiting depths of around 1000 m, with a preference for escarpments (FAO, 1987; Guerra, 1992). In general, the squids that constitute the main prey of this second group, usually inhabit offshore oceanic waters, mainly around depths of 600 to more than 1000 m, and preferentially in areas of steep slope such as submarine canyons, escarpments, etc. (Riedl, 1983, FAO, 1987; Guerra, 1992). In the case of these deep sea squid eaters, the distribution of the predators appears to match also the habitat of their prey.

In a comparison among species, the DW group was non-homogeneous in terms of distribution with respect to depth, with significant differences within the group. A gradient of depth preferences within this group was apparent based on the median and mean depth of encounters for each species (Table 1). Species were distributed by depth as follows: striped dolphins (with the lowest mean), long-finned pilot whales, sperm whales, Risso's dolphin and beaked whales (with the highest mean). This would explain the pairwise differences obtained with the *t*-test: although one element is very similar to the next one in a gradient, the ends accumulate enough differences between them to be statistically significant. But these species all showed a clear preference for waters deeper than 600 m and areas with intermediate or high slopes.

The results of this study are in accordance with the description of these five species in other areas as oceanic species with preference for deep waters over 500 m (Gannier, 1995; Baumgartner, 1997; Gannier, 1998; Davis et al., 1998; Peddemors, 1999; Baumgartner et al., 2000). Baumgartner (1997) defined the slope class of 41.6 to 402.5 m 1.1 km^{-1} as highly preferred for Risso's dolphin in the Gulf of Mexico. In our study, the divisions of the slope classes were performed at fixed intervals of 20 m km^{-1}, and therefore, a similar class to that defined by Baumgartner would include 8 out of 10 of our classes. If we perform such a division, the same result as Baumgartner is obtained. The difference in criteria for defining the classes (equal effort for Baumgartner and equal intervals of slope for us) could explain the difference in results.

As mentioned above, based on the literature, striped dolphins appear to feed not only on squids but also on pelagic fish. Long-finned pilot whales also feed sometimes on fish, although not as much as striped dolphins. This fact separates these species from Risso's dolphins, sperm whales, and beaked whales, which seem to feed exclusively on squid. This gradient of feeding habits appears to coincide with the gradient in their distribution by depth.

4.3. Implications for management

In the context of designing a marine protected area (MPA) in the Gully (Nova Scotia), Hooker et al. (1999) stated: "In the marine environment, species' spatial distributions may be determined by both fixed spatial features such as topography and variable oceanographic features such as sea surface temperature and salinity… . It is therefore critical in any assessment of an area for protection that the relative importance of these fixed and fluid environmental characteristics be investigated."

It is clear that in a region of complex oceanography such as the Alboran Sea, physiography is not the only factor affecting the distribution of cetaceans. Oceanographic variables are of paramount importance in this area, but they are fluid features that change very quickly over time, even from day to day, while physiography stays fixed. Therefore, physiography has been chosen here as a first tool for highlighting the importance of certain regions of the Alboran basin for the conservation of bottlenose and common dolphins.

The final aim of the Spanish Ministry of the Environment's Program for the Identification of Areas of Special Interest for the Conservation of Cetaceans in the Spanish Mediterranean is to identify areas that will be designated as MPAs. From the practical point of view, in a highly dynamic environment as the Alboran Sea, in which the oceanographic features are changing so quickly, it would be very important for the relevant authorities in charge of marine management to have a "fixed" reference on which to base the future MPA, because in area-based conservation, sites are typically chosen based on unchanging physical features. From here, research will extend to other parts of the Alboran basin and its adjacent Mediterranean and Atlantic waters with analysis of abundance and habitat use incorporating other variables such as sea surface temperature, salinity and human activities.

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CHAPTER 6

HABITAT PREFERENCE MODELLING AS A CONSERVATION TOOL

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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.
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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

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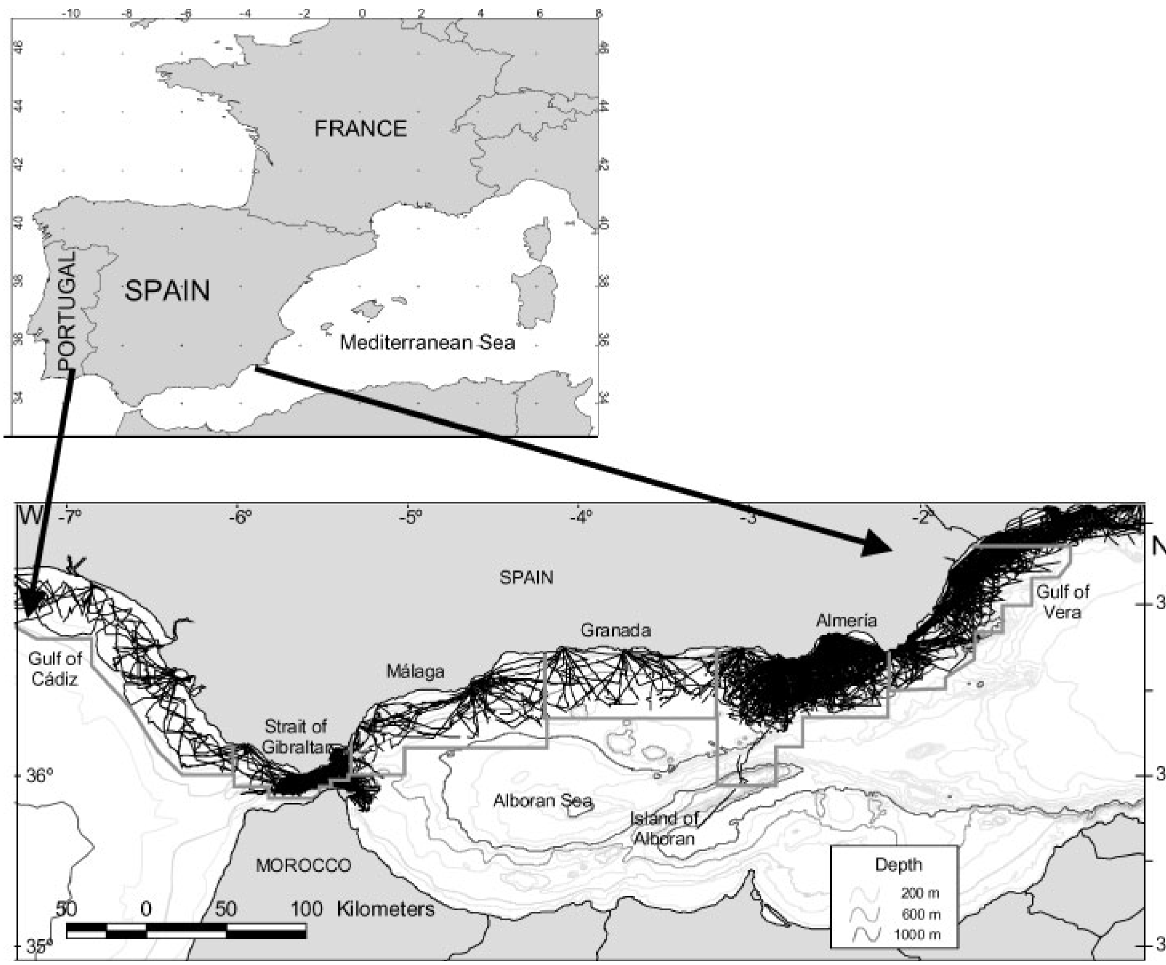

Figure 1. Research area. Depth contours are every 200 m. Survey transects carried out between 1992 and 2002 on effort are shown.

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.

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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 ($m\,km^{-1}$); 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:

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

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 $2\,km^2$.

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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

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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

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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

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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).

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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.

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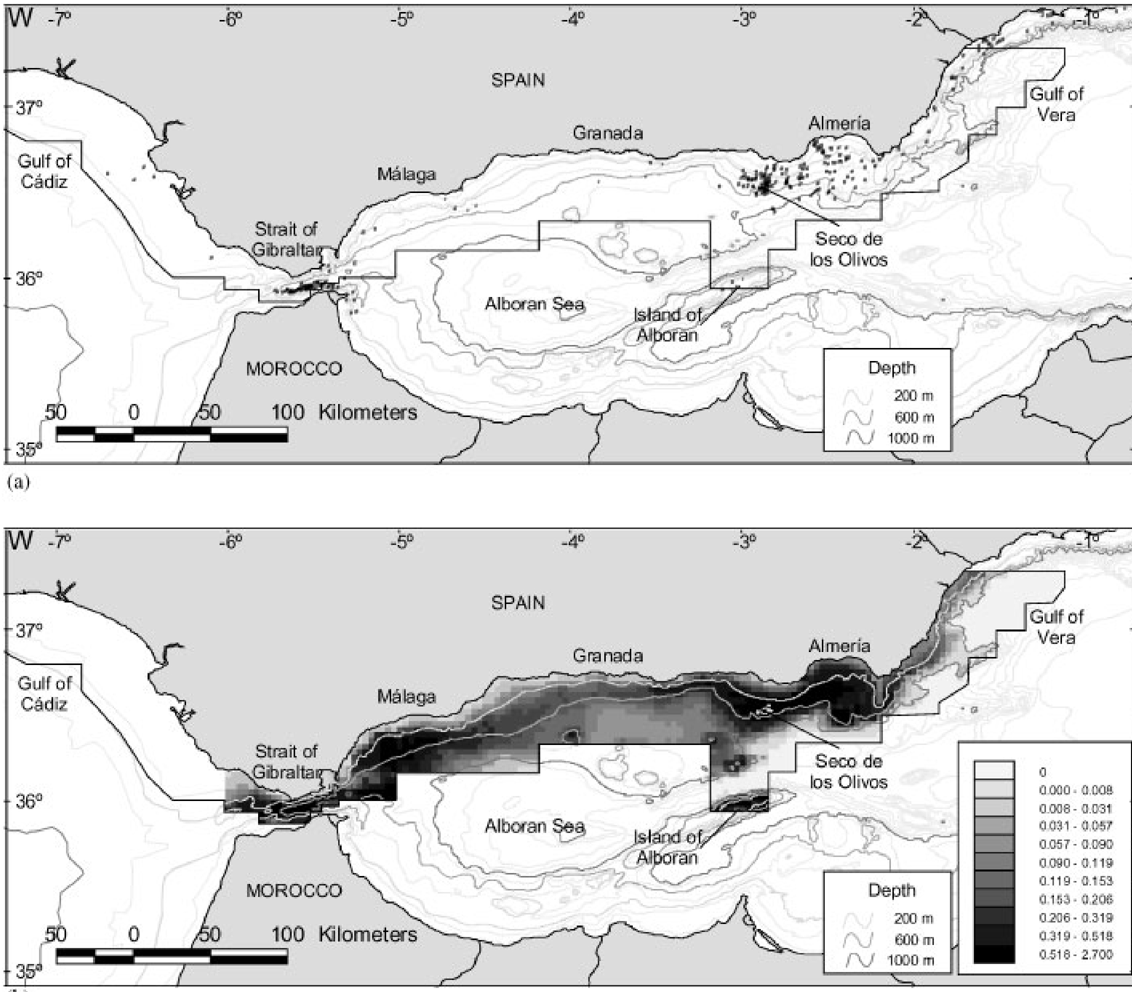

Figure 2. (a) Sightings of common bottlenose dolphins. (b) Prediction of relative density of common bottlenose dolphin in the research area.

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)).

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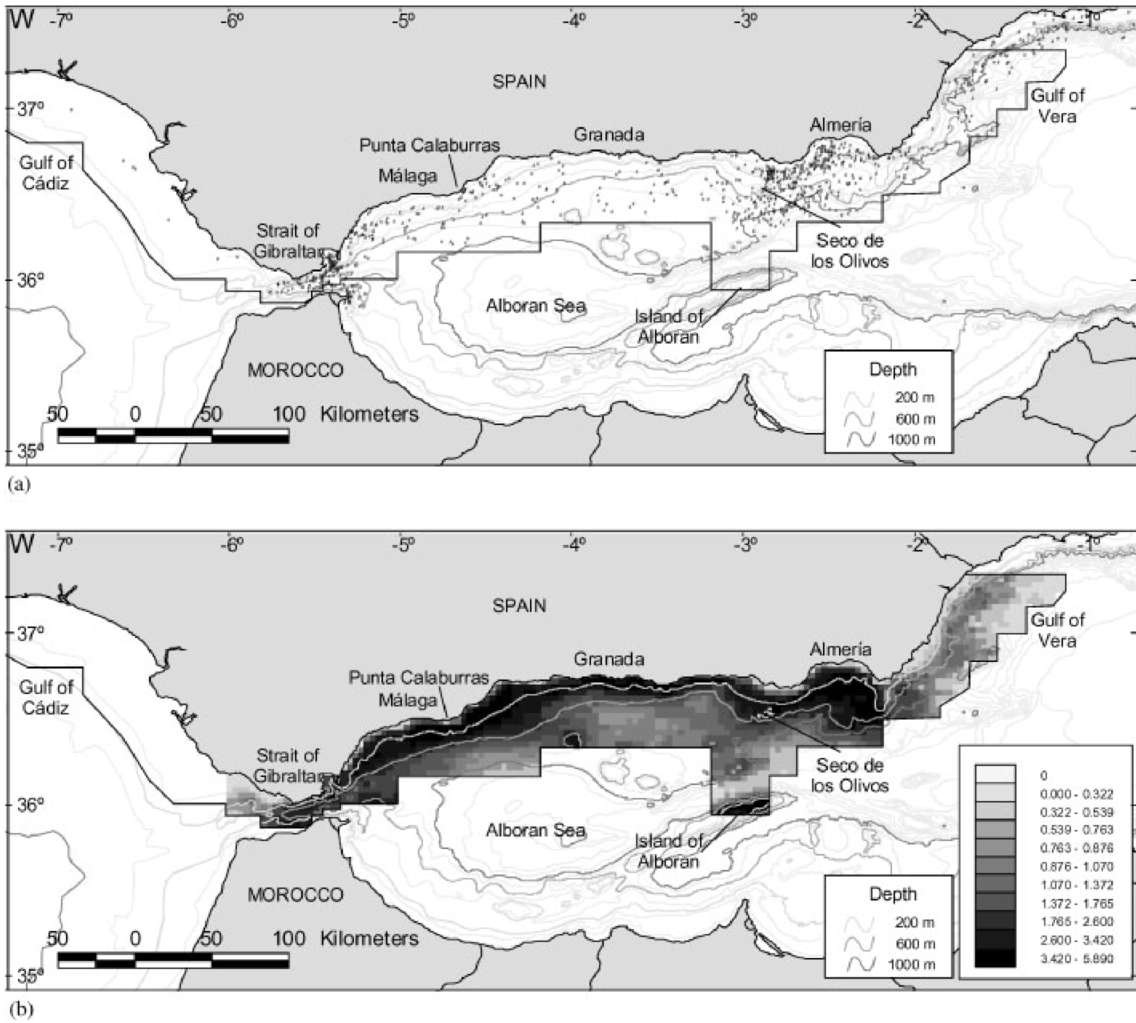

Figure 3. (a) Sightings of short-beaked common dolphins. (b) Prediction of relative density of short-beaked common dolphin in the research area.

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.

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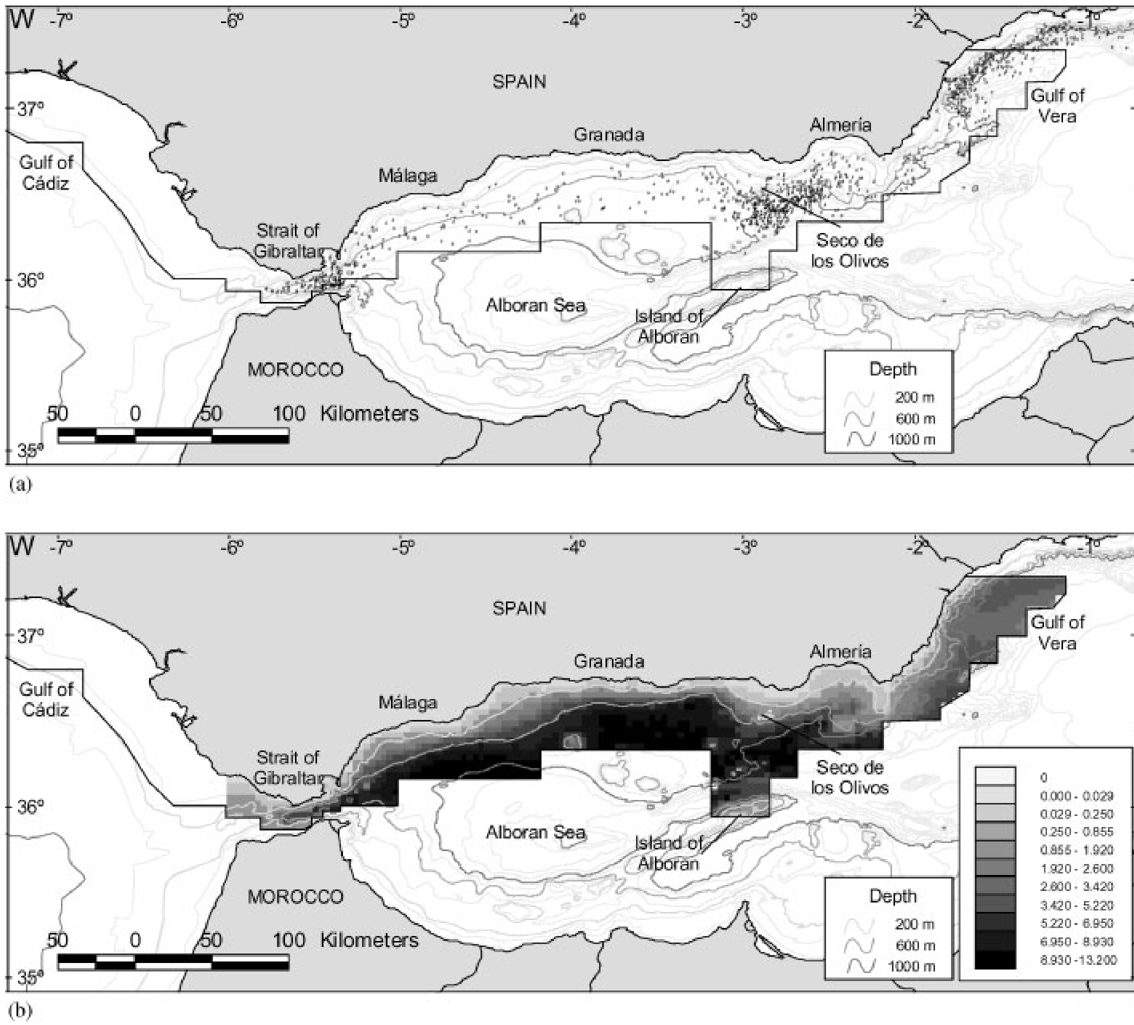


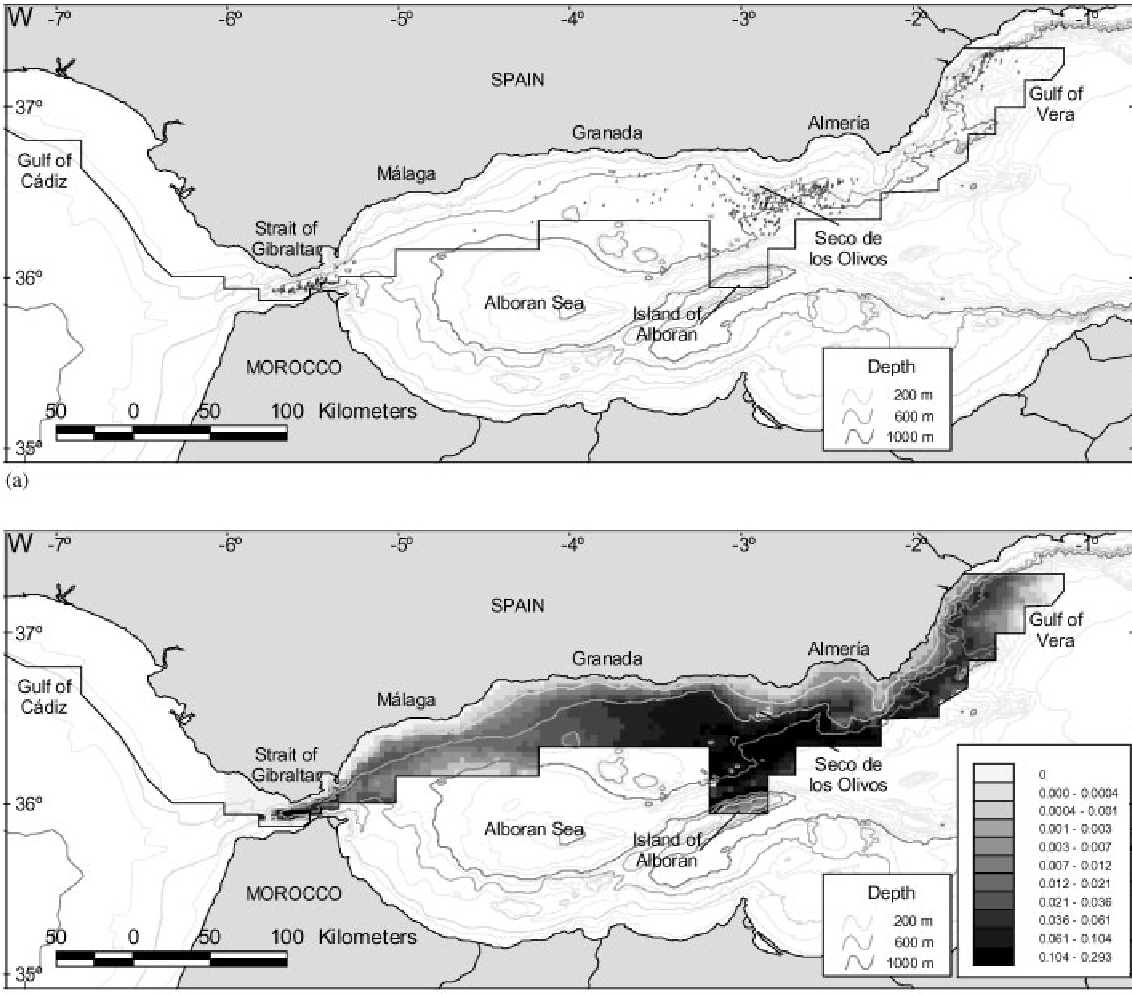
Figure 4. (a) Sightings of striped dolphins. (b) Prediction of relative density of striped dolphin in the research area.

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



(a)

(b)

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

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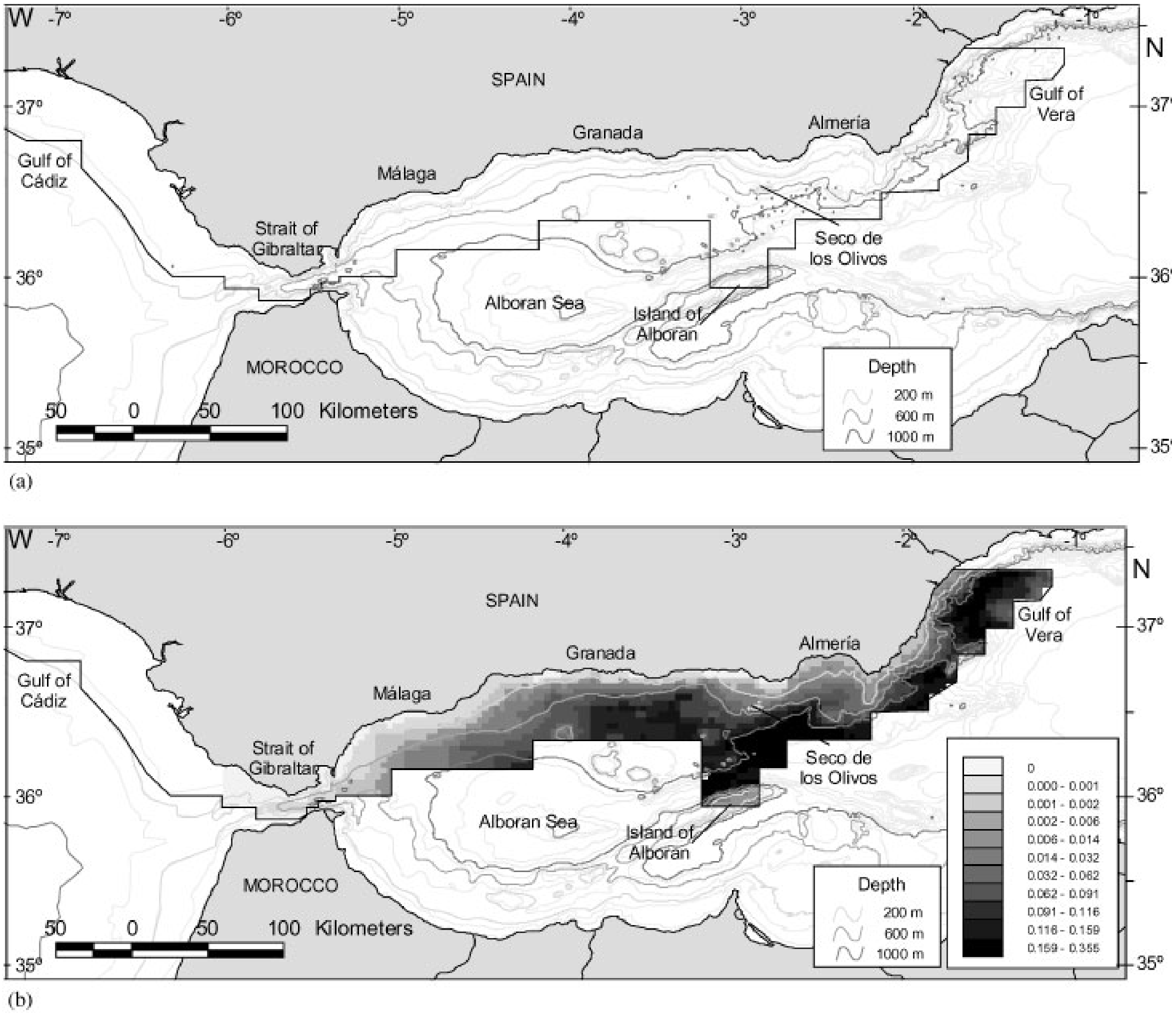

Figure 6. (a) Sightings of Risso's dolphins. (b) Prediction of probability of occurrence of Risso's dolphin in the research area.

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

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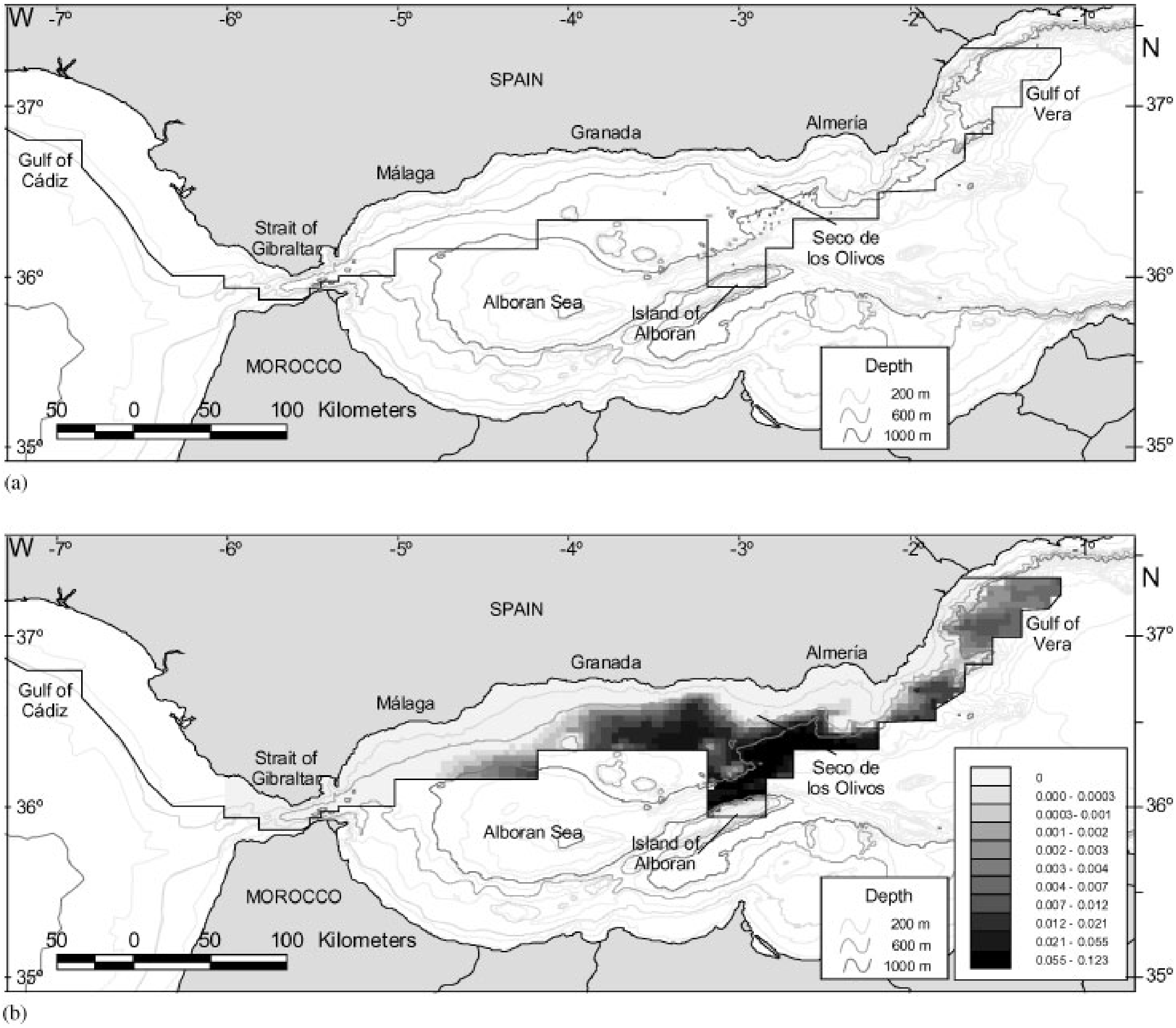

Figure 7. (a) Sightings of beaked whales. (b) Prediction of probability of occurrence of beaked whales in the research area.

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 ($0.54\,\text{nmi}^{-1}$) were an order of magnitude greater than outside them ($0.05\,\text{nmi}^{-1}$), 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

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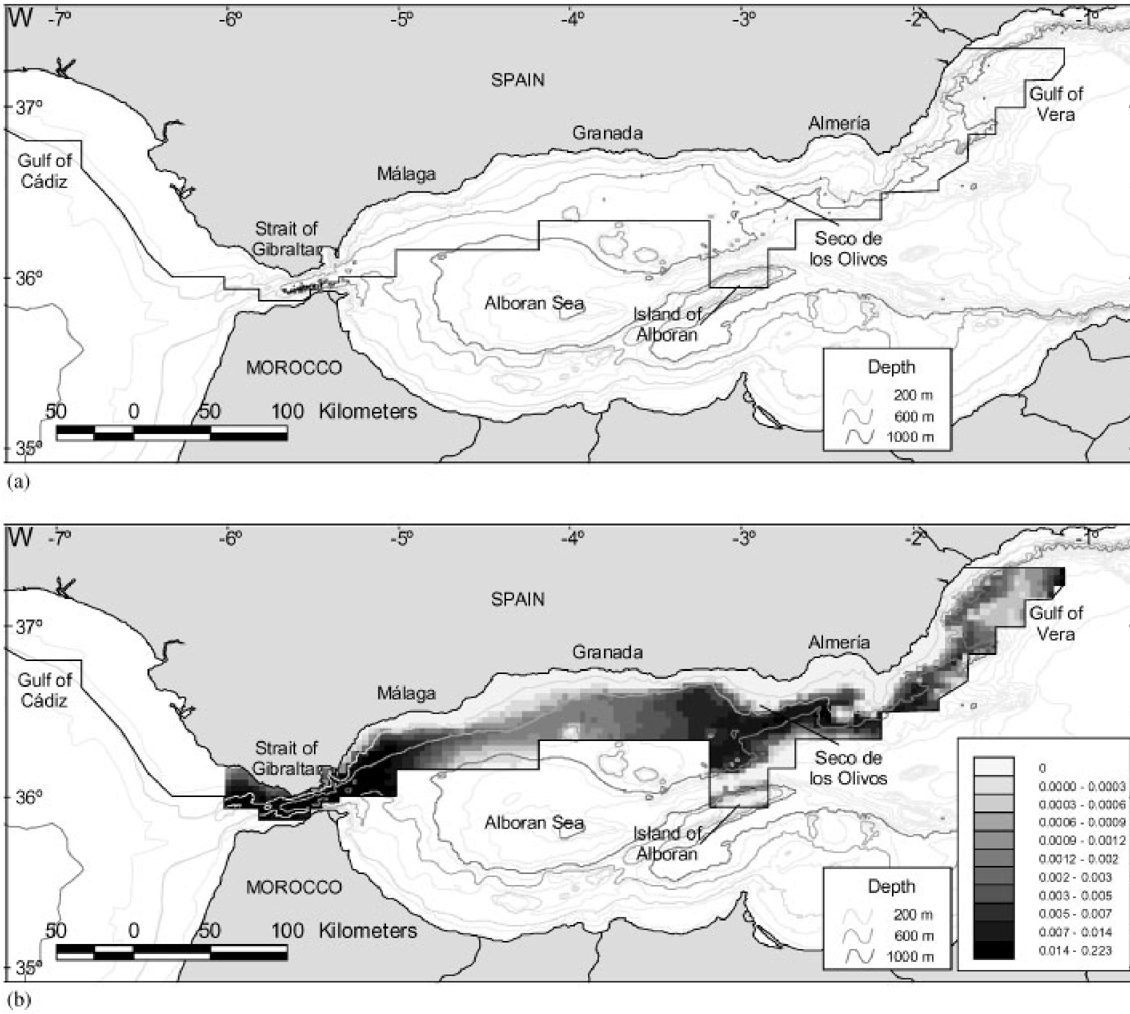

Figure 8. (a) Sightings of sperm whales. (b) Prediction of probability of occurrence of sperm whale in the research area.

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.

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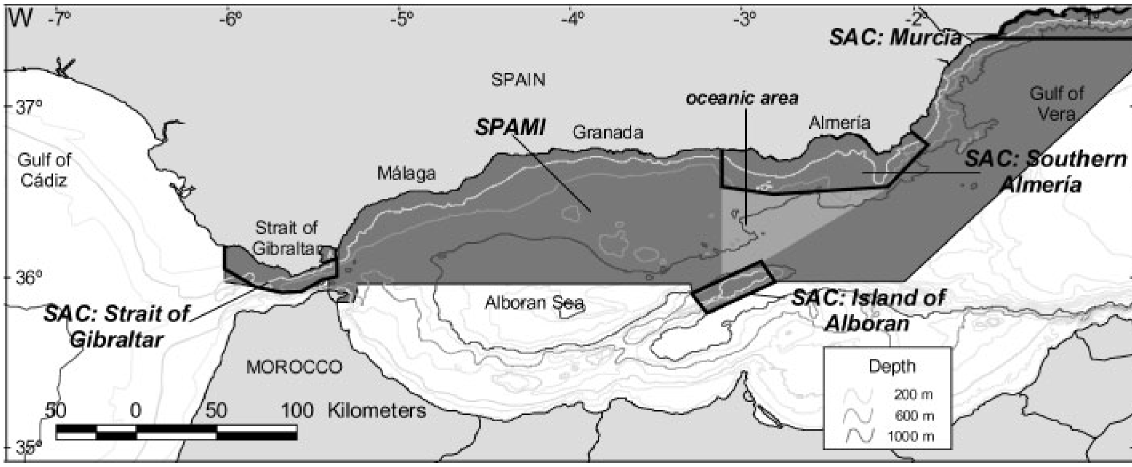

Figure 9. Proposed marine protected areas: SPAMI (dark grey area) and the three SAC: Strait of Gibraltar, Island of Alborán and Southern Almería. In the north-eastern section of the map the existing SAC for bottlenose dolphins in the contiguous area of Murcia is shown. The important oceanic area of the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

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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,

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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

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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

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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.

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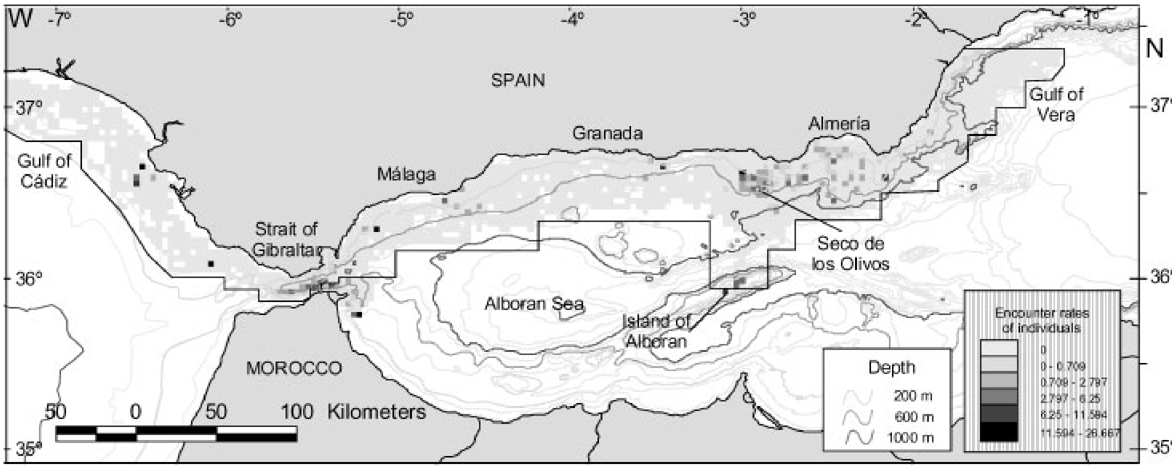

Figure 10. Encounter rates of common bottlenose dolphin in the study area (1992 to 2002).

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

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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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CHAPTER 7

MODEL-BASED ABUNDANCE ESTIMATE OF BOTTLENOSE DOLPHINS IN THE ALBORÁN SEA

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Model-based abundance estimates for bottlenose dolphins off southern Spain: implications for conservation and management

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ABSTRACT

An EU-funded LIFE project was initiated off southern Spain in 2002, with the objective of developing a Conservation Plan for bottlenose dolphins in the area. Baseline information and monitoring of abundance and distribution is needed to determine if the conservation objectives are met in the long-term. To estimate abundance, 12,568km of non-systematic line transects conducted from 2000 to 2003, with 72 sightings, were analysed using spatial modelling methods. Transects were divided into 4,575 small segments (average 2.8km) with similar values for sightability conditions and environmental variables. The point estimate of bottlenose dolphin abundance in the area was 584 dolphins (95% CI=278-744). The same method was applied to investigate changes in abundance since 1992 in the eastern section of the research area, where most dolphins were concentrated, stratifying by three groups of years. Point estimates were 111 dolphins for 1992-1997, 537 for 1998-2000 and 279 for 2001-2003. The higher abundance between 1998 and 2000 corresponded with the observation of an 'immigrant' group of dolphins in these years. These results highlight the importance of long-term studies to understand natural variation in abundance in a specific area subject to conservation activities.

KEYWORDS: ABUNDANCE; BOTTLENOSE DOLPHIN; ALBORÁN SEA; SPAIN; TRENDS; CONSERVATION; SPATIAL MODELLING

INTRODUCTION

The bottlenose dolphin is widely distributed in the Mediterranean Sea, but is considered to be declining in this basin, with fragmented populations (Notarbartolo di Sciara, 2002) supported by recent genetic studies (Natoli, 2004). This species is listed in Annex II of the EU Habitats Directive, which considers it a priority species for conservation, and requires the creation of SACs (Special Areas of Conservation) in European waters.

According to the Habitats Directive, SACs should be managed through a Management Plan to contribute to the maintenance or restoration of favourable conservation status of the target species and their habitats (*http://europa.eu.int /comm/environment/nature*). There is also a requirement within the Habitats Directive (Article 17) for developing a Monitoring Plan to provide information on the conservation status of the habitats and species which SACs aim to conserve, and to assess the effectiveness of the Management Plan in achieving its conservation objectives. The results of the monitoring should inform management and allow for effective revision of any management measures.

In this context, in a previous study for the Spanish Ministry for the Environment between 2000 and 2002, three SACs were proposed in Southern Spain for bottlenose dolphins: one in the Strait of Gibraltar, one around the Island of Alborán and one in southern Almería (Canadas *et al.*, 2005).

As a follow-up to this study, a project entitled 'Conservation of cetaceans in Murcia and Andalucía' was initiated in 2002 supported by the EU Life Nature programme (LIFE02NAT/E/8610). The main aims are to develop the Management and Monitoring Plans for bottlenose dolphins in the region. Under Spanish legislation, a Conservation Plan for the species that applies to the whole region also needs to be developed and the Monitoring Plan should inform this and management of the SACs. The logic of this is that a Monitoring Plan that only covers the SACs is likely to be inadequate for assessing the conservation status of a mobile species in a highly dynamic environment. In the long term a Monitoring Plan covering a wider region may pick up shifts in distribution that may lead to revision of SAC boundaries. It may also lead to greater understanding of the causes of any change in abundance within managed sites. Wilson *et al.* (2004) discuss the impact on SAC management of a range expansion in bottlenose dolphins off the east coast of Scotland.

Although the Management and Monitoring Plans are still under development within the framework of this project, two main conservation objectives are foreseen as inevitable, arising from the definition of 'favourable conservation status' by the Habitats Directive (Article 1) (*http://europa.eu.int/comm/environment/nature*): to avoid a long-term decline in dolphin population (maintaining a stable or increasing population); and to avoid a long-term reduction in the areas used by the population. To determine whether these conservation objectives are being met, monitoring will need to record changes in the population with respect to baseline information.

The main objective of the work presented here was to estimate the current abundance of bottlenose dolphins in this region, and to investigate variability in abundance and distribution of this species over recent years. This information will constitute the first step in the development of the Monitoring Plan by serving as a baseline for future work.

Although the project covers the whole area off Southern Spain, including the Gulf of Cádiz, the Strait of Gibraltar, the Alboran Sea and the Gulf of Vera, the work presented here concentrates on the central section, the Alboran Sea. This area is the westernmost part of the Mediterranean Sea, where it connects to the Atlantic Ocean. It is highly dynamic and productive, of great importance for the hydrology of the whole Mediterranean basin, and hosts a high biodiversity (Rodriguez, 1982; Gascard and Richez, 1985; Parrilla and Kinder, 1987; Tintore *et al.*, 1988; Rubin *et al.*, 1992; Templado *et al.*, 1993; Cañadas *et al.*, 2002; Canadas *et al.*, 2005).

A standard technique for estimating the abundance of biological populations such as cetaceans is line transect sampling (Hammond, 1986a; Buckland *et al.*, 2001). In this method, transects are surveyed in the field and observers record the perpendicular distance (or angle and radial distance) from the line to the detected targets. The most common way of estimating abundance is the so-called design-based method (Buckland *et al.*, 2001), based on a survey design that ensures equal coverage probability is

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achieved across the whole study area, or at least that all portions of the study area have a non-zero coverage probability (Hiby and Hammond, 1989; Buckland *et al.*, 2001). Design-based surveys have been widely used to estimate the abundance of a range of cetacean species (e.g. Gunnlaugsson and Sigurjónsson, 1990; Schweder *et al.*, 1997; Forcada and Hammond, 1998; Hammond *et al.*, 2002).

An alternative technique suitable for estimating abundance from surveys that have not been designed to achieve equal coverage probability, is the model-based method (Hedley *et al.*, 1999; Marques, 2001), in which line transect sampling is combined with spatial analysis. The perpendicular distance data are used to estimate a detection function, which allows abundance to be modelled as a function of physical and environment data associated with the surveyed transects. Abundance can then be estimated for the entire study area through extrapolation and maps of density created. Model-based abundance estimation does not require a randomised or systematic sampling scheme, and is therefore suitable for data collected from platforms of opportunity or dedicated surveys that did not follow a systematic design. Using features of the environment to predict abundance may increase precision. A further advantage is that abundance can be estimated for any subarea within the study area (Hedley *et al.*, 1999). Although a systematic design is unnecessary, reasonable coverage across the range of values for the explanatory variables used is required, including location. The relatively large number of observations needed to allow modelling means that the method may not work very well in areas of low density without a large amount of effort (Williams, R., 2004). There is a risk of creating an 'edge-effect', extrapolation of unrealistically high density at the edges of the study area, where coverage is usually poorer (Clarke *et al.*, 2000; Bravington, 2003). This is a relatively new method that has not yet been widely applied.

In this study, we used model-based methods to estimate the abundance of bottlenose dolphins in the northern section of the Alboran Sea following the methods of Borchers and Burt (2002) and Burt *et al.* (2003).

The abundance of naturally marked cetacean species, including bottlenose dolphins can also been estimated using mark-recapture methods applied to data on photo-identified individuals (e.g. Williams, J.A. *et al.*, 1993; Wilson *et al.*, 1999; Stevick *et al.*, 2003b). Because photo-identification can also provide other useful information on movements, birth rates and survival (e.g. Barlow and Clapham, 1997; Stevick *et al.*, 2003a; Larsen and Hammond, 2004), mark-recapture is a possible alternative technique for achieving the aims of this study. Work on estimating the abundance of bottlenose dolphins in the Alboran Sea using these methods is in progress (S. Garcia Tiscar, pers. comm.). The assumptions made by these methods are quite different to those for line transect and spatial modelling methods. One particularly important assumption concerns avoiding heterogeneity of capture probabilities, which is easy to violate, difficult to account for and can cause substantial bias in estimates of abundance (Hammond, 1986b). In addition, if the study area is not well delimited geographically, it can be difficult to define the population to which the abundance estimate refers. It will be informative to compare estimates of bottlenose dolphin abundance in the Alboran Sea from both methods but line transect/spatial modelling methods are likely to provide more robust estimates for this species in this area, and are more widely applicable for other species in this and other areas.

METHODS

Data collection

Survey area and survey design

Cruise tracks were conducted by the research vessel *Toftevaag* between 2000 and 2003 in the whole northern section of the Alborán Sea, an area of 11,402km^2 (Fig. 1). In 1992 and from 1995 to 1999, surveys were only conducted in the eastern part of this area, the waters off Southern Almería, an area of 4,188km^2 (Fig. 2). During 1993 and 1994, no surveys were conducted in this area. The study area was sampled in January, March, June to September and November from 1999 to 2003. Surveys were also made during March-April, and from June to September from 1992 to 1998. Transects did not follow a systematic design. The relatively small vessel used had a slow cruising speed, was very dependent on weather conditions and had to return to port every night. In addition, time was allocated to other activities during encounters, such as photo-identification. These constraints would reduce considerably the effectiveness of a systematically designed survey. Instead, cruise tracks were designed to cross depth contours and to cover as much of the area as possible (Figs 1 and 2). More detail is given in Cañadas *et al.* (2005).

Searching effort data

The *Toftevaag* is a 18m long motor-sailer with two (non-independent) observation platforms, one on the crow's nest with an eye height of 12m and another on deck with an eye height of 2.5m. Cruising speed was 5kt (9.3km h^{-1}). Sighting effort was measured as the number of kilometres travelled with adequate sighting conditions (i.e. with sea state Douglas 0 to 2 and good visibility) and observers on the lookout posts. Sighting effort stopped with sea states of 3 Douglas (Beaufort 3 to 4) or more. Sighting effort was categorised into 'effort types' according to sea state and position of trained observers, because crow's nest observations were cancelled with excessive swell: 1 (sea state 1 in Douglas scale and one observer in the crow's nest), 1S (sea state 1 and no crow's nest watch), 2 (sea state 2 with crow's nest watch) and 2S (sea state 2 and no crow's nest watch). Any change of effort type was recorded in the log book and in the Logger software, used for real time data logging (*www.ifaw.org*).

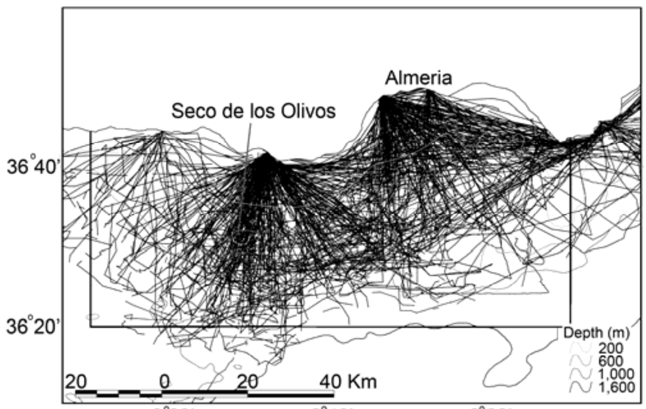

Fig. 1. Study area and cruise tracks between 1992 and 2003 in Southern Almería.

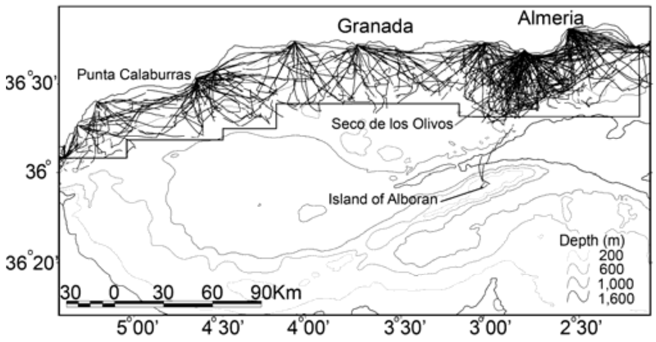

Fig. 2. Study area and cruise tracks between 2000 and 2003 in the Alboran Sea.

During searching on effort, data were recorded every 20 minutes ('sampling stations') on: type of effort, sea state, number of ships (discriminating by type) in a radius of 3 n.miles and other environmental data.

In this study it was not possible to implement the accepted methodology using double platforms to estimate the proportion of animals or clusters missed on the transect line (e.g. Borchers *et al.*, 2002; Hammond *et al.*, 2002). As a result, all abundance estimates are potentially negatively biased. Double platform methods would also allow responsive movement to be accounted for (a potential positive bias for bottlenose dolphins); however, no evidence was found for this (see Results).

Sightings data

Once an animal or group of animals was detected, immediate 'primary data' were taken: time, position, name of the observer making the sighting, position of the observer (mast or deck), type of effort, angle from the detected group to the trackline, estimated radial distance from the detected group to the ship, species, cue (blow, jump, splash, fin or back, birds, other), initial behaviour (see below), direction of swimming, wind and sea state. Before 2001, angle boards were not used and all angles were rounded in general to the nearest 10º. Since 2001, angles were measured with an angle board on the crow's nest or on the bridge, avoiding any rounding. Distances were always estimated by naked eye. No distance estimation experiments were carried out before or during the surveys. If distances were consistently under or overestimated, there is a potential for bias in estimates of density. Nevertheless, no changes in methods to collect distance data were made over the course of the study so this should not affect trends in abundance. Distance training and experiments will be carried out in the future.

All detected animals or groups were approached to a distance of 100m or less, at which point new 'contact data' were recorded: time, position and confirmation of species. If the animals allowed a close approach, the encounter could be prolonged up to several hours to carry out several other tasks (e.g. photo-identification). On leaving the animals, data were recorded again on time, position, wind, sea state and final behaviour, and searching effort started again.

Behaviour was divided into five categories: feeding-foraging (animals observed chasing or eating fish, long synchronised and repeated dives or following trawling fishing boats and repeatedly diving at the level of the trawler net); resting (stationary in one place, almost without any kind of movements); socialising (clear and constant interaction between the animals in the group, normally with much aerial activity and stationary in the area); travelling (moving animals, either on steady course or not, differentiated as travelling slowly (0.1-2kt), travelling moderately (2.1-4kt) and travelling fast (>4kt)); and milling (none of the previous categories, usually stationary in the area, with non-synchronised movements and very active).

Group size was assessed several times during the encounter. Animals were counted repeatedly to obtain the best estimate of group size. The number of calves and the estimated number of animals in any subgroups were also recorded. Any changes in group composition (subgroups joining or leaving) were recorded to ensure that the best estimate was of the group initially sighted.

Environmental data

Data were collated throughout the entire study area on physical and environmental features. Depth and slope of the seabed were extracted from nautical charts of the Hydrographic Institute of the Spanish Navy. Sea surface temperature (sst) and chlorophyll concentration (chl) data were obtained from the CREPAD service of INTA (the Spanish Space Agency), which consisted of NOAA AVHRR images with a pixel resolution of $2km^2$ and their associated ascii data. For sst, data were available for the years 1998 to 2004. For chl, data were available for the years 2000 to 2004. Sst averages were calculated for 1998 to 2000 and 2001 to 2004, and chl averages were calculated for 2000-2004.

Data analysis

Data organisation

The data were organised at two levels: the whole northern section of the Alboran Sea, which was covered from 2000 to 2003; and the waters off southern Almería, using data from 1992 to 2003. Given the small number of sightings for each year, it was not possible to analyse them separately. The Alborán dataset was therefore pooled over years. In the Almería dataset samples sizes were also too small to be analysed by year but did allow grouping over years. Observations in the field recorded the arrival in late 1997 of at least one 'immigrant' group of dolphins (some easily recognisable due to very conspicuous marks) into the study area. These conspicuous animals have not been seen again since 2001. The data were therefore divided into three strata: 1992 to 1997, 1998 to 2000 and 2001 to 2003 to investigate any changes in abundance resulting from these observations.

The study area was divided into 1086 grid cells, with a cell resolution of 2 minutes latitude by 2 minutes longitude each. The grid cells were characterised according to several spatial and environmental variables (see section on Spatial modelling of abundance).

All on effort transects were divided into small segments (average 2.8km, maximum 4km) between two consecutive sampling stations, with homogeneous type of effort along them. It was assumed that there would be little variability in physical and environmental features (like bottom physiography, sst, etc.) within these segments. Each segment was assigned to a grid cell based on the mid point of the segment and values of covariates for each grid cell were associated with the segment.

Encounter rates for each dataset, both of groups and of individuals, were calculated as the average across grid cells. In Almería, only grid cells surveyed during all three periods were considered. To avoid the problems caused by low effort, grid cells with less than 2.8km (1.5 n.miles) of effort were discarded for the calculation of encounter rates.

Spatial modelling of abundance

For model-based abundance estimation, five steps were followed: (1) a detection function was estimated from the distance data and any covariates that could affect detection probability; (2) the number of groups in each segment was estimated through the Horvitz-Thompson estimator (Horvitz and Thompson, 1952; Borchers *et al.*, 1998); (3) the abundance of groups was modelled as a function of spatial and environmental covariates; (4) the groups sizes were modelled as a function of detection probabilities and covariates; (5) steps 3 and 4 were combined and extrapolated to the whole study area to obtain the final abundance of animals.

The method of fitting separate models for abundance of groups and group sizes (steps 3 and 4 respectively) was based on the two-step method developed by Borchers *et al.* (1997) for modelling the spatial distribution of fish eggs, fitting separate GAMs (Generalised Additive Models) to presence/absence data and to the non-zero egg count data. A similar approach with two steps was used in Cañadas *et al.* ((in review)) for modelling the habitat selection of several species of odontocetes off Southern Spain, using GLMs (Generalised Linear Models). In the latter case, first presence/absence and then group size were modelled, yielding a surface map of relative density. If school size is suspected to vary spatially across the study area, it is preferable to estimate spatial school size surfaces through spatial modelling (Canadas *et al.*, (in review); Marques, 2001; Borchers and Burt, 2002). To estimate animal abundance, the estimated number of groups can be modelled instead of presence/absence, and the estimated abundance of groups multiplied by the estimated school size (Borchers and Burt, 2002; Burt *et al.*, 2003).

ESTIMATION OF DETECTION FUNCTION

For calculating the detection function, all sightings made on effort since 1992 were used, which totalled 212 observations (including sightings from adjacent study areas, not included here).

Angle data were rounded until 2000, and the distance data were rounded during the whole period because of being estimated by eye, so a smearing procedure was adopted following the method described in Buckland *et al.* (2001). Distances were smeared for the whole research period, and angles only for years 1992 to 2000, keeping the non-rounded angles taken in the field since 2001. The parameters for the smearing procedure were chosen after visual inspection of the data.

The software *DISTANCE* 4.0 release 2 (Thomas *et al.*, 2002) was used to estimate the detection function, using the multiple covariate distance sampling (MCDS) method (Marques, 2001; Thomas *et al.*, 2002). The perpendicular distance data were right truncated prior to the analysis, following the recommendations of Buckland *et al.* (2001). All covariates given in Table 1 and combinations of them, were tried. The selection of the best detection function was made using Akaike's Information Criterion (AIC).

Table 1

Covariates incorporated in modelling the detection function, indicating if they were treated as a continuous variable or as a factor, and the levels used in this case.

Covariate	Type	Levels
Group size	Continuous	
	Continuous (logarithm)	
	Factor	3 levels: 1-10/11-40/41-180
Type of effort	Factor	4 levels: 1/1S/2/2S
		3 levels: 1/2/1S-2S
		2 levels: 1/1S-2-2S
Observer	Factor	2 levels: M (mast)/D (deck)
Year	Factor	11 levels: 1992 to 2002
		4 levels: 1992-1994/1995-1997/1998-2000/ 2001-2002
Cue	Factor	3 levels: FB (fin-back)/SP (splash)/OT (other)
		2 levels: FB (fin-back)/OT (other)
Sea state	Factor	2 levels: 0-1/2 (Douglas)

ESTIMATION OF NUMBER OF GROUPS PER SEGMENT

The response variable used to formulate a spatial model of abundance of groups was the estimated number of groups ($\hat{N}$) in each segment, rather than the actual counts (Hedley *et al.*, 1999). They were estimated through the Horvitz-Thompson estimator (Horvitz and Thompson, 1952), where the probability of detection was obtained from the detection function fitted to the data:

$$\hat{N}_i = \sum_{j=1}^{n_i} \frac{1}{\hat{p}_{ij}} \quad (1)$$

where n_i is the number of detected groups in the i^{th} segment, and $\hat{p}_{ij}$ is the estimated probability of the j^{th} detected group in segment i, obtained from the detection function.

MODELLING ABUNDANCE OF GROUPS AND GROUP SIZE

For both models, the potential explanatory variables used were: longitude, slope of the sea floor (meters per km), relative sst in relation to overall average temperature, temporal variability of sst (standard deviation of the weekly average sst in a given grid cell over the year), trawling area (defined as 0 if trawlers were never observed fishing in a given location, and 1 if they were observed at least once), encounter rate of trawlers (number of trawlers observed fishing per sampling station), distance from the 'Seco de los Olivos' sea mount (an underwater mountain located in the north-eastern section of the study area, between 200 and 600m and rising up to 72m depth), and one of the following set of variables: depth, logarithm of depth, distance from the coast, distance from the 200m isobath, distance from the 1,000m isobath and latitude (only one of these was used at a time, because they are all correlated). Interactions between pairs of variables were also investigated.

The abundance of groups was modelled using a Generalised Additive Model (GAM) with a logarithmic link function. A Poisson error distribution was not considered appropriate for the response variable due to over-dispersion. Therefore, a quasi-poisson family was used, with variance proportional to the mean. The general structure of the model was:

$$\hat{N}_i = \exp\left[\ln(a_i) + \theta_0 + \sum_k f_k(z_{ik})\right] \quad (2)$$

where the offset a_i is the searched area for the i^{th} segment (calculated as the length of the segment multiplied by two times the truncation distance), θ_0 is the intercept, f_k are smoothed functions of the explanatory covariates, and z_{ik} is the value of the k^{th} explanatory covariate in the i^{th} segment.

Models were fitted using package 'mgcv' version 1.0-5 for R (Wood, 2001). Automated model selection by a stepwise procedure was not yet implemented in the version of R used (1.9.0) (*http://cran.r-project.org*). Therefore, manual selection of the models was done using three indicators: (a) the GCV (General Cross Validation score) which is in practice an approximation to AIC (Wood, 2000) and in which smoothing parameters (in terms of number of knots and degrees of freedom) are chosen by the software to minimise the GCV score for the model, unless they are directly specified; (b) the percentage of deviance explained; and (c) the probability that each variable is included in the model by chance. The decision to drop a term from the model was adopted following the criteria proposed by Wood (2001). In all models, a visual inspection of the residuals was also made, especially to look for trends.

Group size was also modelled using a GAM with a logarithmic link function. In this case, the response variable was the number of individuals counted in each group (s_j) and, given the large overdispersion due to the wide range of group sizes (1-180), a quasi-poisson error distribution was used, with the variance proportional to the mean. In this case, the detection probability was included as a linear predictor (Borchers and Burt, 2002) in order to avoid the bias introduced by the selective detection of larger groups at larger distances or by other covariates affecting the detection of the groups (Universidad de Barcelona, 2002). The general structure of the model was:

$$E(s_j) = \exp\left[\hat{g}_j(y,\nu) + \theta_0 + \sum_k f_k(z_{jk})\right] \qquad (3)$$

where $\hat{g}_j(y,\nu)$ is the conditional detection probability of the j^{th} group given that it was detected at perpendicular distance y and with covariates ν, θ_0 is the intercept, f_k are smoothed functions of the explanatory covariates, and z_{jk} is the value of the k^{th} explanatory covariate in the j^{th} group. Manual selection of the models was done following the same criteria described for the models of abundance of groups.

ESTIMATES OF ABUNDANCE

Predictions of abundance of groups and of group size were produced over all the grid cells of the study area, according to the values of the covariates used in the final models. The estimated abundance of animals for each grid cell was calculated as the product of its predicted abundance of groups and its predicted group size. The final point estimate of abundance was obtained by summing the abundance estimate of all grid cells over the study area.

AVAILABILITY ON THE TRACKLINE

This was estimated following Forcada *et al.* (2004), to investigate how much the probability of detection on the track line might be influenced by availability bias. The average dive time (68.7s) and average surface time (231.3s) used were those estimated by Forcada *et al.* (2004) for bottlenose dolphins in the Balearic Islands and north-eastern waters of Spain. The amount of time the sea on the trackline was in the observers' view was estimated based on the distances at which bottlenose dolphins may be detected on the trackline (up to 20º on each side) and the speed of the ship.

Estimation of variance

Four hundred non-parametric bootstrap resamples of the whole process were done, using day as the resampling unit, to obtain the coefficient of variation and percentile based 95% confidence intervals. For both models in each bootstrap, the degree of smoothing of each model term was chosen by 'mgcv', thus incorporating some model selection uncertainty in the variance. The final CV for each subset was calculated using the delta method (Seber, 1982), combining the CV of the detection function with the CV of the models from the bootstrap. These values were plotted as surface maps of abundance and of variability.

Random and responsive movement

The average searching speed of the ship was 5kt, which is slow compared to most line transect surveys for cetaceans. Because random movement of animals leads to increasing bias as the ratio of animal speed to ship speed increases (Hiby, 1982), we investigated whether this was a problem in our data. The average speed of the dolphins (at the moment of the encounter) was calculated by assigning an average speed to each behavioural category (from the 'primary sighting data'): 0kt for socialising, milling, feeding and resting; 1kt for travelling slowly; 3kt for travelling at moderate speed and 5kt for travelling fast. The average speed for all sightings, according to their initial behavioural category was then obtained. For this analysis, all sightings of bottlenose dolphins since 1992 were considered.

We also investigated whether responsive movement had occurred before detection by calculating the ratio of animals/groups with swimming direction in the third quadrant (180º-270º) to the first quadrant (0º-90º), relative to the transect line following Palka and Hammond (2001). The ratio between these quadrants was evaluated using a chi-square test, to see if there was any evidence of attraction (Q3/Q1>1) or avoidance (Q3/Q1<1).

RESULTS

Effort and sightings

For the sub-area of Almería, surveys were conducted on 460 days between 1992 and 2003, totalling 19,485km on effort (Fig. 1; Table 2). For the area of Alborán, surveys were conducted on 306 days between 2000 and 2003 (including the time spent in Southern Almería since 2000), totalling 12,568km on effort (Fig. 2; Table 2). In total, 24,643km were surveyed on effort in the whole study area since 1992, of which between 48% and 57% (depending on the year) were made under the best conditions (with effort type 1; Table 1). A total of 177 sightings of bottlenose dolphins were made while searching on effort. The effort, number of sightings, average encounter rate and average group size for each of the data subsets is shown in Table 2.

Detection function

Perpendicular distance was truncated at 2,500m after visual inspection of the data. This discarded 5% of the data with

Table 2

Days surveyed, total effort (in km), percentage of segments per effort type, number of groups (number of individuals), mean group size and encounter rates (ER) for groups and for individuals for each subset of data.

Year	Days	Total effort	Effort 1	Effort 2	Effort 1S	Effort 2S	Nº of groups (indiv.)	Mean group size (SE)	ER groups (SE)	ER indiv. (SE)
Almería										
1992 - 1997	136	6,251	52.6%	11.8%	13.4%	22.2%	41 (683)	16.8 (2.95)	0.0046 (0.0010)	0.073 (0.020)
1998 - 2000	181	7,715	51.5%	11.3%	17.3%	19.9%	84 (2,851)	33.2 (4.03)	0.0120 (0.0019)	0.406 (0.087)
2001 - 2003	143	5,520	48.2%	12.2%	22.8%	16.8%	34 (833)	26.4 (4.75)	0.0069 (0.0018)	0.164 (0.046)
TOTAL	460	19,485	50.8%	11.7%	17.8%	19.8%	159 (4,367)	27.5 (2.53)	0.0084 (0.0010)	0.238 (0.038)
Alborán										
2000 - 2003	306	12568	55.6%	13%	18.3%	13.8%	72 (2,071)	25.0 (2.84)	0.0043 (0.0008)	0.122 (0.034)
Total										
1992 - 2003	580	24,643	53.9%	11.7%	17.1%	17.3%	177 (3,625)	24.2 (2.19)	0.0052 (0.0009)	0.145 (0.035)

the largest distances, leaving 202 sightings for analysis (including those made outside the study area).

Ninety-two models were fitted, starting with single covariates and continuing with combinations of two, three and four covariates. Year had very little effect on the detection function. We assumed, therefore, that detection probability had not changed over time, and data for all years were pooled. The best fitting model was a half-normal key function with cosine series expansion and two adjustment terms. Four covariates were selected: position of the observer, sea state, group size, and cue. The next best models had delta AIC>4, so they were not competitive. They all incorporated the position of the observer, the cue and the group size (or its logarithm) as important covariates. Effort type was selected also in all these models, with either 2, 3 or 4 levels, but the best model incorporated sea state instead (the definition of effort type includes sea state). In Table 3, the coefficients for the covariates and the parameters for the detection function are shown. Fig. 3 shows the observed frequencies at given distances, pooled over all covariates, and the fitted half-normal function.

Table 3

Coefficients for the covariates and parameters for the detection function. Covariates modelled together with perpendicular distance for each sighting in these models are: position of the observer (OBS), sea state (SEA), group size (CLSIZE) and cue with 2 levels (CUE).

Parameter	Point estimate	Standard Error
Intercept	773.1	25.92
Level D of factor covariate OBS	-0.5934	0.1241
Level 0-1 of factor covariate SEA	0.5520	0.1631
Covariate CLSIZE	0.0103	0.0041
Level FB of factor covariate CUE	-0.4206	0.1881
Adjustment term of order 2	0.1597	0.1693
Adjustment term of order 3	0.3932	0.1311
f(0)	0.001668	0.000114

Abundance models

The variables retained in the two steps of the model, for each data subset, are shown in Table 4. The shapes of the functional forms for the smoothed covariates used in the models for the four datasets are shown in Figs 4 to 6. The most important variables, selected in many of the models, were depth (or logdepth), distance from 'Seco de los Olivos' and slope. In the model of abundance of groups for Alborán, the encounter rate of trawlers was selected and in one of the Almería datasets the average chlorophyll concentration contributed significantly to the model, apparently with a preference for areas with high concentration.

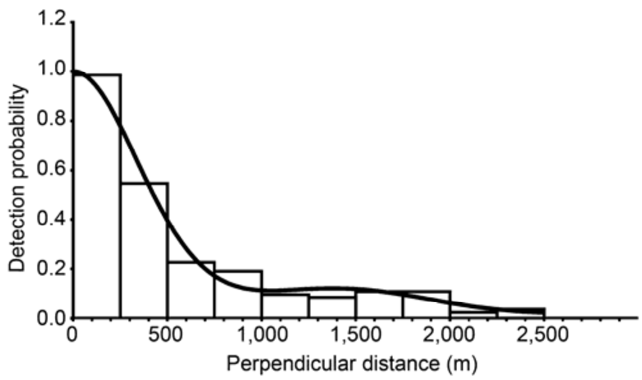

Fig. 3. Perpendicular distance distribution, pooled over all covariates (histograms) and fitted half-normal detection function, conditional on the observed covariates (line).

The small number of sightings did not allow the use of the best fitting models in the bootstrap simulations in many cases. The best-fitting but more complex models caused the bootstraps to fail frequently indicating a possible overfitting of the data. Therefore, simpler models were used in some cases, both for the point estimate and for the bootstrap, mainly by reducing the degrees of freedom allowed for variables such as depth or slope. This procedure had the disadvantage of using a model that explained a smaller percentage of the deviance. Furthermore, when modelling group size, the 'edge effect' constituted a problem in some models. When this occurred, the covariate causing the 'edge effect' (usually the slope) was either forced to use fewer degrees of freedom or was discarded, with the penalty of yielding a smaller percentage of deviance explained. Visual inspection of the residuals did not show any unacceptable pattern.

Estimated distribution, abundance and trend.

Estimates of abundance and variability are given in Table 5. For the Alborán area, the point estimate of abundance for the whole period was 584 dolphins, mainly concentrated in southern Almería, the coastal areas of Granada and south of Punta Calaburras in Málaga (Fig. 8). This abundance estimate yields an estimated average density of 0.049 dolphins per sq km. In Figs 9 and 10, the lower and upper 95% confidence limits are plotted, respectively. The lower and upper 95% CL surface maps still show what seem to be the core areas for bottlenose dolphins.

For Almería, the surface maps of estimated abundance are shown in Fig. 11. The surface maps of variability are not included for the Almería datsets due to space limitations but also showed the core areas. In the second period, after the arrival of the 'immigrant' animals, estimated abundance increased markedly by a factor of four (Table 5). In 2001-2003, estimated abundance decreased by a factor of two. The abundance estimate for the second period was significantly different from the first and period (d_{1-2}=-3.320, p<0.001), but abundance estimates in the first and third and second and third periods were not different (d_{1-3}=-1.786; 0.10>p>0.05; d_{2-3}=1.844, 0.10>p>0.05). Average encounter rates of individuals followed the same pattern and mean group size was also higher in the second period (Table 2).

To test the robustness of the abundance estimates, we ran two additional models: for Alborán 2001-2003 to compare to that for Almería 2001-2003; and for Almería 2000-2003 to compare to that for Alborán 2000-2003. The estimates from the models of Almería were similar to those obtained by summing the estimated abundance of the grid cells corresponding to Almería in the models for Alborán in both periods tested: 2001-2003, 228 animals (Alborán model) *vs*. 279 (Almería model); 2000-2003, 372 animals (Alborán model) *vs*. 424 (Almería model). This, together with the strong similarities of all surface maps corresponding to different datasets, suggests that the estimates were robust.

Availability on the trackline

Bottlenose dolphins were seen up to a radial distance of more than 3,000m, and regularly up to 2,000m ahead of the ship. Small groups of dolphins (1-5 animals) were regularly detected up to a distance of 1,000m ahead of the ship. Given the average ship speed of 5kt, the estimated time the 1,000m in front of the ship is in the view of the observer is 6 minutes. Using these data the Forcada *et al.* (2004) method estimates the probability of availability as 1.

Random and responsive movement

There were 271 sightings of bottlenose dolphins on effort (including sightings from adjacent areas) for which data on initial behaviour, and therefore estimated speed, were available. The average estimated speed of the dolphins was 1.3kt (SE=0.11kt). The ratio of dolphins speed to ship speed was therefore 0.26, well below the value of 0.5 considered as problematic (Hiby, 1982; Palka and Hammond, 2001).

For the study of possible responsive movement of the animals before detection, data on initial heading relative to the transect line were available to 86 sightings of bottlenose dolphins. Of these, 20 sightings (23.3%) were stationary and not heading in any direction. For the remaining sightings, the ratio Q3/Q1 was 0.83, which is not significantly different from one (χ^2=0.28, df=1, p>0.05), suggesting no responsive movement of the animals before detection.

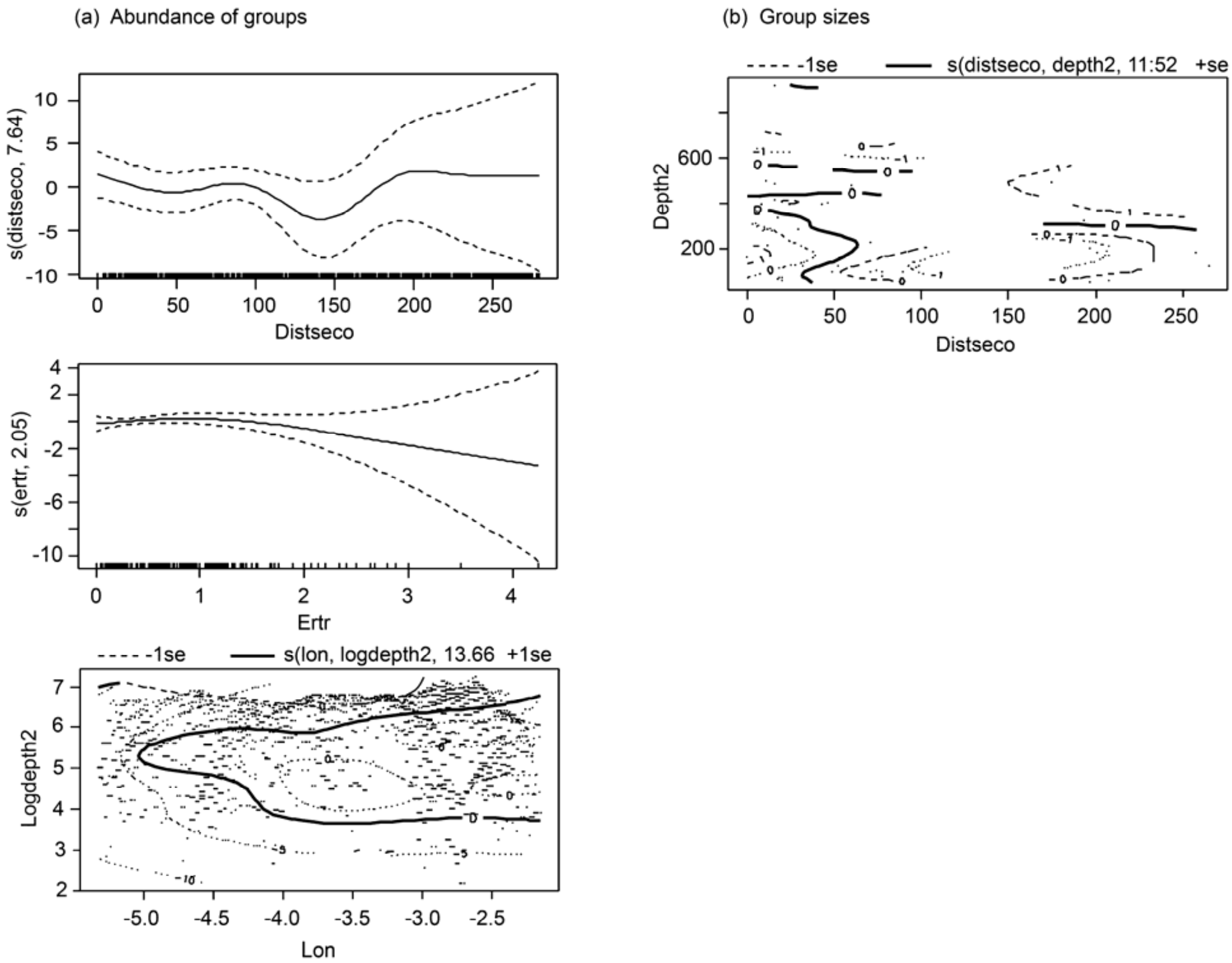

Fig. 4. Shapes of the functional forms for the smoothed covariates used in the models for the dataset of Alborán 2000-2003. Zero on the vertical axes corresponds to no effect of the covariate on the estimated response (group density on the left and group size on the right). The dashed lines represent twice the standard errors of the estimated curve (95% confidence band). The locations of the observations are plotted as small tick marks along the horizontal axes. The interactions between two variables are shown as two-dimensional plots. In these cases, the locations of the observations are plotted as small dots. The variables are abbreviated as in Table 4.

Table 4

Model results for all the subset data analysed. For each row, the two models are shown (abundance of groups and group size), indicating the variables (':' indicates an interaction between two variables) retained in the best model (estimated degrees of freedom in parentheses: 1 means a linear relationship), and the percentage of deviance explained by the model. The variables are abbreviated as follows: lon = longitude, depth = depth of the sea floor, logdepth = logarithm of depth, slope = slope of the sea floor, distseco = distance from the "Seco de los Olivos", dist200 = distance to the 200 m depth contour, ertr = encounter rate of trawlers, cav0004 = average chlorophyll concentration for 2000-2004, g(*y*,*v*) = conditional probability of detection (always as a linear predictor). Variables are ordered from more to less significant according to their p-value in the final model.

Subset	Model	Variables	% Deviance explained
Alborán	Groups	distseco (7.6) + logdepth:lon (13.2) + ertr (2.0)	19.0
2000-2003	Group size	depth:distseco (11.5) + g(*y*,*v*)	28.0
Almería	Groups	distseco (4.5) + cav0004 (4.3) + depth (3.2)	13.0
1992-1997	Group size	g(*y*,*v*) + logdepth (2.4) + slope (5.3)	48.7
Almería	Groups	lat:lon (19.2) + dist200 (4.7)	15.3
1998-2000	Group size	distseco (4.2) + depth:slope (13.3) + g(*y*,*v*)	37.5
Almería	Groups	distseco (2.3) + logdepth (4.2)	17.8
2001-2003	Group size	slope (2) + g(*y*,*v*)	20.9

Table 5

Point estimates of abundance, density, and mean abundance, CV and 95% CI after 400 bootstrap resamples.

Subset	Area (km^2)	Period	Estimated abundance	Estimated density	Mean abundance after bootstrap	95% CI after bootstrap	CV after bootstrap
		1992-97	111	0.026	113	54 - 234	0.45
Almería	4,232	1998-2000	537	0.127	487	332 - 746	0.24
		2001-03	279	0.066	305	146 - 461	0.28
Alborán	11,821	2000-03	584	0.049	462	278 - 744	0.28

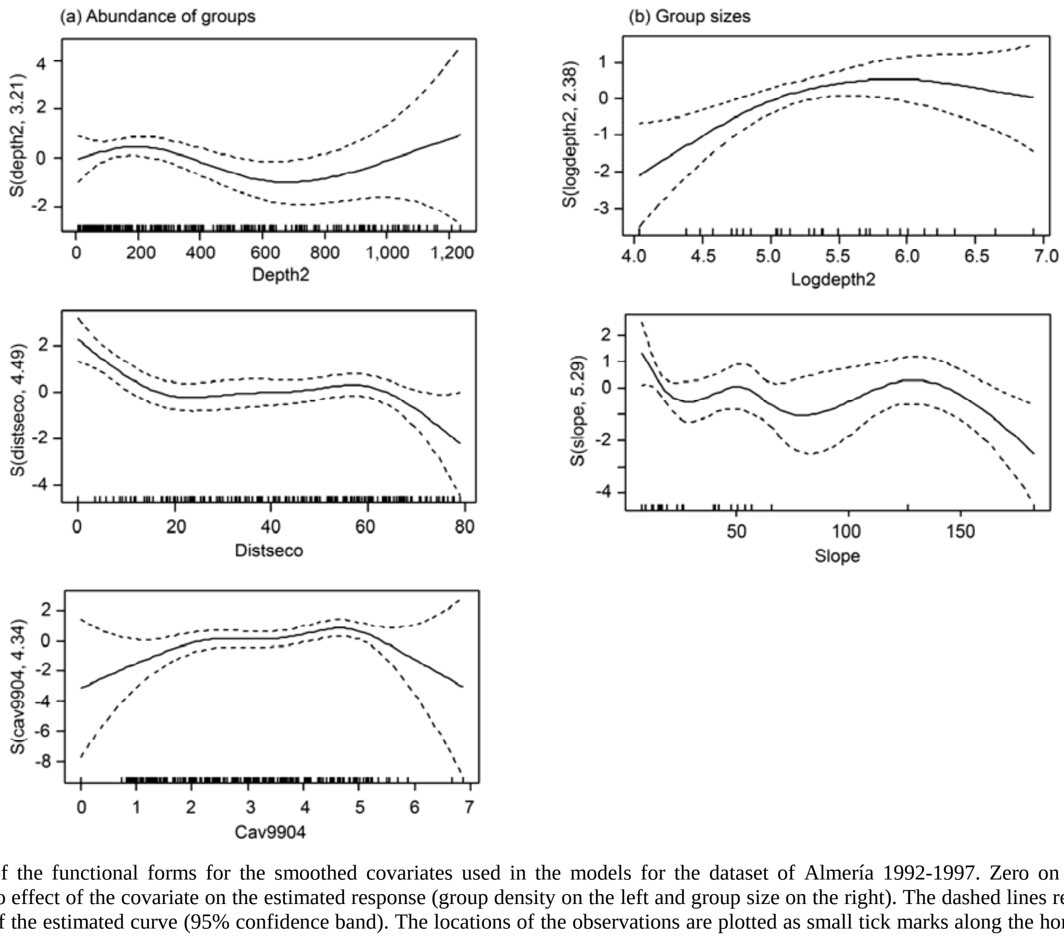

Fig. 5. Shapes of the functional forms for the smoothed covariates used in the models for the dataset of Almería 1992-1997. Zero on the vertical axes corresponds to no effect of the covariate on the estimated response (group density on the left and group size on the right). The dashed lines represent twice the standard errors of the estimated curve (95% confidence band). The locations of the observations are plotted as small tick marks along the horizontal axes. The interactions between two variables are shown as two-dimensional plots. In these cases, the locations of the observations are plotted as small dots. The variables are abbreviated as in Table 4.

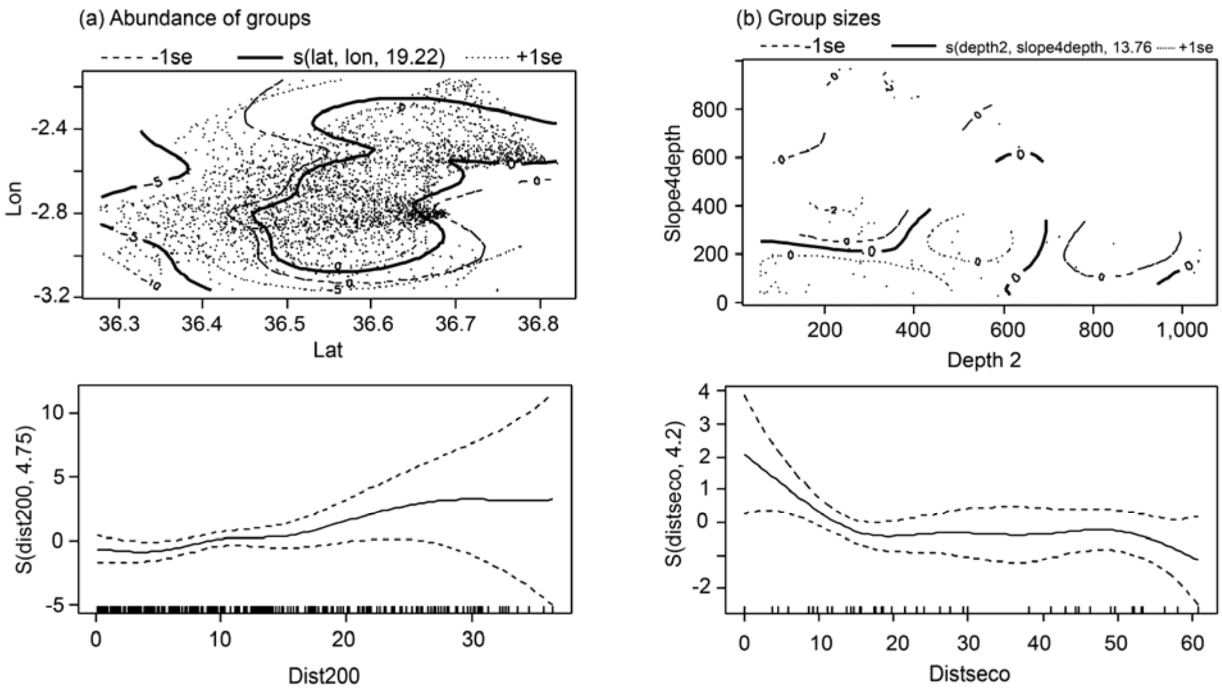

Fig. 6. Shapes of the functional forms for the smoothed covariates used in the models for the dataset of Almería 1998-2000. Zero on the vertical axes corresponds to no effect of the covariate on the estimated response (group density on the left and group size on the right). The dashed lines represent twice the standard errors of the estimated curve (95% confidence band). The locations of the observations are plotted as small tick marks along the horizontal axes. The interactions between two variables are shown as two-dimensional plots. In these cases, the locations of the observations are plotted as small dots. The variables are abbreviated as in Table 4.

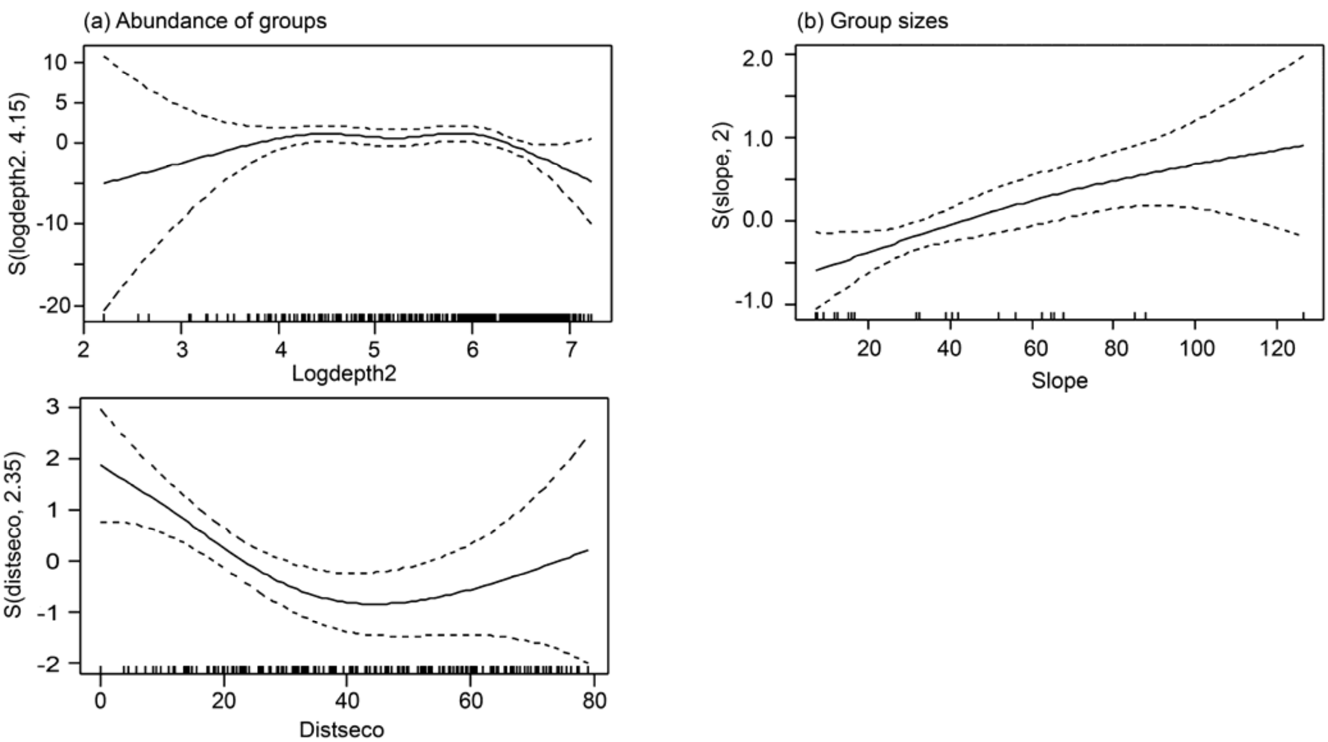

Fig. 7. Shapes of the functional forms for the smoothed covariates used in the models for the dataset of Almería 2001-2003. Zero on the vertical axes corresponds to no effect of the covariate on the estimated response (group density on the left and group size on the right). The dashed lines represent twice the standard errors of the estimated curve (95% confidence band). The locations of the observations are plotted as small tick marks along the horizontal axes. The interactions between two variables are shown as two-dimensional plots. In these cases, the locations of the observations are plotted as small dots. The variables are abbreviated as in Table 4.

DISCUSSION

Distribution and abundance

Bottlenose dolphins appear to respond to the different characteristics of their environment by clustering (both in terms of groups and by increased group size) in some parts of the study area, with a preference for waters between 200 and 600m depth and a steep sea bottom (especially around the 'Seco de los Olivos'), areas usually heavily used also by trawlers. This agrees with this species' most common feeding habits reported in the western Mediterranean (mainly demersal fish prey; Gannier, 1995; Blanco *et al.*, 2001; Cañadas *et al.*, 2002). In most models, depth (or logdepth) was the favoured variable over all other related covariates (e.g. distance from coast or from the 200m isobath), indicating that they prefer a certain range of depths, not necessarily linked to distance from features such as the coast. In the models, longitude takes the role of a proxy variable that helps explain the spatial distribution of this species from west to east in the study area. As expected, the results are similar to those from the habitat selection modelling undertaken in the same area (Canadas *et al.*, 2005).

The distribution and abundance of species with complex ecology, social structure and behaviour living in a highly dynamic and, as yet, mostly unknown three-dimensional environment, are difficult to model. Variables that are expected to influence directly the distribution and abundance of dolphins in the open sea are at best difficult to measure (e.g. distribution and abundance of prey). Furthermore, the very low proportion of positive observations in the datasets (due to the low density of the species and the small size of the segments) might be limiting the variability that could possibly be explained with the available variables. This problem was increased by the need to discard variables yielding a strong 'edge-effect' and to fit simpler models for the bootstraps. Nevertheless, the surface maps, and the fact that they remain very similar across the datasets, suggest that the general distribution pattern of this species in the area has been satisfactorily reflected by the models (Figs 8 to 11). To check if there was overfitting, nominal parameter SEs and bootstrap SEs were compared. If the bootstrap SEs were substantially bigger than the nominal, then the model will tend to be overfitted and undersmoothed. The SEs from both sources in this work were comparable, suggesting that no problem of overfitting existed. Bootstrap at a week level was tried and compared with the daily level in order to explore if some underlying 'spatial week effect' was missed. SEs were similar and therefore the daily level was kept.

In the area of Almería, despite the differences in estimated abundance over time, the core area was the same in the three periods: around the 'Seco de los Olivos' sea mount. This is an important area of upwelling induced by the topography, which has been highlighted for having the highest concentrations of ichthyoplankton of the northern half of the Alboran Sea (Rubin *et al.*, 1992). In the second period with higher abundance, the most heavily used areas are more extensive; they narrow again in the third period following the decrease in estimated abundance. A possible explanation of this might be that when the abundance is relatively low, the dolphins tend to concentrate in the most productive areas, where they may have the best possibilities of success finding their prey. When abundance is higher, they may also need to explore other areas.

There is a potential for the trends in abundance to be confounded with changes in group size because $g(0)$ is assumed to be one but $g(0)$ is expected to be smaller for small groups than for big groups. In the second time period when estimated abundance was higher, group size was also higher than during the other two periods. Although we cannot estimate perception bias, because there is no availability bias even for small groups of 1 to 5 individuals, we do not believe that the trend in abundance is a consequence of a change in $g(0)$ due to changes in group size.

As it was not possible to implement a double platform survey method for estimating $g(0)$, the abundance estimates presented here are potentially an underestimation of true abundance. Further data are being collected with a double platform installed on the research vessel, with the aim of estimating $g(0)$ in the near future and therefore correcting the abundance estimates. However, we do not expect this to change the results significantly. Availability bias is unlikely and we believe perception bias is also likely to be small given the sea states in which the survey was carried out, the relatively large group sizes encountered, the slow speed of the ship and the height of the observation platform. Therefore, it is likely that $g(0)$ is close to one.

Implications for conservation and management

It is important to highlight that these estimates represent the average number of bottlenose dolphins in the study areas during the defined periods, not the size of a population using the areas. Neither the area of Alborán nor the sub-area of Almería are closed areas, and our results show that they do not contain a closed population, with movement of individuals into and out of the adjacent areas of the Strait of Gibraltar, the Gulf of Vera and the southern portion of the Alboran Sea. This, together with the negative bias produced by assuming $g(0)=1$, means that the size of the population of bottlenose dolphins that uses the study area is larger (by an unknown extent) than our estimates. In terms of monitoring conservation status within a defined area such as an SAC, we are interested in wheIn the area of Almería, the field observations of the presence of the conspicuous 'immigrant' group between late 1997 and 2001 was echoed by a significant change in estimated abundance. Analysis of the photo-identification data will help to provide more detail of this.

[Text continues on p. 000]

Table 6

Encounter rates (ER) of groups and individuals (per km), and mean group sizes of bottlenose dolphins in Spanish Mediterranean waters. Encounter rates and mean group size were calculated as the average over grid cells for this work. Other data represent overall values. '*' means estimated density corrected for availability bias (Forcada *et al.*, 2004); all other densities are underestimations.

Area	Period	Density (animals/km^2)	ER of groups	ER of indiv.	Mean group size	Source
Gibraltar	2001-02		0.0056	0.1157	27.8	De Stepahins *et al.* (in review)
Alborán	2000-03	0.049	0.0043	0.1220	25.0	This work
Almería	1992-97	0.026	0.0086	0.1356	16.7	This work
Almería	1998-2000	0.127	0.0222	0.7524	33.9	This work
Almería	2001-03	0.066	0.0128	0.3031	24.5	This work
Gulf of Vera	1993-2004		0.0016	0.0161	10.5	Unpublished data of the authors
Valencia	2000-02	0.026	0.0006	0.0066	11	Gómez de Segura *et al.* (in prep.)
Catalonia	2001-02		0.0017	0.0117	7	Universidad de Barcelona (2002)
Catalonia and Balearic Sea	2002	0.088*			7	Forcada *et al.* (2004)
Balearic Islands	2001-02		0.0018	0.0142	6.3	Universidad de Barcelona (2002)
Balearic Islands	2002	0.085*			7	Forcada *et al.* (2004)

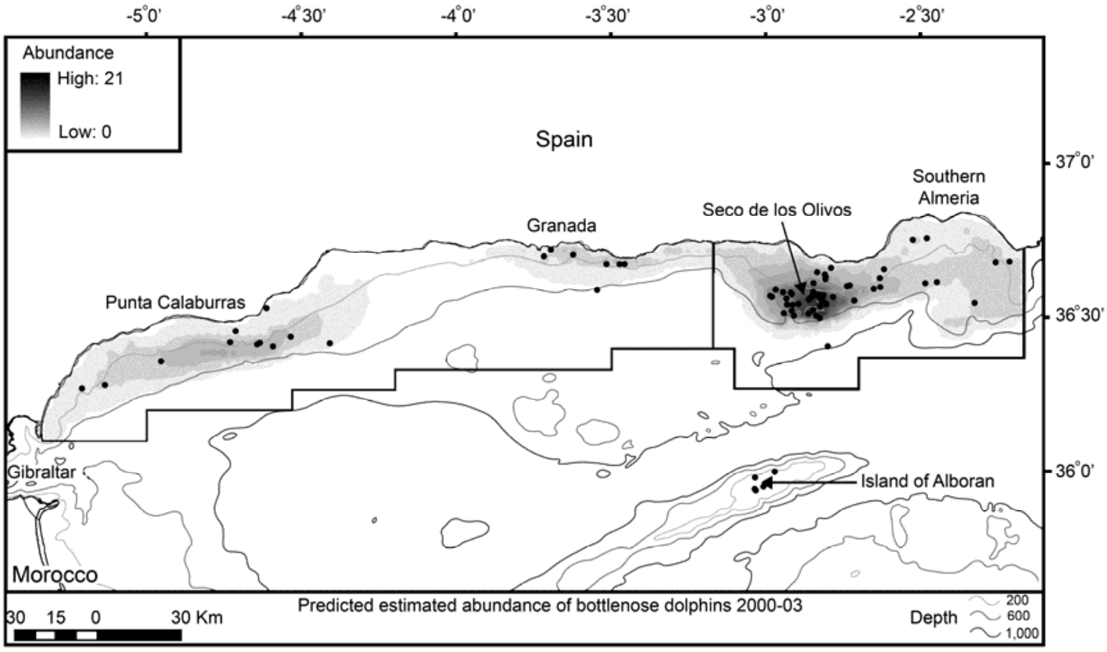

Fig. 8. Surface map of abundance for bottlenose dolphin in the northern section of the Alborán Sea, for years 2000 to 2003.

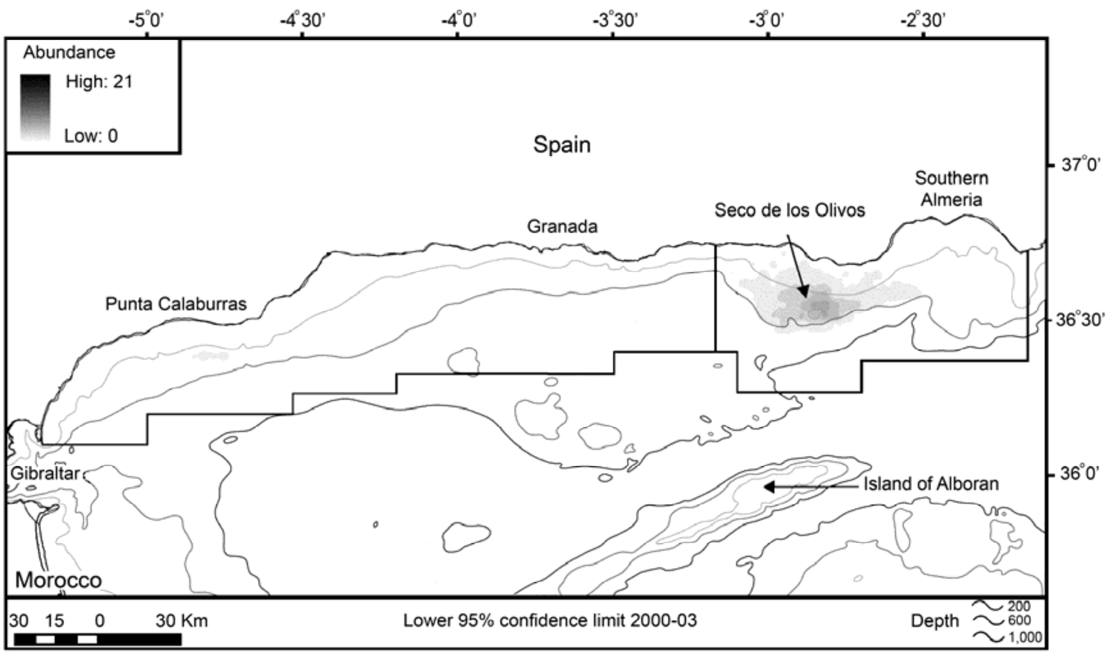

Fig. 9. Surface map of lower 95% confidence limit after 400 bootstrap resamples for the study area of Alboran, for years 2000 to 2003.

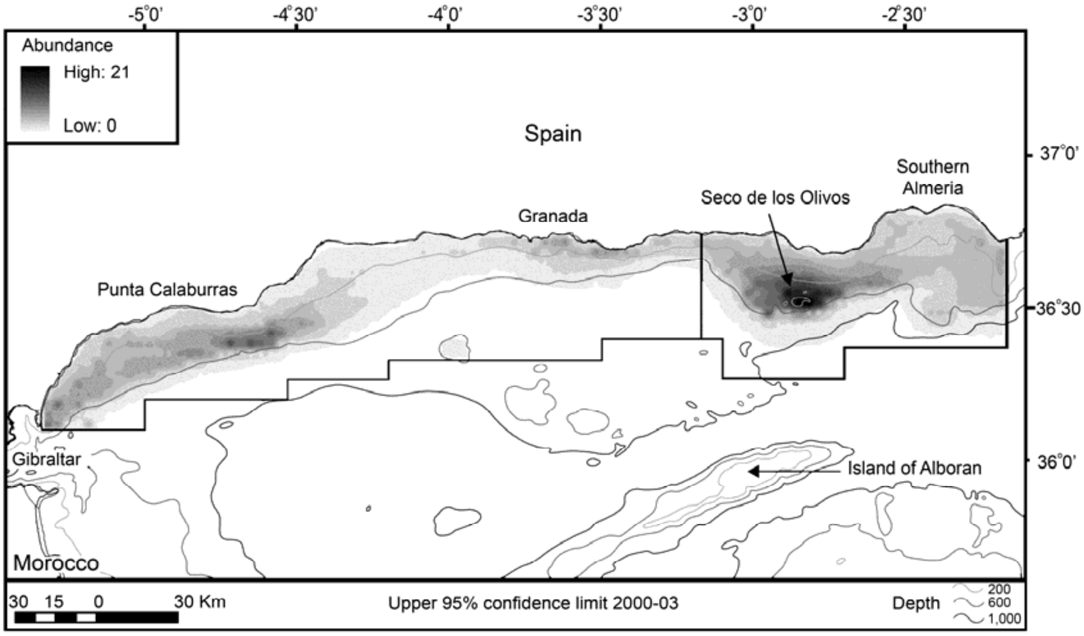

Fig. 10. Surface map of upper 95% confidence limit after 400 bootstrap resamples for the study area of Alboran, for years 2000 to 2003.

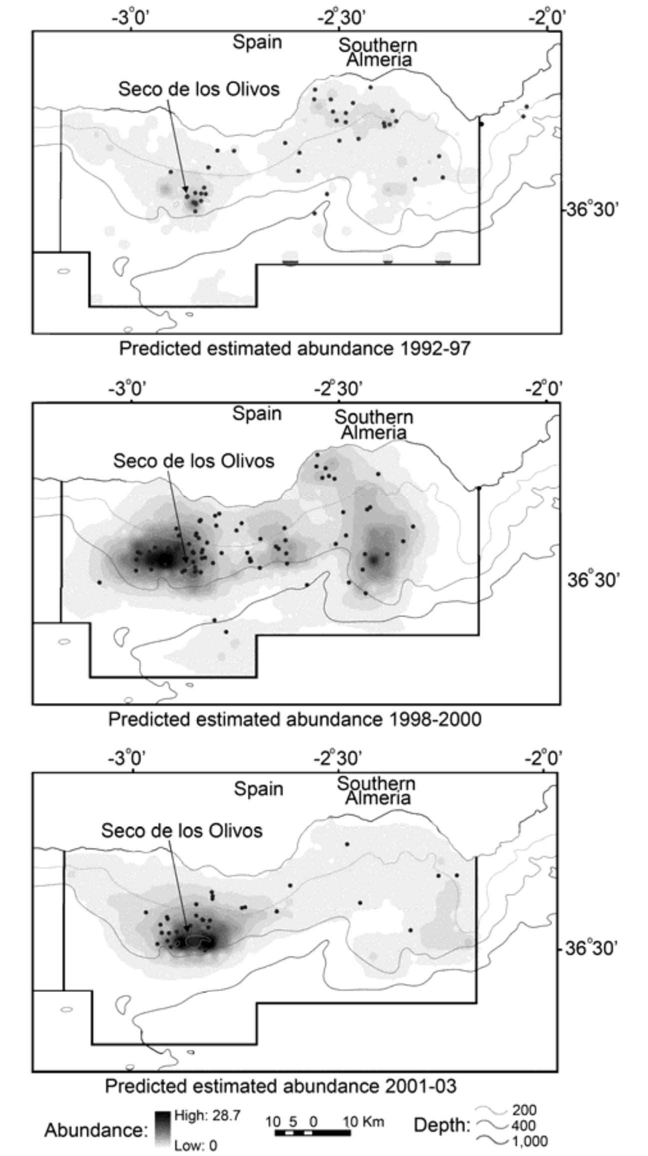

Fig. 11. Surface maps of abundance in the study area of Southern Almería for the three periods: 1992 to 1997, 1998 to 2000 and 2001 to 2003.

Our results highlight the importance of long-term studies to understand variation in abundance in a given area. For example, if this study had started in 1998, we could be alarmed at detecting an apparent decline in numbers of animals in the Almería area.. Instead, the longer time series of data allowed the documentation of an increase and subsequent decrease in abundance that is likely a result of natural fluctuations in abundance. This highlights the need for an adequate long-term monitoring programme. An important question for the Monitoring Plan of the proposed SAC in this area is when should an abundance 'baseline' be established to base future assessments of conservation status. Should this be the lowest abundance estimated over the past 12 years, or perhaps the average over the last 12 years? This will depend in part on the conservation objectives of the Management Plan.

Ideally, the monitoring programme should be developed not only to allow the detection of changes in abundance in the long-term, but also the differentiation between natural fluctuations and real trends in the abundance of the population. The observed fluctuations in abundance in the Almería area stress the need for the monitoring programme to cover not only the proposed SAC but also a wider area outside it to improve our understanding of fluctuations or trends in numbers and shifts in distribution. This wider information may have important implications for the management of the protected areas (Wilson *et al.*, 2004).

There is limited information on abundance of bottlenose dolphins in other areas of the western Mediterranean Sea. Aerial line transect surveys carried out off Valencia (Eastern Spain), from 2000 to 2002 (Gomez de Segura *et al.* pers. comm.) estimated a density of 0.026 dolphins per sq km, lower than estimated here, except for Almería in 1992-1997. The encounter rates of groups and of individuals were also much lower than in Almería, as was the mean group size (11 in Valencia *vs.* 24 in Alborán). However, caution must be exercised when comparing these results, as very different survey platforms were used (ship *vs.* aircrafts) and *g*(0) was not estimated in either analysis. An abundance estimate for this species has been obtained recently also for the NW Mediterranean (north of Spain and Balearic Islands), based too on aerial survey. The estimated density in this area was of 0.085 to 0.088 dolphins per sq km. In this case, the estimate was corrected for availability bias, and underestimation due to perception bias was considered to be very small (Forcada *et al.*, 2004; Table 6). The available information suggests that encounter rates, and average group sizes, decrease from west to east in Spanish Mediterranean waters (Table 6). Although there are methodological issues with comparing these results, as described above, they suggest that the Alboran Sea, and especially the area off Southern Almería, are important areas for bottlenose dolphins in the westernmost part of the Mediterranean Sea.

Applicability of the method

The model-based method for estimating abundance is shown to be a good approach for describing cetacean distribution, and estimating abundance based on the data collected in this study. Much of the data on cetacean distribution and density in Europe is being collected through non-systematically designed surveys similar to those presented here. This method constitutes, therefore, a promising way to analyse these large collections of data.

Nevertheless, caution should be exercised when applying very flexible models like GAMs, especially to avoid overfitting the data and the 'edge effect', which could yield unrealistic densities and surface maps. This method is still in a relatively early stage of development, and some questions remain unsolved, such as whether the bootstrap is the most appropriate way of obtaining 95% confidence intervals, or how to deal better with the problem of the 'edge-effect'.

The models described in this paper should be revised when data on more potential explanatory variables become available, and especially when this method becomes better developed and tested (for example through analysis of simulated data).

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CHAPTER 8

MODEL-BASED ABUNDANCE ESTIMATE OF COMMON DOLPHINS IN THE ALBORÁN SEA

ABSTRACT

The short-beaked common dolphin is believed to have suffered a steep decline in Mediterranean in recent years. ACCOBAMS (Agreement for the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic waters) is therefore developing a Conservation Plan for this species. Effective conservation will depend critically on our understanding and ability to predict the relationship between the population and its habitats. The Alborán Sea is believed to be the most important remaining habitat for this species in the basin and constitutes, therefore, a vital source of information on its ecology, essential for the development of conservation measures.

Spatial modelling using GAMs was used to estimate the abundance of common dolphins in the area. In total, 37,385 km of non-systematic line transects conducted from 1992 to 2004, generating 738 sightings in a 19,189 km^2 study area. Analyses examined differences among sub-areas, years and seasons.

Seasonal variation in abundance was detected, with higher average density in summer (1.01 animals/km^2) than in winter (0.5 animals/km^2). Geographical differences were also found, with higher density in the west (1.55 animals/km^2) than in the east (0.14 animals/km^2) during summer. No overall trend in abundance was observed in the whole area but a decline was observed in the eastern portion (Gulf of Vera) with a summer density of 0.34 in 1992-1995 and 0.11 in 1996-2004. With respect to depth, a bimodal distribution was predicted, with higher densities around the continental slope (100-400m) and in deeper waters (800-1200m).

The lack of trends in the abundance estimates for the northern Alborán Sea between 1992 and 2004 contrasts with the apparent decline of this species in the rest of the Mediterranean Sea, but common dolphins inhabiting this basin have proven to belong to a different population than that of the rest of the Mediterranean Sea. It also contrasts with the reported high levels of by-catch in Moroccan drift-nets in the southern Alborán Sea. This could be due to several factors, which are discussed. Information on accurate abundance estimates for the whole Alborán Sea and the population structure of the dolphins inhabiting this basin, together with a continuation and extension to other ports of the monitoring of the by-catch along the Moroccan coast, are necessary to assess the impact of by-catch (and other threats) and therefore to develop adequate and effective conservation measures.

One reason for the decline of common dolphin density in the Gulf of Vera may be the exponential grow of aquaculture in the area since the mid 1990s, which implied a very large increase in the catches of round sardinella (*Sardinella aurita*), one of the main prey for common dolphins in the area, to feed fish in these aquaculture farms. However, it could also be the product of other factors that have been proposed as reasons for the general decline in the rest of the Mediterranean. The control and close monitoring of the aquaculture activities and their effects on the fish stocks should be part of any attempt to develop conservation measures for common dolphin.

8.1 INTRODUCTION

Short-beaked common dolphins (hereafter called simply 'common dolphin') in the Mediterranean appear to have suffered a steep decline over recent decades (UNEP/UICN 1994; Aguilar *et al*. 1994; Bearzi *et al*. 2003), although no reliable time series of abundance data exist. In 1999, the Spanish Ministry for the Environment included the common dolphin in its National Endangered Species Act as 'vulnerable'. In 2003, the Mediterranean common dolphin 'subpopulation' was listed as endangered in the IUCN Red List of Threatened Animals, based on criterion A2, which refers to a 50% decline in abundance over the last three generations (35-45 years), the causes of which 'may not have ceased or may not be understood or may not be reversible' (http://www.redlist.org).

For these reasons, the conservation of the Mediterranean common dolphin has become an urgent task (Bearzi *et al.*, 2003; Bearzi *et al*., 2004). The IUCN/SSC Cetacean Specialist Group has recommended that studies to 'investigate the distribution, abundance, population structure, and factors threatening the conservation of short-beaked common dolphins in the Mediterranean and Black Seas' be intensified (Reeves *et al*. 2003). Soon after this, ACCOBAMS commissioned the elaboration of a 'Conservation Plan for the short-beaked common dolphin in the Mediterranean Sea' (Bearzi *et al*. 2004). In the ACCOBAMS Implementation Priorities (ACCOBAMS 2002) it was proposed that areas containing critical habitat for priority species be identified, in which pilot conservation and management projects should be developed and implemented immediately. In the Conservation Plan, areas considered to be of special conservation value for common dolphins ("Areas of Conservation Importance" or ACIs) were selected based on the admittedly limited present knowledge of the distribution and frequency of occurrence of common dolphins in the Mediterranean.

In these ACIs, knowledge of stock structure, distribution and movements, present and past abundance and other population parameters, ecology and behaviour, as well as information on the scale and relative priorities of actual or potential anthropogenic threats to dolphins and possible mitigation measures must be increased quickly if the implementation of effective conservation actions is to occur (Bearzi *et al*. 2004). It is of fundamental importance to this effort to obtain baseline population abundance estimates and distributional information and to monitor these. This baseline information (and a suitable monitoring programme) is needed *inter alia* to put any identified threats to common dolphins into a context that will allow the establishment of priority conservation and mitigation measures as well as the monitoring of trends to determine whether these measures are enabling any conservation objectives established to be met.

However, estimating and monitoring the abundance of cetaceans is not easy, especially species such as the common dolphin with its broad geographical range and range of habitats (including both inshore and offshore waters (Forcada *et al*. 1990; Goujon *et al.* 1993, Harwood and Wilson 2001, Hammond *et al.* 2002, Lopez 2003, Silva and Sequeira 2003)) and its often large seasonal and shorter-term movements (Cockroft and Peddemors 1990; Reilly 1990; Pollock *et al*. 1997; Ó Cadhla *et al*. 2003; Northridge *et al*. 2004; Brereton *et al*. 2005). Nevertheless, there are a limited number of abundance estimates of common dolphins in discrete areas around the world, including parts of the NE Atlantic (Goujon *et al*. 1993; Hammond *et al*. 2002; Cañadas *et al*. 2004), obtained from 'conventional' line transect surveys (e.g. see Buckland *et al.* 2001).

There is a serious lack of information on the abundance of common dolphins (and most other species) in the Mediterranean (Cañadas *et al*. 2004). There has been only one large scale cetacean survey in the western part of the basin and that was carried out in 1991-1992 (Forcada and Hammond 1998). From this systematic line transect survey, the abundance of common dolphins could only be estimated for the Alborán Sea, due to the lack of encounters in other areas: 14,736 common dolphins (95% CI = 6,923 – 31,366; CV = 0.40). The only other estimate of abundance in the Mediterranean is for a small inshore area in the Ionian Sea, based on photo-identification: around 100 animals (Bearzi *et al*. 2003). A large scale, basin-wide survey to estimate the abundance of common dolphins and other species is being planned within the framework of ACCOBAMS and will hopefully occur within the next two years (Cañadas *et al*. 2004). Meanwhile, the only other information available on common dolphins in the region (which does not include abundance estimates) comes from small-scale studies by local research groups.

In the NE Atlantic, three major summer surveys, using line transect methods, have yielded density and abundance estimates of common dolphins. In 1993, the MICA93 survey carried out by the IFREMER (Institut Francais de Recherche pour l'Exploitation de la Mer) in the Gulf of Biscay estimated 0.16 individuals per km^2 and 61,888 dolphins (95% CI = 35,461 – 108,010) in a 370,00 km^2 area (Goujon *et al*.1993). In the Celtic Sea, the SCANS survey in 1994 estimated a density of 0.37 individuals per km^2 and an abundance of 75,449 dolphins (CV = 0.67, 95% CI = 22,900 – 248,900) (Hammond *et al*. 2002). The Faroese NASS95 survey to the west of Britain and Ireland (an area of 371,544 km^2) estimated a density of 0.74 individuals per sq km and an abundance of 273,150 animals (CV = 0.26, 95% CI = 153,392 – 435,104) (Cañadas *et al*. 2004; Cañadas *et al*. in press). In the first two surveys, no correction was made for schools missed in the trackline (g(0)) or for responsive movement. In the NASS95 survey, estimates were corrected for both responsive movement and g(0).

Line transect surveys are the most frequently used method to estimate the abundance of wide-ranging cetacean populations (e.g. IWC 2005). However, to generate robust estimates, these require *inter alia* the use of relatively large vessels with double platforms and a survey design that gives representative coverage (e.g. Hammond *et al*. 2002; Cañadas *et al*. 2004). Such requirements are usually beyond the resources of local research groups (usually NGOs) in the Mediterranean. Although mark-recapture methods (using photographs of natural markings) to estimate abundance of cetaceans have less stringent requirements in terms of vessels and survey design (e.g. Williams *et al*. 1993; Wilson *et al*. 1999; Stevick *et al*. 2003b), the method has not been applied yet to common dolphins.

One of the ACIs selected in the Conservation Plan for common dolphins in the Mediterranean Sea was the Alborán Sea, largely because the encounter rates of this species in this area are the highest in the whole Mediterranean basin (Bearzi *et al*. 2004). The aim of this work is to provide the first absolute abundance estimate of common dolphins in this region since the estimate from 1991-92 (Forcada and Hammond 1998) and to provide the first insight into trends in density over the past 14 years for the northern section of the Alborán Sea and the Gulf of Vera. The approach used to achieve this is the recently developed model-based method (Hedley *et al*. 1999; Marques 2001), already applied to bottlenose dolphins in this area (Cañadas and Hammond in press; Chapter 7). Valuable information on habitat preference is also obtained from this method. This is described and discussed in Chapter 9.The conservation implications of the findings are discussed.

8.2. METHODS

8.2.1. Data collection

8.2.1.1. Survey area and survey design

Cruise tracks were conducted by the research vessel *Toftevaag* between 2000 and 2004 in the whole northern section of the Alborán Sea and in the Gulf of Vera, an area of 19,189 km^2 (Figure 8.1). The research vessel *Else* surveyed the region of Murcia (northern Gulf of Vera) in 2003 and 2004. From 1992 to 1999, surveys were only conducted in the eastern part of the Alborán Sea, the waters off Southern Almería (4,232 km^2), and the Gulf of Vera (6,164 km^2). During 1993 and 1994, surveys were conducted only in the Gulf of Vera, and in 1999 only off Southern Almería. The study area was sampled in January, March, June to September and November from 1999 to 2004. From 1992 to 1998 surveys were made during March-April and from June to September. For some analysis the study area was divided into three major areas: the Gulf of Vera, Southern Almería and Western Alborán Sea (Figure 8.1). Transects did not follow a systematic design. The relatively small vessels used had a slow cruising speed, were very dependent on weather conditions and had to return to port every night. In addition, time was allocated to other activities during encounters, such as photo-identification. Instead, cruise tracks were designed to cross depth contours and to cover as much of the area as possible. More detail is given in Cañadas *et al*. 2005 (Chapter 6).

8.2.1.2. Searching effort data

The *Toftevaag* is a 18 m long motor-sailor with two (non-independent) observation platforms, one on the crow's nest with an eye height of 11 m and another on deck with an eye height of 2.5 m. The *Else* is a 15 m long motor-sailor also with two non-independent observation platforms, crow's nest and deck, at approximately the same eye of height as the other ship. Cruising speed for both ships was 5 kt (9.3 km h^{-1}). Sighting effort was measured as the number of kilometres travelled with adequate sighting conditions (i.e. with sea state Douglas 0 to 2 and good visibility) and observers on the lookout posts. Sighting effort stopped with sea states of 3 Douglas (Beaufort 3 to 4) or more. Sighting effort was categorized into 'effort types' according to sea state and position of trained observers, because crow's nest observations were cancelled with excessive swell: 1 (sea state 1 in Douglas scale and one observer in the crow's nest), 1S (sea state 1 and no crow's nest watch), 2 (sea state 2 with crow's nest watch) and 2S (sea state 2 and no crow's nest watch). Any change of effort type was recorded in the log book and in the Logger software, used for real time data logging (www.ifaw.org).

During searching on effort, data were recorded every 20 minutes ('sampling stations') on: type of effort, sea state, number of ships (discriminating by type) in a radius of 3 nmi, remote ships noise (detected with a towed array hydrophone) and other environmental data.

In this study it was not possible to implement the methodology using double platforms to estimate the proportion of animals or clusters missed on the transect line (e.g. Borchers *et al.* 2002; Hammond *et al*. 2002). As a result, all abundance estimates are potentially negatively biased.

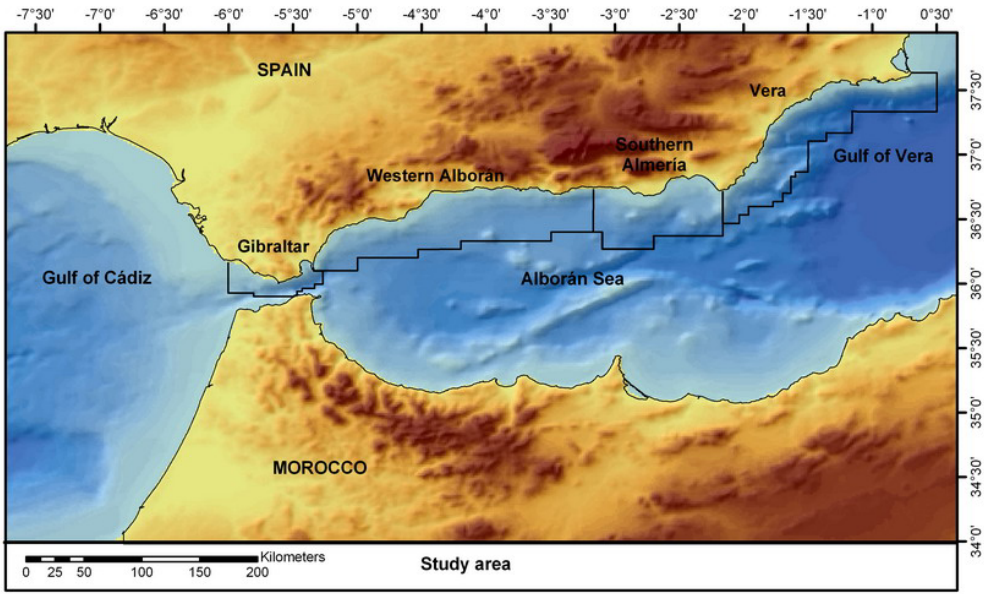


Figure 8.1. Study area

8.2.1.3. Sightings data

Once an animal or group of animals was detected, immediate 'primary data' were taken: time, position, name of the observer making the sighting, position of the observer (mast or deck), type of effort, angle from the detected group to the trackline, estimated radial distance from the detected group to the ship, species, cue (blow, jump, splash, fin or back, birds, other), initial behaviour (see below), direction of swimming, wind and sea state. Before 2001, angleboards were not used and all angles were rounded in general to the nearest 10º. Since 2001, angles were measured with an angleboard on the crow's nest or on the bridge, avoiding any rounding. Distances were always estimated by naked eye. No distance estimation experiments were carried out before or during the surveys.

All detected animals or groups were approached to a distance of 100 m or less, at which point new 'contact data' were recorded: time, position and confirmation of species. If the animals allowed a close approach, the encounter could be prolonged up to several hours to carry out several other tasks (e.g. photo-identification). On leaving the animals, data were recorded again on time, position, wind, sea state and final behaviour, and searching effort started again. When a group was composed by more than one species, each species was considered a different sighting, although linked, and a new form was filled in for each one keeping the same 'primary data'.

Behaviour was divided into five categories: feeding-foraging, resting, socialising, travelling (whenever possible differentiated as travelling slowly, moderately or fast), and milling, according to definitions given in Cañadas and Hammond (2005) (Chapter 6).

Group size was assessed several times during the encounter. Animals were counted repeatedly to obtain the best estimate of group size. The number of calves and the estimated number of animals in any subgroups were also recorded. Any changes in group composition (subgroups joining or leaving) were recorded to ensure that the best estimate was of the group initially sighted.

8.2.1.4. Environmental data

Data were collected throughout the entire study area on physical and environmental features. Depth and slope of the seabed were first extracted from nautical charts of the Hydrographic Institute of the Spanish Navy. Since 2001, depth was obtained also at every sampling station through an echo-sounder. These more than 5,500 data points were used together with the depth obtained from the nautical charts to produce much more detailed depth information.

Other data obtained from the echo-sounder were presence of fish schools (total and pelagic) and presence and depth of scattering layers. Encounter rates were calculated for these variables in terms of number of sampling stations with detections of fish or scattering layers by total number of sampling stations.

Sea surface temperature (sst) and chlorophyll concentration (chl) data were extracted from the ascii data of satellite images obtained from the CREPAD service of the INTA (Spanish Space Agency), which consisted of NOAA AVHRR images for the sst and SeaWIFS images for the chl with a pixel resolution of 2 km^2. Data from 1998 to 2004 was provided for sst, and from 2000 to 2004 for chl. Averages for both sst and chl were calculated for summer and for winter months, for all data available and by groups of years according to the datasets to be analyzed (see ‘Data organisation’). For analysis of datasets of the earlier years, were no sst and chl data was available, averages for the later periods were used as proxies of the usual conditions. Temporal variability of the sst was also estimated by calculating the standard deviation of the daily sst along the periods to be analyzed.

Human activities were also recorded, both in terms of number of ships in the area at each sampling station, and of ship noise. Encounter rates of trawler were calculated as the number of trawlers encountered by the number of sampling stations. An index of acoustic pollution was calculated as the number of acoustic detections, multiplied by their mean value of ‘intensity’ (an arbitrary scale going from 1 –very faint- too 5 –very loud-), by the number of sampling stations.

8.2.2 Data analysis

8.2.2.1. Data organisation

The study area was divided into 1,827 grid cells, with a cell resolution of 2 minutes latitude by 2 minutes longitude each. The grid cells were characterised according to several spatial and environmental variables. Table 1 shows the variables associated to the grid cells.

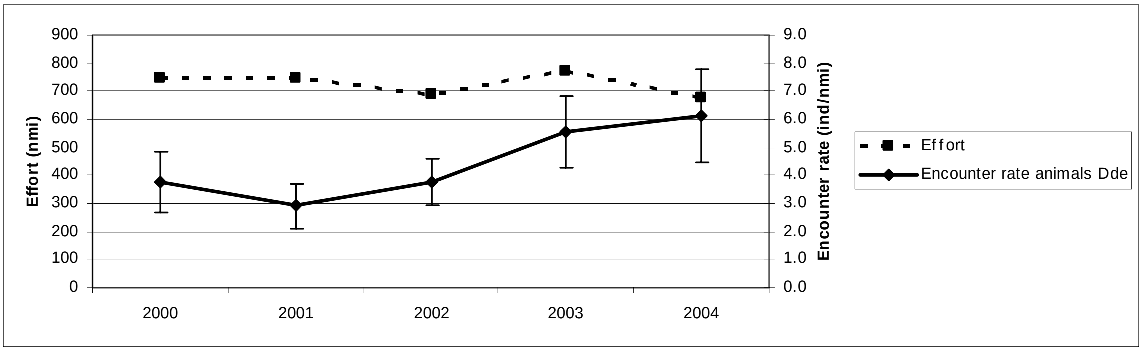
Data was separated into two seasons: summer (June to September) and winter (October to May). Due to the small sample size in winter, these data were pooled over years (1992 to 2004), and was only considered for the waters off Southern Almería and the Gulf of Vera (winter effort in the rest of the area was minimum). Therefore, two datasets were built: Southern Almería 1992-2004 and Almería-Vera 1992-2004.

Encounter rates for each year and season, both of groups and of individuals, were calculated as the average across grid cells. To avoid the problems caused by low effort, grid cells with less than 0.9 km (0.5 nmi) of effort were discarded for the calculation of encounter rates. Average group sizes were also calculated for different months, areas and other parameters.

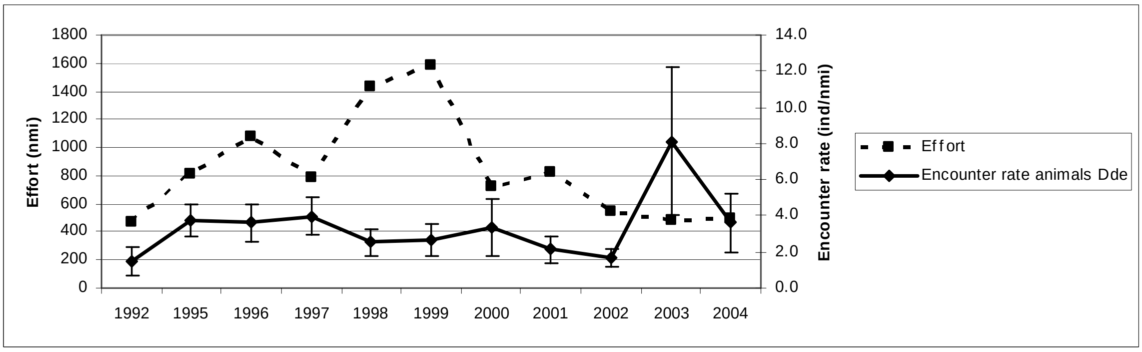
The summer data were organised at five levels, yielding 17 datasets for analysis. The smaller datasets (c,d and e below) were built to test how different the estimates might be when analysing a small area *vs*. a bigger area from which results the abundance for the target area can be extracted.

a) Alborán-Vera dataset: the whole study area, which was covered from 2000 to 2004. This was further organized into three sub-datasets: all five years pooled together, 2000 to 2002, and 2003 to 2004. The separation of these two groups of years was decided after inspection of the yearly encounter rates of animals, where there was a slight increase during the last two years (Figure 8.2).

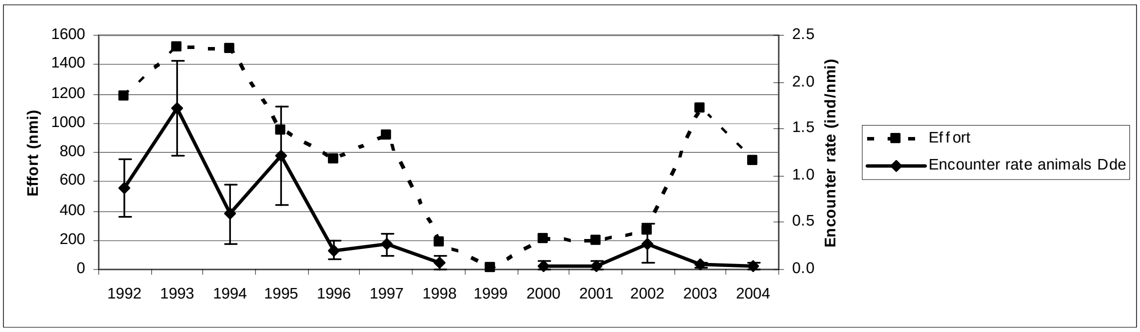
a) Western Alborán



b) Southern Almería



c) Gulf of Vera (common dolphins)



d) Gulf of Vera (striped dolphins)

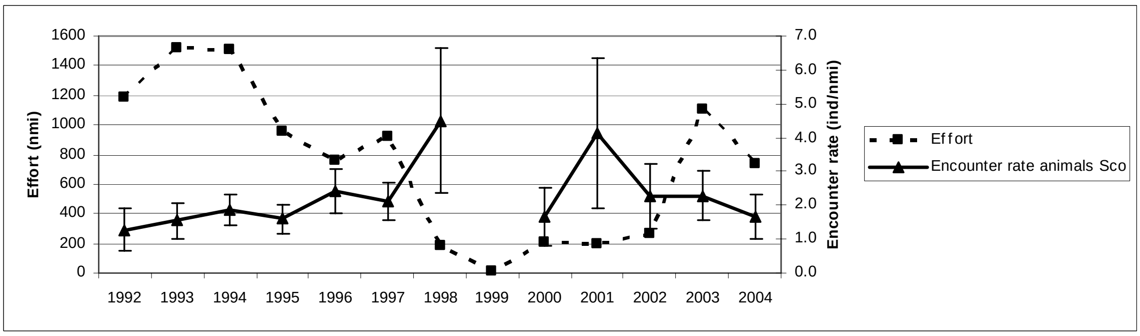


Figure 8.2. Average encounter rates of common dolphins (animals) during the summer months (June to September). a) Western Alborán, b) Southern Almería, and c) Gulf of Vera; d) average encounter rates of striped dolphins (animals) in the Gulf of Vera. Vertical bars show the standard error.

b) Almería-Vera dataset: the waters off southern Almería and Gulf of Vera, using data from 1992 to 2004. This dataset was further organized into six sub-datasets: the whole period from 1992 to 2004 (to be able to compare with the winter months of the same period of years), and four groups of years, according to the encounter rates observed (Figure 8.2): 1992 to 1995, 1996 to 1998, 2000 to 2004 and 1996 to 2004. The reasons for considering 1999 alone are given in Cañadas et al. 2002, and it was not included here as only Southern Almería was surveyed on this year (therefore it is included in the 'Southern Almería dataset' below). Further stratification was attempted for 2003-2004, given the increase in encounter rates during these two years, but there was not enough sample size for the Almería-Vera area to do it, therefore, these years were kept together with 2000-2002.

c) Western Alborán dataset: This was further organized into three sub-datasets: all five years pooled together, 2000 to 2002, and 2003 to 2004.

d) Southern Almería dataset: This was further organized into three sub-datasets: 1996-1998, 1999 and 2000-2004. The sample size in this area between 1992 and 1995 was too small to build a separated dataset.

e) Gulf of Vera dataset: This was further organized into two sub-datasets: 1992-1995 and 1996-2004.

All on effort transects were divided into small segments (average 2.7 km, maximum 3.9 km) between two consecutive sampling stations, with homogeneous type of effort along them. It was assumed that there would be little variability in physical and environmental features (like bottom physiography, sst, etc.) within these segments. Each segment was assigned to a grid cell based on the mid point of the segment and values of covariates for each grid cell were associated with the segment.

8.2.2.2. Spatial modelling of abundance

For model-based abundance estimation, five steps were followed, according to Cañadas and Hammond (in press) (Chapter 7): (1) a detection function was estimated from the line transect data and any covariates that could affect detection probability; (2) the number of groups in each segment was estimated through the Horvitz-Thompson estimator (Horvitz and Thompson 1952); (3) the abundance of groups was modelled as a function of spatial and environmental covariates; (4) the groups sizes were modelled as a function of detection probabilities and covariates; (5) steps 3 and 4 were combined and extrapolated to the whole study area to obtain the final abundance of animals.

The possibility of pooling together data from different vessels and from very different sighting conditions (such as observer on the crow's nest or only on deck), which require preferably different truncation distances and different detection functions, is a great advantage of the spatial analysis.

Estimation of detection function.

There was a large amount of mixed groups of common and striped dolphins. Despite being recorded independently as two different sightings, a mixed group of these species was considered as one single group for the estimation of the detection function, as was the group as a whole the detected target. Group sizes of both species were then combined yielding one single estimated group size for the mixed group. Taking also into account the very similar size, cues and group sizes for common and striped dolphins, the detection functions were calculated for both species together, including mixed groups.

Four different detection functions were obtained: for each ship and for two different levels of effort: with or without mast watch, as the difference in sightability might be very large. For the *Else*, all dolphin species were included in the datasets for estimating the detection functions: common (15 sightings), striped (85), bottlenose (10), Risso's dolphins (10) and common-striped dolphins mixed groups (3), to increase the sample size. For effort types 1S and 2S (without mast watch), a total of 53 sightings were used (45 striped or common dolphins or mixed groups, and 8 bottlenose and Risso's dolphins). For effort types 1 and 2 (with mast watch), 70 sightings were used (58 striped or common dolphins or mixed groups, and 12 bottlenose and Risso's dolphins).

For the *Toftevaag*, only common and striped dolphins (from 1992 to 2004) were used to estimate the detection function. For effort types 1S and 2S, a total of 334 sightings were used (164 common dolphin groups, 142 striped dolphins and 28 mixed groups). For effort types 1 and 2 1,361 sightings were used (510 common dolphin groups, 688 striped dolphins and 163 mixed groups).

Angle data were rounded until 2000, and the distance data were rounded during the whole period because of being estimated by eye, so a smearing procedure was adopted following the method described in Buckland *et al.* (2002). Distances were smeared for the whole research period, and angles only for years 1992 to 2000, keeping the non-rounded angles taken in the field since 2001. The parameters for the smearing procedure were chosen after visual inspection of the data.

The software DISTANCE 5.0 release 1 (Thomas *et al.* 2005) was used to estimate the detection function, using the multiple covariate distance sampling (MCDS) method (Marques 2001; Thomas et al. 2002). The perpendicular distance data were right truncated prior to the analysis, following the recommendations of Buckland et al. (2001). All covariates given in Table 8.1 and combinations of them were tried. The selection of the best detection function was made using Akaike's Information Criterion (AIC).

Table 8.1. Covariates incorporated in modelling the detection function, indicating if they were treated as a continuous variable or as a factor, and the levels used in this case.

Covariate	Type	Levels
Group size	continuous continuous (logarithm)	
Species (only for *Else*)	factor	2 levels: common-striped dolphins / bottlenose-Risso's dolphins
Observer	factor	2 levels: mast / deck
Year	factor	4 levels: 1992-1994 / 1995-1997 / 1998-2000 / 2001-2002
Cue	factor	2 levels: fin-back (less conspicuous) / other (conspicuous)
Sea state	factor	3 levels: 0 / 1 / 2 Douglas 2 levels: 0-1 / 2 Douglas
Time (hours from sunrise)	continuous	

Estimation of number of groups per segment.

The response variable used to formulate a spatial model of abundance of groups was the estimated number of groups ($\hat{N}$) in each segment, rather than the actual counts (Hedley *et al.* 1999). They were estimated through the Horvitz-Thompson estimator (Horvitz and Thompson 1952), where the probability of detection was obtained from the corresponding detection function fitted to the data (according to ship and effort types):

$$\hat{N}_i = \sum_{j=1}^{n_i} \frac{1}{\hat{p}_{ij}} \qquad (1)$$

where n_i is the number of detected groups in the i^{th} segment, and $\hat{p}_{ij}$ is the estimated probability of the j^{th} detected group in segment i, obtained from the detection function.

Modelling abundance of groups and group size.

For both models, the potential explanatory variables used are listed in Table 8.2. Interactions between variables were also investigated.

The abundance of groups was modelled using a Generalized Additive Model (GAM) with a logarithmic link function. A Poisson error distribution was not considered appropriate for the response variable due to over-dispersion. Therefore, a quasi-poisson family was used, with variance proportional to the mean. The general structure of the model was:

$$\hat{N}_i = \exp\left[\ln(a_i) + \theta_0 + \sum_k f_k(z_{ik}) \right] \qquad (2)$$

where the offset a_i is the effective searched area for the i^{th} segment (calculated as the length of the segment multiplied by two times the truncation distance), θ_0 is the intercept, f_k are smoothed functions of the explanatory covariates, and z_{ik} is the value of the k^{th} explanatory covariate in the i^{th} segment.

Models were fitted using package 'mgcv' version 1.0-5 for R (Wood 2001). Automated model selection by a stepwise procedure was not yet implemented in the version of R used (2.0.0) (http://cran.r-project.org). Therefore, manual selection of the models was done using three indicators, as described in Cañadas and Hammond (in press) (Chapter 7) and following the criteria proposed by Wood (2001): (a) the GCV (General Cross Validation score); (b) the percentage of deviance explained; and (c) the probability that each variable is included in the model by chance. In all models, a visual inspection of the residuals was also made, especially to look for trends.

Table 8.2. Variables, and groups of variables, associated to the grid cells and used in the models

Variables and groups:		
Geographic		
	lat	latitude
	lon	longitude
Physiographic (depth)		
	depth	depth
	logdepth	logarithm of depth
	distcoast	distance from coast
	logdistcoast	logarithm of distance from coast
	dist200	distance from the 200 m isobath
	dist1000	distance from the 1000 m isobath
Physiographic (bottom)		
	cvdepth	coefficient of variation of depth
	sddepth	standard deviation of depth
	slope	slope (meters per km)
	ci	contour index ((max depth-min depth)*100/max depth)
Oceanographic (echo-sounder)		
	ersl1	encounter rate of first scattering layer
	lowersl1v	lower limit of first scattering layer in summer
	ersl2	encounter rate of second scattering layer
	fishpelv	encounter rate of pelagic fish in summer
	fishv	encounter rate of all fish in summer
Oceanographic (satellite image)		
	cavv	average summer chlorophill concentration
	cav	average annual chlorophill concentration
	tavv	average summer sst
	tav	average annual sst
	tdsv	standard deviation of summer sst
	tds	standard deviation of annual sst
Anthropogenic		
	distpesq	distance from fishing ports
	acshv	index of summer acoustic pollution
	ertr	encounter rate of trawlers

Group size was also modelled using a GAM with a logarithmic link function. The response variable was the number of individuals of common dolphins counted in each group (s_j) and, given the large overdispersion due to the wide range of group sizes (1 – 1000), a quasi-poisson error distribution was used, with the variance proportional to the mean. The detection probability was included as a linear predictor (Borchers and Burt 2001) in order to avoid the bias introduced by the selective detection of larger groups at larger distances or by other covariates affecting the detection of the groups (Universidad de Barcelona 2002). Therefore, in the case of mixed groups, the response variable included only the number of common dolphins in the group, but the detection probability included as linear predictor was that of the group as a whole (including the animals of both species), as it was the complete group what was detected. The general structure of the model was:

$$E(s_j) = \exp\left[\hat{g}_j(y,\nu) + \theta_0 + \sum_k f_k(z_{jk})\right] \qquad (3)$$

where $\hat{g}_j(y,\nu)$ is the conditional detection probability of the j^{th} group given that it was detected at perpendicular distance y and with covariates ν, θ_0 is the intercept, f_k are smoothed functions of the explanatory covariates, and z_{jk} is the value of the k^{th} explanatory covariate in the j^{th} group. Manual selection of the models was done following the same criteria described for the models of abundance of groups.

Estimates of abundance.

Predictions of abundance of groups and of group size were produced over all the grid cells of the study area, according to the values of the covariates used in the final models. The estimated abundance of animals for each grid cell was calculated as the product of its predicted abundance of groups and its predicted group size. The final point estimate of abundance was obtained by summing the abundance estimate of all grid cells over the study area.

Estimation of variance.

Four hundred non-parametric bootstrap resamples of the whole process were done, using day as the resampling unit, to obtain the coefficient of variation and percentile based 95% confidence intervals. For both models in each bootstrap, the degree of smoothing of each model term was chosen by 'mgcv', thus incorporating some model selection uncertainty in the variance. These values were plotted as surface maps of abundance and of variability. As there were four different detection functions applied to the data, according to the ship and effort type on which each sighting was made, the final CV for each subset could not be calculated using the delta method (Seber 1982) combining the CV of the detection function with the CV of the models from the bootstrap. A possible way of solving this problem would be to include the detection function estimation in the bootstrap by calling the Distance analysis engine from R to do the detection function estimation. But this would require a complex and time consuming coding. Another less precise way of calculating a final CV is to give a lower and upper bound instead of a point CV. This was the method applied in this work. For each dataset, a delta method was applied for the CV from the bootstrap and each of the CVs from the detection functions used in that dataset. This yielded two to four combined CVs (depending on the number of detection functions used in that dataset). The final CV is given then as a range in which the lower bound is the lowest combined CV and the upper bound is the largest combined CV.

Random and responsive movement.

The average searching speed of the ship was 5 kt, which is slow compared to most line transect surveys for cetaceans. Because random movement of animals leads to increasing bias as the ratio of animal speed to ship speed increases (Hiby 1982), we investigated whether this was a problem in our data. The average speed of the dolphins (at the moment of the encounter) was calculated by assigning an average speed to each behavioural category (from the 'primary sighting data'): 0 kt for socialising, milling, feeding and resting; 1 kt for travelling slowly; 3 kt for travelling at moderate speed and 5 kt for travelling fast. The average speed for all sightings, according to their initial behavioural category was then obtained.

We also investigated whether responsive movement had occurred before detection by calculating the ratio of animals/groups with swimming direction relative to the ship in the third quadrant (180º - 270º) to the first quadrant (0º - 90º), relative to the transect line following Palka and Hammond (2001). The ratio between these quadrants was evaluated using a chi-square test, to see if there was any evidence of attraction (Q3/Q1 > 1) or avoidance (Q3/Q1 < 1).

8.3. RESULTS

8.3.1. Effort and sightings

A total of 37,385km was surveyed on effort between 1992 and 2004 in the study area during the summer months (June to September). Of these, 17,688km were surveyed in the Gulf of Vera, 17,133km off Southern Almería, and 6,724km between 2000 and 2004 in the western portion of the Alborán Sea (including the Strait of Gibraltar). Figures 8.3a, b, c and d show the effort carried out from 1992 to 1995, from 1996 to 1998, in 1999 and from 2000 to 2004 respectively (periods used later for the analysis, see below). A total of 762 sightings of common dolphins within the truncation distance (see below) were made while searching on effort during these months. A total of 7,533km were surveyed on effort during the winter months (October to May) from 1992 to 2004, of which 3,224km were surveyed in the Gulf of Vera, and 4,309km off Southern Almería (Figure 8.3e). A total of 96 sightings of common dolphins within the truncation distance were made during these months. The effort, number of sightings, average encounter rates and average group size for each of the data subsets are shown in Table 8.3.

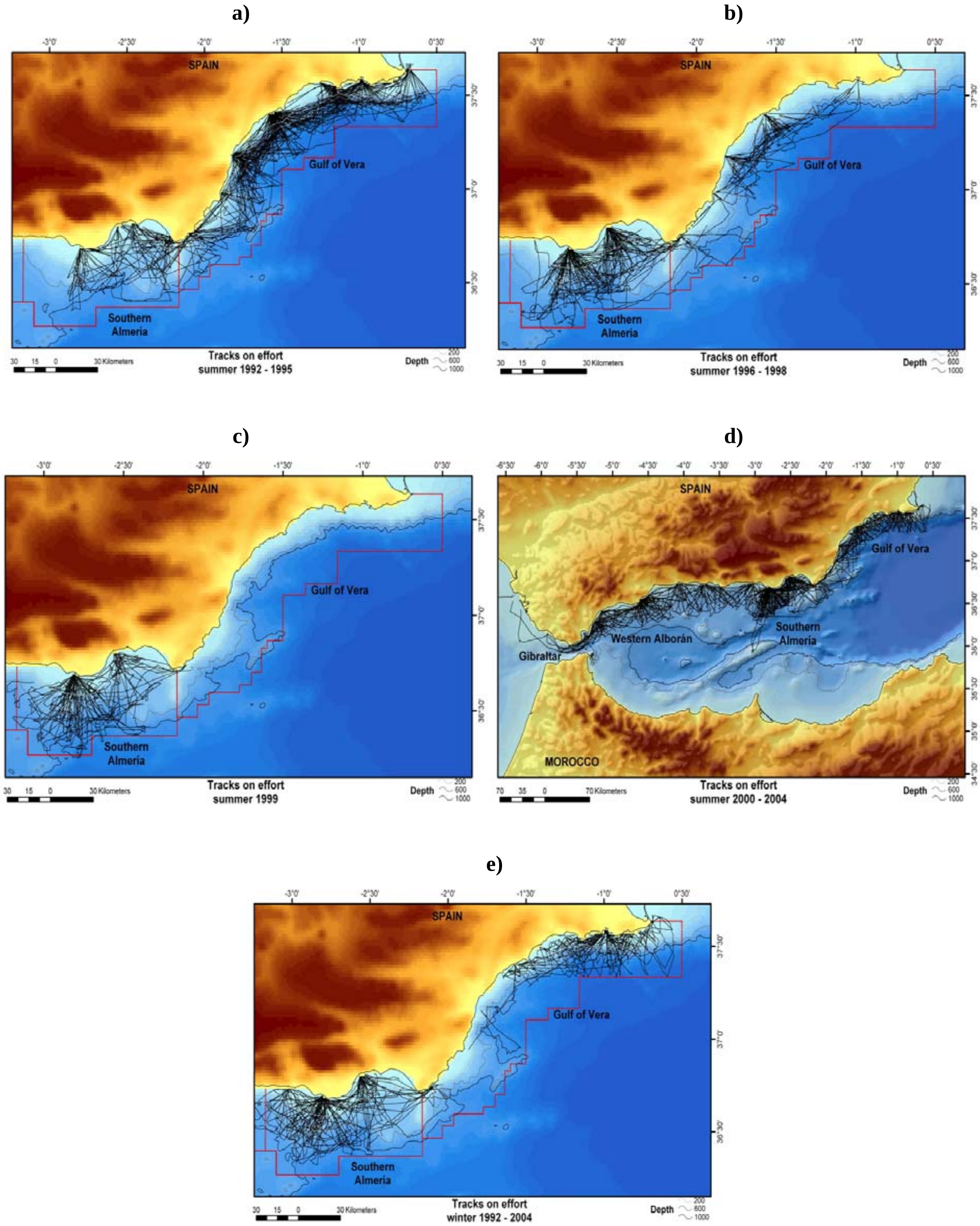


Figure 8.3. Tracklines on effort during the summer months from (a) 1992 to 1995, (b) 1996 to 1998, (c) 1999 and (d) 2000 to 2004 and (e) winter months from 1992 to 2004.

Table 8.3. Total effort (in nmi, km in braquets), total n umber of segments, percentage of segments per effort type, number of groups (number of individuals), mean group size and encounter rates (ER) for groups and for individuals (per nmi) for each subset of data.

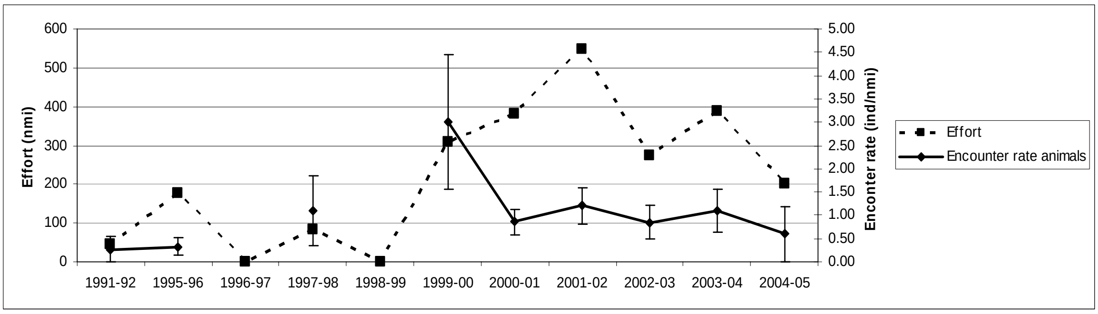
Year	Total effort	Total segments	Effort 1-2	Effort 1S-2S	Nº of groups (indiv.)	Mean group size (SE)	ER groups (SE)	ER indiv. (SE)
Western Alborán summer (including Strait of Gibraltar)								
2000 - 2002	2180 (4037)	1455	74.8%	25.2%	174 (7955)	46.5 (4.72)	0.0731 (0.0077)	3.238 (0.482)
2003 - 2004	1451 (2686)	979	70.3%	29.7%	133 (9231)	71.7 (9.58)	0.0813 (0.0095)	5.515 (0.989)
TOTAL 2000 - 2004	3631 (6724)	2434	73.0%	27.0%	307 (17186)	55.8 (4.56)	0.0795 (0.0064)	4.320 (0.552)
Southern Almería summer								
1992 - 1995	1277 (2365)	806	64.3%	35.7%	45 (3847)	84.9 (12.85)	0.0320 (0.0045)	3.091 (0.539)
1996 - 1998	3289 (6091)	2280	60.0%	40.0%	127 (12767)	104.3 (11.94)	0.0383 (0.0052)	3.281 (0.526)
1999	1587 (2939)	1051	73.9%	26.1%	60 (3295)	59.2 (14.02)	0.0468 (0.0095)	2.662 (0.914)
2000 - 2004	3087 (5718)	2062	62.9%	37.1%	102 (11222)	112.8 (20.27)	0.0313 (0.0038)	3.593 (0.866)
1996 - 2004	7963 (14748)	5393	63.8%	36.2%	289 (27284)	97.9 (9.56)	0.0358 (0.0030)	3.356 (0.510)
TOTAL 1992 - 2004	9240 (17113)	6199	64.3%	35.7%	334 (31131)	96.1 (8.41)	0.0357 (0.0027)	3.276 (0.447)
Southern Almería winter								
TOTAL 1992 - 2004	2327 (4309)	1590	52.2%	47.8%	78 (3234)	39.5 (8.24)	0.0324 (0.0076)	1.151 (0.382)
Gulf of Vera summer								
1992 - 1995	5171 (9576)	3370	51.8%	48.2%	93 (4910)	54.0 (6.03)	0.0210 (0.0030)	1.097 (0.211)
1996 - 2004	4380 (8112)	2932	57.3%	42.7%	28 (699)	25.4 (5.74)	0.0072 (0.0016)	0.126 (0.032)
TOTAL 1992 - 2004	9551 (17688)	6302	54.3%	45.7%	121 (5609)	47.1 (4.90)	0.0136 (0.0017)	0.575 (0.099)
Gulf of Vera winter								
TOTAL 1992 - 2004	1741 (3224)	1158	49.6%	50.4%	18 (311)	20.3 (4.24)	0.0110 (0.0030)	0.261 (0.089)
TOTAL summer								
TOTAL 1992 - 2004	22422 (37385)	14935	61.7%	38.3%	762 (53926)	65.0 (3.40)	0.0472 (0.0017)	2.552 (0.138)
TOTAL winter								
TOTAL 1992 - 2004	4068 (7533)	2748	52.4%	47.6%	96 (3599)	34.8 (6.92)	0.0303 (0.0052)	0.683 (0.134)

8.3.2. Encounter rates and group sizes

Yearly encounter rates were calculated separately for the Gulf of Vera, Southern Almería and Western Alborán Sea for the summer season (Figure 8.2a, b and c). For the winter months, encounter rates were calculated only for the Gulf of Vera and Southern Almería (Figure 8.4), as the effort during these months in Western Alborán was minimum.

No apparent trend was observed in the encounter rates of any of these datasets, except for the Gulf of Vera in summer (Figure 8.2c). In this area, the encounter rate of animals dropped strongly since 1996. The average encounter rate from 1992 to 1995 was 1.10 animals per nmi on effort (SE = 0.21), from 1996 to 1998 it went down to 0.21 animals per nmi (SE = 0.07), and from 2000 to 2004 it still dropped down to 0.08 animals per nmi (SE = 0.03). The encounter rates for the two later periods were significantly different from that of the first period ($d_{1-2} = 2.490$, $p<0.02$; $d_{1-3} = 3.858$, $p<0.001$). To test if the drop in encounter rates of common dolphins in the Gulf of Vera after 1996 was an artefact of the lower level of effort, encounter rates for the same area were also calculated for the striped dolphin. In this case, no trend at all in encounter rates was observed (Figure 8.2d).

a) Southern Almería



b) Gulf of Vera

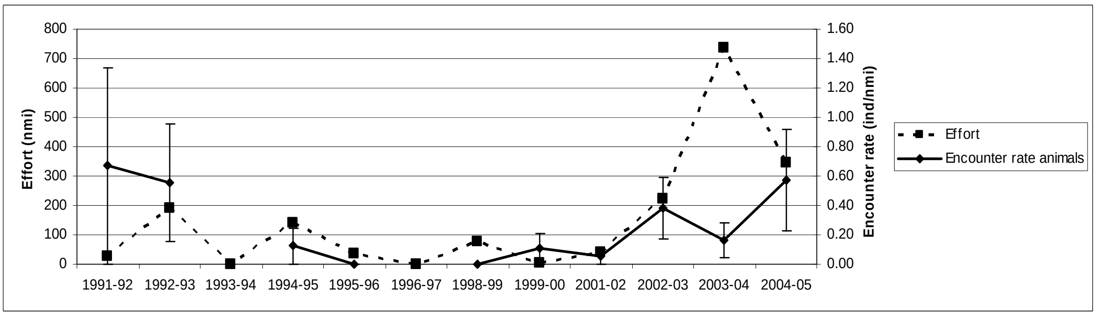


Figure 8.4. Average encounter rates of common dolphins (animals) during the winter months (October to May). a) Southern Almería and b) Gulf of Vera. Vertical bars show the standard error.

A total of 897 sightings of common dolphins (including those discarded after right truncation for the detection functions) were used for the analysis of group sizes. First of all, differences in group sizes depending on effort type were explored to investigate if there was any bias in the counting of animals in the groups according to effort type. No significant differences were found. Overall mean group size was 65.7 (95%CI = 58.8 - 72.6, SE = 3.53, SD = 105.78) with median=30, ranging from 1 to 1000 animals.

The average group size increased during the summer months, especially from July to September. Differences were significant ($H=39.08$, $p<0.0001$), July, August and September having larger median group sizes than the other months. Two seasons were considered: Summer (S: June to September) and Autumn-Winter-Spring (W: October to May). Differences were highly significant between these two seasons ($U=30,197.5$ $p<0.00001$). The same distinction between seasons was considered, therefore, for the spatial analysis. Table 8.4 shows summary statistics for the group sizes observed during the different months and seasons.

Table 8.4. Summary statistics for group sizes by months.

	Month							Season	
	1	**4**	**6**	**7**	**8**	**9**	**11**	**S**	**W**
Valid N	17	40	96	285	196	207	56	784	113
Mean	13.3	22.7	39.0	73.4	87.6	63.5	50.7	70.1	35.1
Median	10	15	20	30	37.5	30	20	30	15
Minimum	1	1	1	1	1	1	1	1	1
Maximum	50	80	400	600	1000	500	500	1000	500
Standard Deviation	14.28	20.39	59.52	105.96	144.51	87.79	96.24	109.27	70.51
Standard Error	3.46	3.23	6.08	6.28	10.32	6.10	12.86	3.90	6.63

The average group size was significantly larger during summer months ($H=15.59$, $p=0.0036$) in Southern Almería. There were no significant differences among areas during winter months, although average group size was still larger in Almería. Table 8.5 shows summary statistics of group sizes for the areas in the two different seasons. The average group size was quite constant across the years for each area during the summer months, although with some fluctuations. Nevertheless, statistical significant differences in the median were found for two groups of years in the Gulf of Vera: 1992 to 1995 against 1996 to 2004 ($mean_{92\text{-}95}=52.3$, $median_{92\text{-}95}=40$, $mean_{96\text{-}04}=25.0$, $median_{96\text{-}04}=20$, $U=797.5$, $p=0.0013$). No statistical differences were found among years for other areas. No significant differences were found for any area for the winter months.

Table 8.5. Summary statistics for group sizes by areas.

	S months				W months			
	Gibraltar	**Alborán W**	**Almería**	**Vera**	**Gibraltar**	**Alborán W**	**Almería**	**Vera**
Valid N	28	260	291	105	3	40	126	35
Mean	59.6	59.1	99.4	48.2	9.7	23.6	44.4	27.1
Median	37.5	25	40	30	9	15	20	15
Minimum	2	1	1	1	8	1	1	1
Maximum	200	600	1000	300	12	140	500	120
Standard Deviation	64.48	87.15	146.31	52.63	2.08	25.81	81.07	26.67
Standard Error	12.19	5.40	8.58	5.14	1.20	4.08	7.22	4.51

8.3.3. Random and responsive movement.

There were 707 sightings of common dolphins on effort for which data on initial behaviour, and therefore estimated speed, were available. The average estimated speed of the dolphins was 2.2 kt (SE = 0.08 kt). The ratio of dolphins speed to ship speed was therefore 0.44, just below the value of 0.5 considered as problematic (Hiby 1982, Palka and Hammond 2001). If there is any bias as a result of random movement it is small.

For the study of possible responsive movement of the animals before detection, data on initial heading relative to the transect line were available for 497 sightings of common dolphins. Of these, 142 sightings (28.6 %) were stationary and not heading in any direction. For the remaining sightings, the ratio Q3/Q1 was 1.17, which is close to and not significantly different from one (χ^2 =0.95, df=1, p>0.05), suggesting no responsive movement of the animals before detection.

8.3.4. Detection function.

Perpendicular distances for the four detection functions were right truncated for the largest distances after visual inspection of the data. Models were fitted starting with single covariates and continuing with combinations of two, three and four covariates.

Ship Else.

Effort types 1 and 2. Perpendicular distance was truncated at 1500 m. This discarded 13.2% of the data with the largest distances, leaving 64 sightings for analysis. The best fitting model was a half-normal key function with cosine series expansion and one adjustment term. Three covariates were selected: position of the observer, sea state and group size.

Effort types 1S and 2S. Perpendicular distance was truncated at 900 m. This discarded 8.6% of the data, leaving 46 sightings for analysis. The best fitting model was a hazard-rate key function with no series expansion and adjustment terms. Only one covariate was selected (probably due to the small sample size): group size.

Ship Toftevaag.

Effort types 1 and 2. Perpendicular distance was truncated at 3600 m. This discarded 2.9% of the data with the largest distances, leaving 1,321 sightings for analysis. The best fitting model was a hazard-rate key function with simple polynomial series expansion and one adjustment term. Four covariates were selected: position of the observer, sea state, cue and group size.

Effort types 1S and 2S. Perpendicular distance was truncated at 1500 m. This discarded 9.9% of the data, leaving 301 sightings for analysis. The best fitting model was a hazard-rate key function with no series expansion and adjustment terms. Four covariates were selected: sea state, cue, group size and time.

Table 8.6. Results for the four detection functions. For each one, the following information is given: type of model, truncation distance (# obs = resulting number of observation after truncation), p = probability of detection (SE), ESW = effective strip width (SE), %CV = coefficient of variation of p and ESW, and the levels of the variables selected in the models, their coefficients and their standard errors. For the variables, OBS = position of the observer, SEA = sea state, CUE = cue for detection, TIME = hours since sunrise, LOGCLSIZE = logarithm of group size, CLUSTER SIZE = group size. The remaining level for each factor is included in the intercept.

Dataset	Model	Trunc. Distance (# obs.)	p (SE)	ESW (SE)	%CV	Variables	Coefficient	Std. Error
Ship Else Effort 1-2	Half-normal	1500m (64)	0.256 (0.037)	388.75 (56.70)	14.78	Intercept of the scale parameter	371.8	23.04
						level D of factor covariate OBS	-0.9488	0.2865
						covariate CLUSTER SIZE	0.0373	0.0112
						level 0 of factor covariate SEA	0.3636	0.3406
						level 1 of factor covariate SEA	-0.4702	0.4150
						Cosine adjustment term of order 2	0.3353	0.2178
Ship Else Effort 1S-2S	Hazard-rate	900m (46)	0.235 (0.033)	211.71 (29.65)	14.01	Intercept of the scale parameter	94.39	6.18
						power parameter	1.978	4.293
						covariate CLUSTER SIZE	0.0241	0.0204
Ship Toftevaag Effort 1-2	Hazard rate	3600m (1321)	0.187 (0.006)	672.86 (20.49)	3.05	intercept of the scale parameter	144.8	10.16
						power parameter	1.274	0.5329
						level D of factor covariate OBS	-0.7801	0.1414
						covariate LOGCLSIZE	0.5315	0.1107
						level 0 of factor covariate SEA	0.6368	0.2263
						level 1 of factor covariate SEA	0.2202	0.1912
						level FB of factor covariate CUE	-0.8442	0.1390
						Simple polynomial adjustment term of order 4	-0.9578	0.0759
Ship Toftevaag Effort 1S-2S	Hazard-rate	1500m (301)	0.148 (0.010)	221.94 (14.85)	6.69	intercept of the scale parameter	23.26	3.74
						power parameter	1.275	1.131
						level FB of factor covariate CUE	-0.8397	0.2605
						covariate LOGCLSIZE	0.5866	0.2566
						level 0 of factor covariate SEA	2.1200	0.5091
						level 1 of factor covariate SEA	0.5952	0.2566
						covariate TIME	0.0386	0.0431

The most important covariates were group size and sea state (except for *Else* with effort 1S-2S, probably due to the small sample size of this dataset) (Table 8.6). Group size had a positive influence on detection probability. This covariate might be especially important when analysing very gregarious species like common dolphins whose group sizes can vary widely (e.g. 1 – 1000 in this study). For this reason, this covariate seems to be much more important on the *Toftevaag*, with such range of group sizes, than on the *Else*, where the maximum group size was 250 animals. Sea state '0' (calm sea) had a much more positive effect on detection probabilities than sea state '1' (ripples and small wavelets), which in turn had also a more positive influence than sea state '2' (with whitecaps), except in the dataset of *Else* with effort 1-2, for unknown reasons. Position of the observer detecting the animals was selected by the two models in which the two platforms were being used, and in both cases the coefficient for level 'D' (observer on deck) was negative, compared to the observer on the crow's nest. Covariate Cue was only selected for the *Toftevaag*, where the larger number of observations allowed the incorporation of more covariates. Level 'FB' (fin or back – inconspicuous cue) had a clear negative effect on detection probability compared to the other level (splash or jump – very conspicuous), as expected. It is interesting to note the selection of covariate Time (hours since sun rise) in the model of *Toftevaag* with effort 1S-2S. This covariate had a positive effect on detection probability, although with a very small coefficient. The reasons for this are unknown. The opposite effect could be more understandable, considering the possible increasing tiredness of the observers as the day passed. Years (or groups of years) and groups of species (in the case of the *Else*) were not significant. Figure 8.5 shows the observed frequencies at given distances, pooled over all covariates, and the fitted half-normal or hazard-rate functions for the four models.

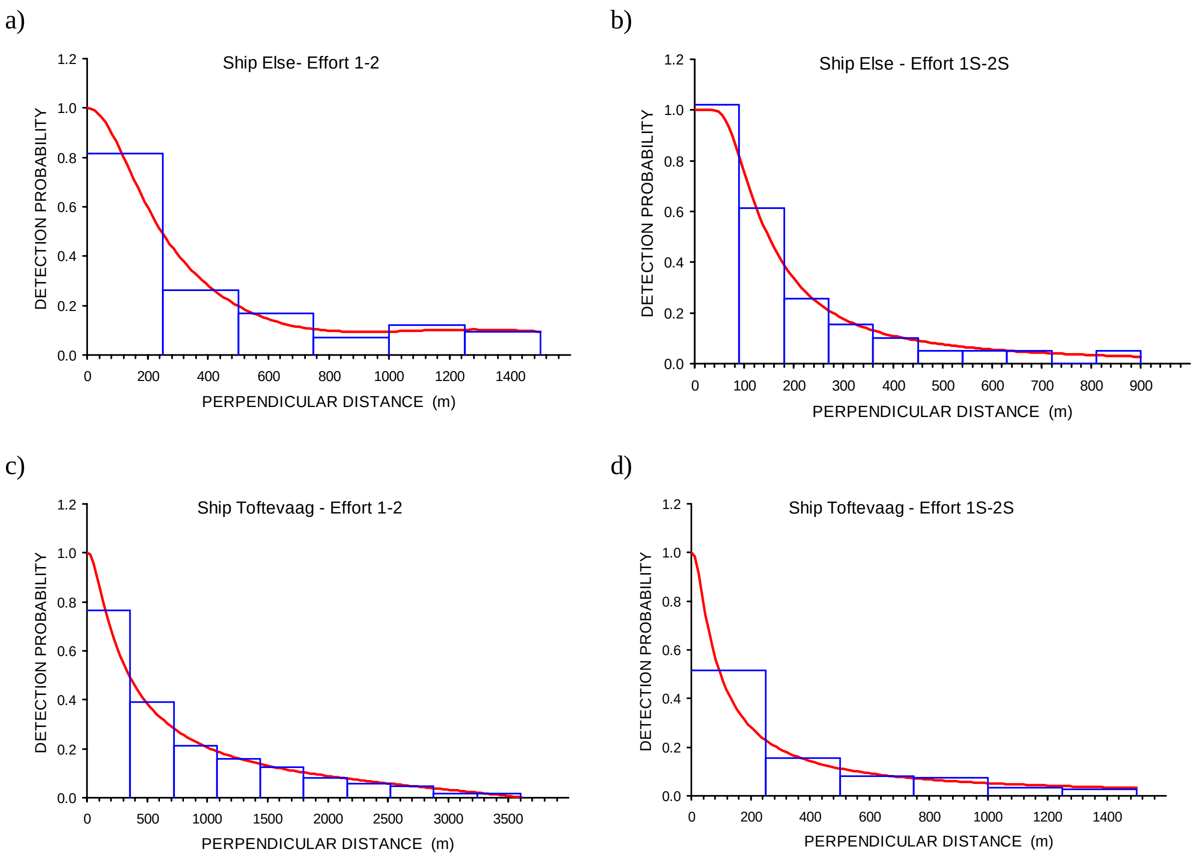


Figure 8.5. Perpendicular distance distribution, pooled over all covariates (histograms), and fitted detection functions, conditional to the observed covariates (lines). A) Ship *Else* with effort types 1-2, b) ship *Else* with effort types 1S-2S, c) Ship *Toftevaag* with effort types 1-2, b) ship *Toftevaag* with effort types 1S-2S.

8.3.5. Abundance models.

It is important to highlight that some variables were correlated, and some correlations varied from area to area. After visual inspection of plots of each variable against each other, the following moderate to high correlations were detected: all variables within the depth group; all variables within the satellite images group; all variables within the bottom physiography group; for the Gulf of Vera, latitude with the variables in the group of satellite images and longitude with the variables in the depth group and with distance from fishing ports; for Southern Almería, latitude with the variables in the depth, echo-sounder and satellite images groups, and with the distance to fishing ports; and for Western Alborán, longitude with the variables in the satellite images group, and latitude with the variables in the depth group and with the distance to fishing ports. Correlated covariates were not generally allowed in the same model but in a few cases the incorporation of two correlated covariates improved significantly the model fit.

The variables retained in the two steps of the model for each dataset are shown in Table 8.7. The shapes of the functional forms for the smoothed covariables retained by the final models for each dataset are plotted in Figures 8.6 to 8.10 at the end of the chapter. The selection of variables varied with the area, but for the same area it was fairly similar from period to period. In none of the models were anthropogenic variables selected.

Table 8.7. Model results for all the datasets analysed. For each row, the two models are shown (abundance of groups and group size), indicating the variables (':' indicates an interaction between two variables) retained in the best model (estimated degrees of freedom in parentheses: 1 means a linear relationship), and the percentage of deviance explained by the model. The variables are abbreviated as follows: lon = longitude, lat = latitude, depth = depth of the sea bed, logdepth = logarithm of depth, slope = slope of the sea bed, dist200 = distance to the 200 m depth contour, dist1000 = distance to the 1000 m depth contour, distcoast = distance to the coast, sddepth = standard deviation of depth, cvdepth = coefficient of variation of depth, ci = contour index, tav = annual sst average, tavv = summer sst average, cavv = summer chlorophyll concentration average, cavi = winter chlorophyll concentration average (numbers following all sst and chl variables indicate years over which the average was calculated, e.g. 0004 = 2000 to 2004), g(y,v) = conditional probability of detection (always as a linear predictor). Variables are ordered from most to least significant according to their p-value in the final model.

Subset	Model	Variables	% Deviance explained
Winter			
Almería-Vera 1992-2004	Groups	tav9804:lat (4.5)	4.4
	Group size	dist1000 (1) + g(*y*,*v*) + cavi0004 (4.9)	37.5
Almería 1992-2004	Groups	distcoast (5.2)	2.3
	Group size	cavi0004 (4.8) + dist1000 (5) + g(*y*,*v*)	43.9
Summer Alborán-Vera			
Alborán-Vera 2000-2002	Groups	tavv0002:lon:logdepth (17.6)	10.5
	Group size	distcoast (6.5) + lon (7.9) + ci (3.4) + g(*y*,*v*)	23.3
Alborán-Vera 2003-2004	Groups	tavv0304:lon (13.3) + logdepth:distcoast (19.1) + slope (3.1)	25.4
	Group size	distcoast:ci (5.3) + lon (8.1) + g(*y*,*v*)	31.9
Alborán-Vera 2000-2004	Groups	tavv0004:lo:logdepth (24.2)	12.9
	Group size	distcoast (5.8) + lon (3.6) + ci (3.1) + + g(*y*,*v*)	18.7
Summer Almería-Vera			
Almería-Vera 1992-1995	Groups	tds9804:dist1000 (3.4)	3.2
	Group size	distcoast:cavv0004 (10.2) + cvdepth2 (6.8) + lat (1) + g(*y*,*v*)	28.8
Almería-Vera 1996-1998	Groups	tavv9804:distcoast (9.7)	9.1
	Group size	depth :lon (8.4) + sddepth (1) + g(*y*,*v*)	24.0
Almería-Vera 2000-2002	Groups	logdepth (3.6) + tavv0002:lon (3.8)	9.5
	Group size	distcoast (7.1) + cavv0002 (1.6) + g(*y*,*v*)	41.6
Almería-Vera 2003-2004	Groups	lat (4.7) + lon (4.1) +distcoast (3.8) + slope (2.2)	20.0
	Group size	dist1000 (5.3) + lon (3) + g(*y*,*v*)	51.3
Almería-Vera 2000-2004	Groups	tavv9804:logdepth (8.7)	9.7
	Group size	distcoast :cavv0004 (18.9) + lat (1) + g(*y*,*v*)	45.1
Almería-Vera 1996-2004	Groups	tavv9804:logdepth (10.4)	6.8
	Group size	distcoast :cavv0004 (10.2) + cvdepth2 (6.8) + lat (1) + g(*y*,*v*)	28.8
Almería-Vera 1992-2004	Groups	tav9804 (5.6)	3.2
	Group size	cavv0004 :logdepth (10.1)	18.9
Summer Western Alborán			
Western Alborán 2000-2002	Groups	cavv0002:depth (3.2)	3.8
	Group size	ersl1 (1) + ersl2 (4.3) + g(*y*,*v*)	11.2
Western Alborán 2003-2004	Groups	cavv0004 (5.5) + dist200 (7.4) + ci (3.7)	15.8
	Group size	distcoast (3.3) + ci (1) + g(*y*,*v*)	17.2
Western Alborán 2000-2004	Groups	cavv0004:logdepth (9.1)	4.9
	Group size	dist200 (1) + ersl1 (1) + g(*y*,*v*)	8.8
Summer Southern Almería			
Southern Almería 1996-1998	Groups	distcoast (4.5) + lon (3.4)	6.2
	Group size	depth (4.5) + ci (1) + g(*y*,*v*)	17.1
Southern Almería 1999	Groups	depth (4.4) + cavv0004 (2.7)	14.1
	Group size	cavv0004 (7.6) + g(*y*,*v*)	49.1
Southern Almería 2000-2004	Groups	logdepth (3.7)	4.2
	Group size	logdistcoast (7.6) + ci (1) + g(*y*,*v*)	30.5
Summer Gulf of Vera			
Gulf of Vera 1992-1995	Groups	depth (2.1)	3.0
	Group size	sddepth (5.4) + logdepth :tav0004 (8.0) + g(*y*,*v*)	28.1
Gulf of Vera 1996-2004	Groups	depth (1)	2.1
	Group size	distcoast (8.1) + cvdepth (3.1) + g(*y*,*v*) + lat (1.7)	91.1

Alborán-Vera: For density of groups, the most important variables, selected in the models for the three periods of years, were summer average sst, longitude and logarithm of depth. For group size, the same variables were retained for the three periods of years: longitude, distance from coast and contour index (Figure 8.6).

Almería-Vera: For density of groups, the most important variables for all datsets (except 2003-2004), including that of the winter months, were sst and one of the variables of the depth group. For the 2003-2004 dataset, the most important were a combination of latitude and longitude and again a variable of the depth group. For group size, the selection was more variable, but in general the most important ones were a variable of the depth group (in all models) and either sst or chlorophyll. A variable of the bottom physiography group was selected in three of the models, but was less significant than the other variables (Figure 8.7).

Western Alborán: The selected variables for density of groups were chlorophyll and a variable of the depth group in all three datasets. The contour index was also selected, but with the least significance, in one of the datasets. For group size, the variables selected differed more from the other datasets: the scattering layers were selected in two of the models, although a variable from the depth group was also selected in two of the models (Figure 8.8).

Southern Almería: A variable from the depth group was selected in all models for density of groups and for group size for 1996-1998 and 2000-2004. For 1999, chlorophyll concentration was selected in both model steps (Figure 8.9).

Gulf of Vera: The only variable selected for density of groups, in both datasets, was depth. For group size, a variable in the depth group was again selected, together with a variable in the bottom physiography group. In the first period (1992-1995), sst was also selected, while in the second period it was latitude (Figure 8.10).

The general trend for the variables in the depth group was bimodality, with a peak at intermediate depths (around the shelf edge) and another one in deep waters. In the bottom physiography group the general trend was towards less complexity and steep sea floor. Within the satellite images group there was in general a positive trend towards cooler and more productive waters (Figures 8.6 to 8.10).

8.3.6. Estimated abundance and trends.

Estimates of abundance, density and variability are given in Table 8.8. Plots of the estimates are given in Figure 8.11.a. The point estimate of abundance for the whole area was 19,428 (%CV = 10.7 – 18.0; 95%CI = 15,277 – 22,804) dolphins between 2000 and 2004, mainly concentrated in Southern Almería and the westernmost end of the Alborán Sea (Figure 8.12). This abundance estimate yields an estimated average density of 1.012 dolphins per sq km (95%CI = 0.796 – 1.188). The estimated density decreases from West to East for all datasets in this period (Figure 8.11.d), being the differences significant ($d_{Alborán\text{-}Almería} = 2.449$, $p < 0.02$; $d_{Alborán\text{-}Vera} = 8.584$, $p < 0.001$; $d_{Almería\text{-}Vera} = 5.152$, $p < 0.001$).

For the area of Western Alborán, the estimated density is slightly larger in 2003-2004 than between 2000 and 2002, but the differences are not significant (Figure 8.11.a). Therefore, we consider the density estimate for the whole period, from 2000 to 2004, as the best estimate: 13,019 dolphins (1.72 dolphins per sq km; %CV = 11.8 – 13.2; 95%CI = 1.31 - 2.06) from the Western Alborán model, and 11,721 dolphins (1.55 dolphins per sq km; 95%CI = 1.21 – 1.93) from the Alborán-Vera model.

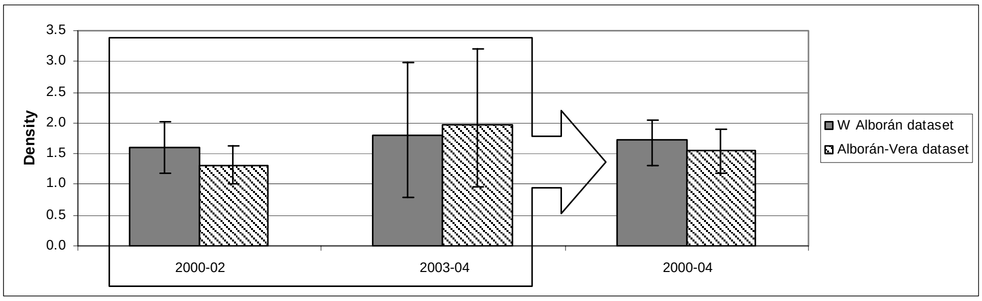
There is also no trend in the density estimate for the area of Southern Almería between 1992 and 2004, with any of the datasets explored. There is again an increase in 2003-2004, but the CV and 95%CI are very large in this period, and this difference is not significant (Figure 8.11.b). The density in 1999 is slightly smaller than in the other years, but the differences are not statistically significant. Hence, we also consider in this case the density estimate for the whole period of 13 years as the best estimate: 4,670 dolphins (1.10 dolphins per sq km; %CV = 8.6 – 10.4; 95%CI = 0.87 – 1.20). Figure 8.13 shows the surface maps of estimated abundance for the area of Almería-Vera for the four periods: 1992-1995, 1996-1998, 2000-2004 and 1992-2004, where the distribution patterns are very similar. Figure 8.14 shows the surface maps of estimated abundance for the area of Southern Almería for the periods: 1996-1998, 1999 and 2000-2004. There is a clear difference in the distribution pattern during 1999, with higher density towards deep waters (Figure 8.14). The summer of 1999 has the smallest average group size of all (Table 8.3).

In the Gulf of Vera there has been a strong decrease in density since 1992-1995 (Figure 8.11.c); this was also seen in the encounter rates (Table 8.3). The estimated abundance for 1992-1995 was 2,893 dolphins (0.47 dolphins per sq km; %CV = 13.5 – 14.8; 95%CI = 0.35 – 0.57). It decreased in 1996-1998 to an estimated abundance of 1223 animals (0.20 dolphins per sq km; %CV = 31.8 – 32.4; 95%CI = 0.10 – 0.36), and to 1052 animals in 2000-2004 (0.17 dolphins per sq km; %CV = 23.0 – 27.2; 95%CI = 0.11 – 0.27). Differences were significant between the first period and the two others ($d_{9295\text{-}9698} = 2.490$, $p < 0.02$; $d_{9295\text{-}0004} = 3.858$, $p < 0.001$). Figure 8.15 shows the surface maps of estimated abundance for the area of Vera for the two periods. In both periods depth was the only significant covariate in the model of abundance of groups, with a trend of preference for deeper waters in the second period, although group sizes were again larger in shallower waters (Figure 8.15).

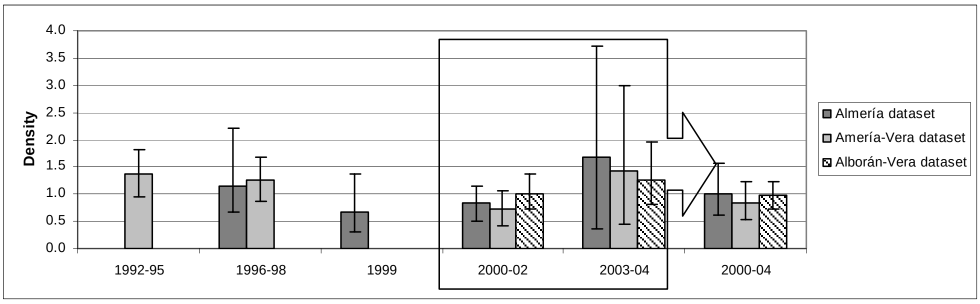
Table 8.8. Point estimates of abundance, density; mean density, mean abundance, 95% CI and CV after 400 bootstrap resamples; and final CV for all datasets. In italics the results are extracted for smaller areas from the larger datasets. (*): does not include the northern section of the Gulf of Vera; (**) does not include the area of Gibraltar; (***) the area searched during these years was smaller, (****) bootstrap could not be run due to small sample size.

Dataset	Area (km^2)	Est. abund. (mean after bootstrap)	Est. density (mean after bootstrap)	95% CI density after bootstrap	%CV after bootstrap	Final %CV
Summer Alborán-Vera						
Alborán-Vera 2000-2002 *	16642	17630 (17599)	1.059 (1.057)	0.867 – 1.332	11.4	11.8 – 13.2
Vera	*3620*	*629 (916)*	*0.174 (0.253)*	*0.102 – 0.450*	*36.4*	*36.5 – 37.0*
Almería	*4232*	*4311 (3744)*	*1.019 (0.885)*	*0.604 – 1.239*	*19.4*	*19.6 – 20.5*
W Alborán	*7589*	*9946 (10547)*	*1.311 (1.390)*	*1.095 – 1.714*	*11.2*	*11.6 – 13.0*
Gibraltar	*1203*	*2744 (2174)*	*2.281 (1.807)*	*0.955 – 3.494*	*36.4*	*36.5 – 37.0*
Alborán-Vera 2003-2004 **	17987	20636 (18910)	1.147 (1.051)	0.544 – 1.643	28.6	28.8 – 32.2
Vera	*6164*	*394 (1130)*	*0.064 (0.183)*	*0.054 – 0.417*	*51.9*	*52.0 – 54.0*
Almería	*4232*	*5316 (3189)*	*1.256 (0.753)*	*0.298 – 1.454*	*39.2*	*39.3 – 39.8*
W Alborán	*7589*	*14926 (14591)*	*1.967 (1.923)*	*0.912 – 3.154*	*31.7*	*31.8 – 32.4*
Alborán-Vera 2000-2004	19189	19428 (19070)	1.012 (0.994)	0.796 – 1.188	10.3	10.7 – 18.0
Vera	*6164*	*889 (985)*	*0.144 (0.160)*	*0.081 – 0.294*	*30.0*	*30.2 – 33.4*
Almería	*4232*	*4103 (3682)*	*0.969 (0.870)*	*0.621 – 1.119*	*14.6*	*14.9 – 16.1*
W Alborán	*7589*	*11721 (11853)*	*1.545 (1.562)*	*1.208 – 1.927*	*11.6*	*12.0 – 13.4*
Gibraltar	*1203*	*2716 (2550)*	*2.258 (2.120)*	*1.208 – 3.135*	*21.9*	*22.1 – 22.9*
Summer Almería-Vera						
Almería-Vera 1992-1995 ***	9152	6989 (7179)	0.764 (0.784)	0.596 – 0.964	12.6	13.0 – 14.3
Vera	*6164*	*2893 (2831)*	*0.469 (0.459)*	*0.352 – 0.573*	*13.2*	*13.5 – 14.8*
Almería ***	*2988*	*4096 (4348)*	*1.371 (1.455)*	*1.032 – 1.890*	*15.4*	*15.7 – 16.8*
Almería-Vera 1996-1998	10397	6552 (6256)	0.630 (0.602)	0.401 – 0.784	17.0	17.3 – 18.3
Vera	*6164*	*1223 (1271)*	*0.198 (0.206)*	*0.102 – 0.357*	*31.7*	*31.8 – 32.4*
Almería	*4232*	*5329 (4985)*	*1.259 (1.178)*	*0.784 – 1.609*	*18.3*	*18.6 – 19.5*
Almería-Vera 2000-2002 *	7853	3965 (4342)	0.505 (0.553)	0.350 – 0.790	19.3	19.5 – 20.4
Vera	*3620*	*855 (846)*	*0.236 (0.234)*	*0.101 – 0.400*	*34.6*	*34.7 – 35.2*
Almería	*4232*	*3110 (3496)*	*0.735 (0.826)*	*0.513 – 1.154*	*19.9*	*20.1 – 21.0*
Almería-Vera 2003-2004	10397	6839 (6258)	0.658 (0.602)	0.192 – 1.351	49.2	49.3 – 51.4
Vera	*6164*	*834 (860)*	*0.135 (0.140)*	*0.035 – 0.357*	*63.1*	*63.2 – 64.8*
Almería	*4232*	*6005 (5399)*	*1.419 (1.276)*	*0.311 – 2.839*	*53.1*	*53.2 – 53.5*
Almería-Vera 2000-2004	10397	4659 (4579)	0.448 (0.440)	0.286 – 0.663	20.7	20.9 – 25.4
Vera	*6164*	*1052 (1068)*	*0.171 (0.173)*	*0.108 – 0.268*	*22.8*	*23.0 – 27.2*
Almería	*4232*	*3607 (3512)*	*0.852 (0.830)*	*0.521 – 1.196*	*22.1*	*22.3 – 23.1*
Almería-Vera 1996-2004	10397	5547 (5316)	0.534 (0.511)	0.390 – 0.664	23.1	23.3 – 27.4
Vera	*6164*	*1324 (1379)*	*0.215 (0.224)*	*0.151 – 0.316*	*32.7*	*32.8 – 35.9*
Almería	*4232*	*4223 (3937)*	*0.998 (0.930)*	*0.715 – 1.213*	*20.8*	*21.0 – 21.8*
Almería-Vera 1992-2004	10397	7148 (6812)	0.688 (0.655)	0.560 – 0.757	7.7	8.3 – 16.7
Vera	*6164*	*2478 (2412)*	*0.402 (0.391)*	*0.322 – 0.479*	*10.5*	*10.9 – 18.1*
Almería	*4232*	*4670 (4400)*	*1.103 (1.040)*	*0.874 – 1.202*	*8.0*	*8.6 – 10.4*
Winter Almería-Vera						
Almería-Vera 1992-2004	10397	2429 (2494)	0.234 (0.240)	0.157 - 0.380	32.3	32.4 – 35.5
Vera	*6164*	*688 (718)*	*0.066 (0.069)*	*0.040 – 0.099*	*24.9*	*25.1 – 29.0*
Almería	*4232*	*1741 (1777)*	*0.583 (0.595)*	*0.361 – 0.983*	*38.3*	*38.4 – 38.9*
Almería 1992-2004	4232	1989 (2096)	0.470 (0.495)	0.279 – 0.885	37.0	37.1 – 37.6
Summer Western Alborán						
Western Alborán 2000-2002	7589	12169 (11945)	1.604 (1.574)	1.161 – 1.982	14.0	14.3 – 15.5
Western Alborán 2003-2004	7589	13695 (14835)	1.805 (1.955)	0.927 – 3.126	27.4	27.6 – 28.2
Western Alborán 2000-2004	7589	13019 (13079)	1.716 (1.723)	1.313 – 2.059	11.4	11.8 – 13.2
Summer Southern Almería						
Southern Almería 1996-1998	4232	4867 (5167)	1.150 (1.221)	0.756 – 2.285	33.2	33.3 – 33.9
Southern Almería 1999	4232	2892 (3498)	0.683 (0.826)	0.458 – 1.522	41.7	41.8 – 42.2
Southern Almería 2000-2004	4232	4303 (4614)	1.017 (1.090)	0.690 – 1.641	30.6	30.8 – 31.3
Winter Southern Almería						
Southern Almería 1992-2004	4232	1989 (2096)	0.470 (0.495)	0.279 – 0.885	37.0	37.1 – 37.6
Summer Gulf of Vera						
Gulf of Vera 1992-1995	6164	2066 (1969)	0.335 (0.319)	0.212 – 0.419	19.0	19.2 – 20.1
Gulf of Vera 1996-2004 ****	6164	663	0.108			

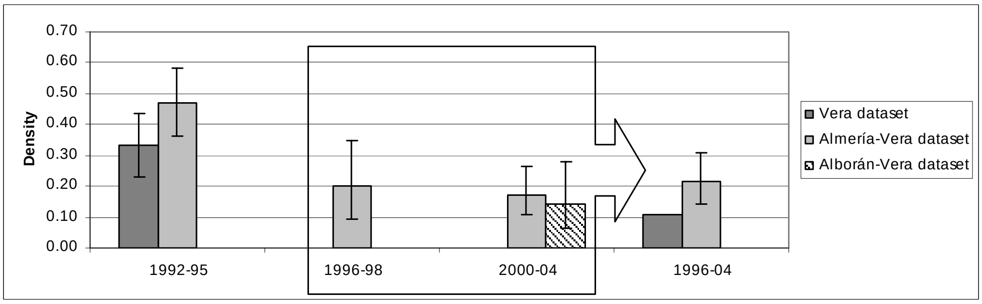
a)



b)



c)



d)

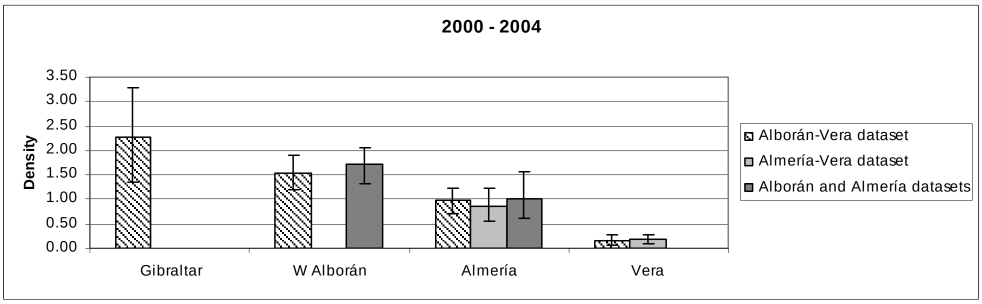


Figure 8.11. Pont estimates of density for all datasets, with a comparison between the estimates from modelling the small datasets and from extraction from the larger datasets. a) Western Alborán, b) Southern Almería, c) Gulf of Vera and d) all areas for 2000-2004. Vertical bars show the 95% CI after the bootstrap.

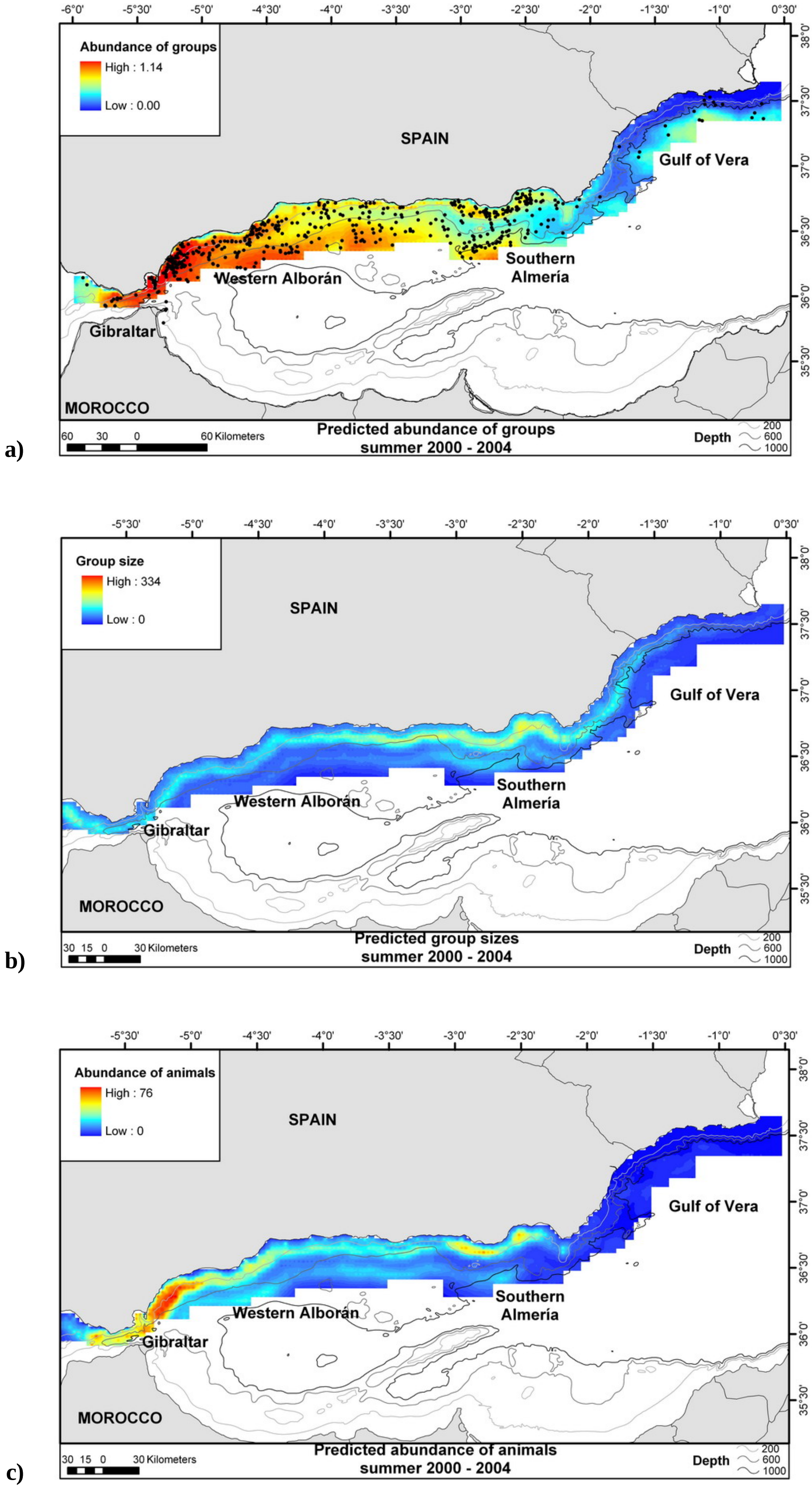


Figure 8.12. Surface map of (a) estimated abundance of groups (b) estimated group sizes and (c) estimated abundance of animals for the whole study area between 2000 and 2004. Black dots represent groups encountered during this period. The scales for the three maps are the same as for the other areas, for comparison, but an extension to the scale has been added to the abundance of groups.

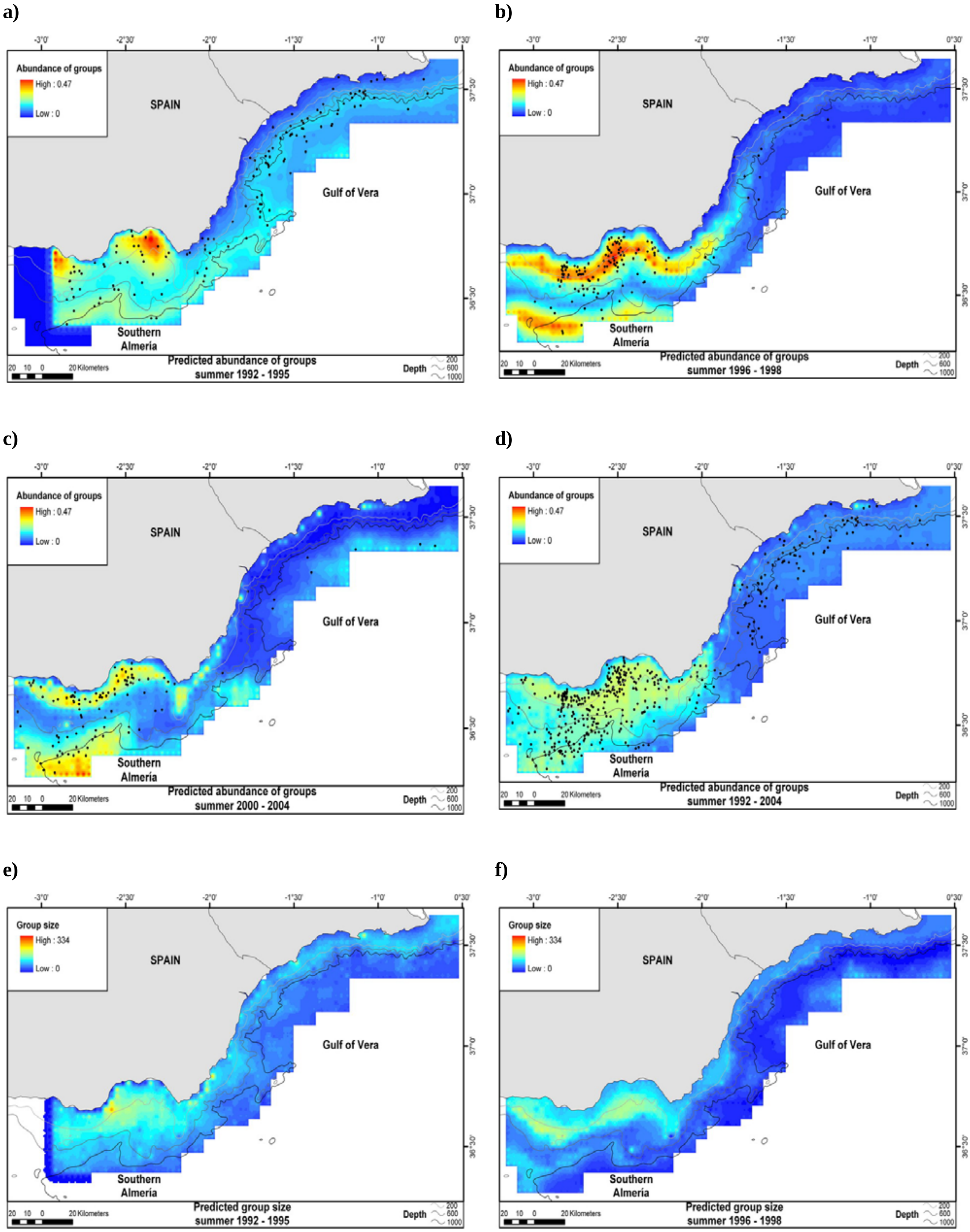


Figure 8.13. Surface maps of (a to d) estimated abundance of groups, (e to h) estimated group sizes and (i to l) estimated abundance of animals for the area of Almería-Vera: (a, e and i) between 1992 and 1995; (b, f and j) between 1996 and 1998; (c, g and k) between 2000 and 2004; and (d, h and l) whole period, between 1992 and 2004. Black dots represent groups encountered during these periods. Dark blue to the left-down corner of the 1992-1995 map represent non-surveyed area in that period. The scales for the three maps are the same as for the other areas, for comparison.

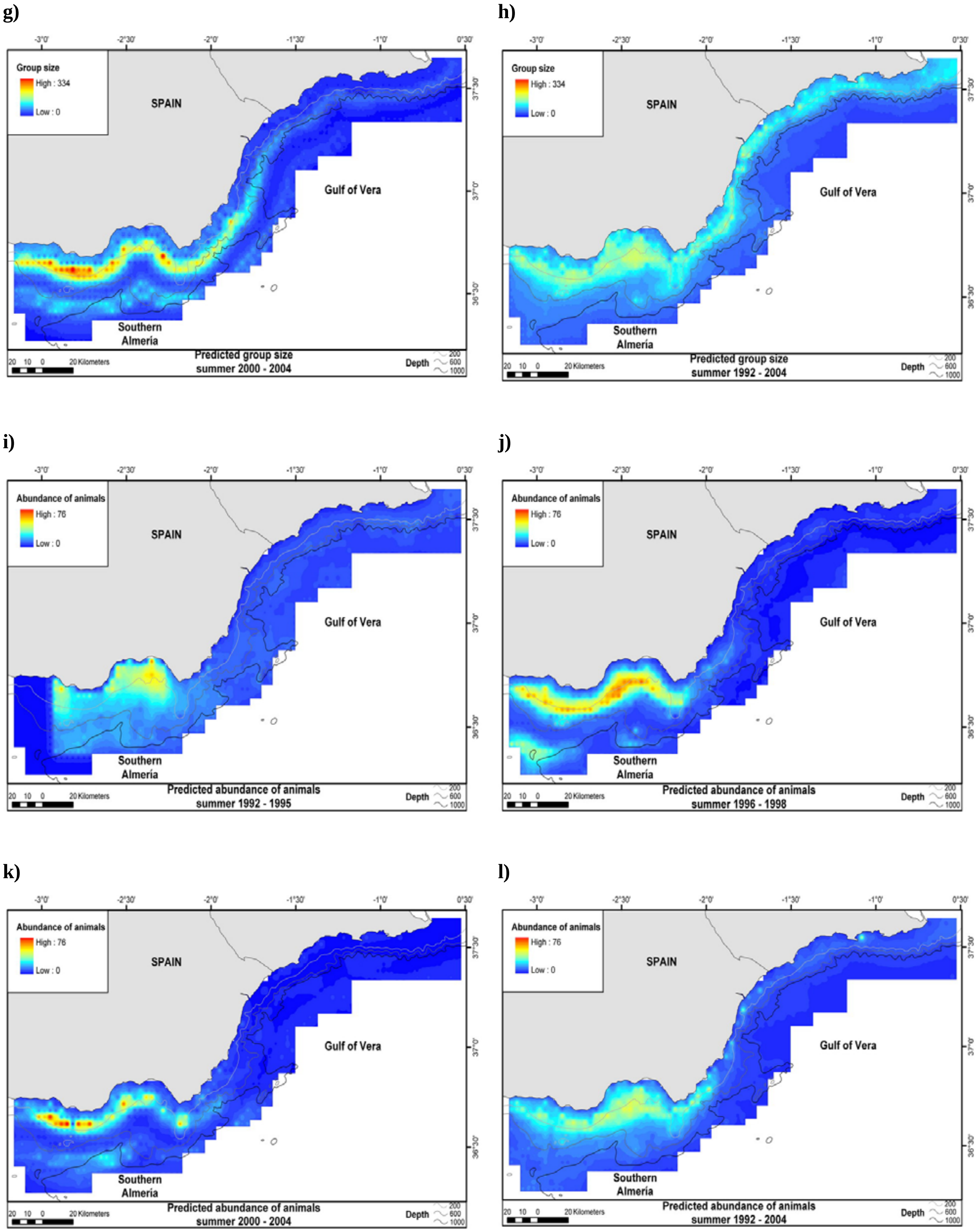


Figure 8.13 (continuation). Surface maps of (a to d) estimated abundance of groups, (e to h) estimated group sizes and (i to l) estimated abundance of animals for the area of Almería-Vera: (a, e and i) between 1992 and 1995; (b, f and j) between 1996 and 1998; (c, g and k) between 2000 and 2004; and (d, h and l) whole period, between 1992 and 2004. Black dots represent groups encountered during these periods. Dark blue to the left-down corner of the 1992-1995 map represent non-surveyed area in that period. The scales for the three maps are the same as for the other areas, for comparison.

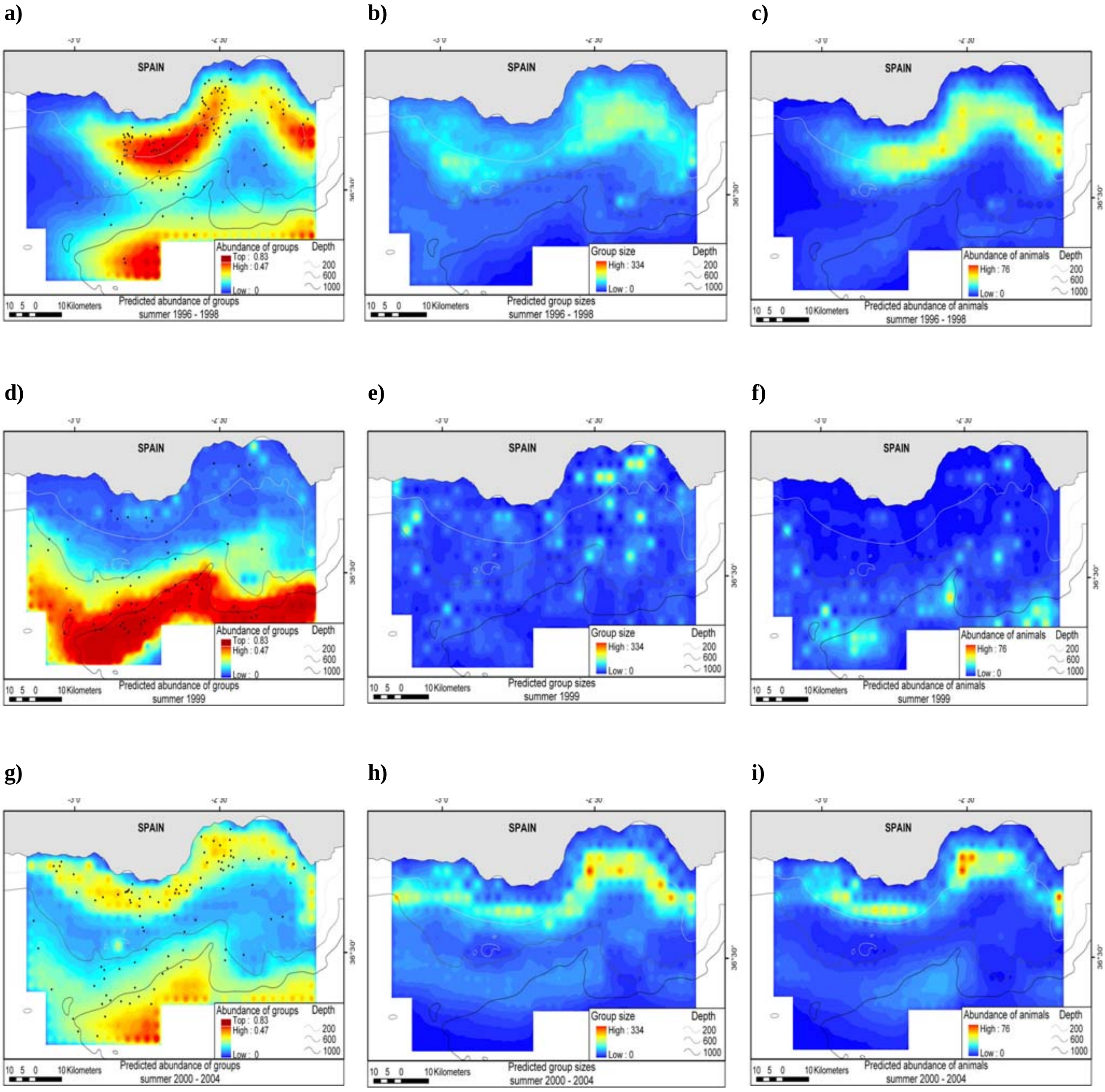


Figure 8.14. Surface maps of estimated abundance of groups, estimated group sizes and estimated abundance of animals for the area off Southern Almería: (a, b and c) between 1996 and 1998, (d, e and f) 1999, and (g, h and i) between 2000 and 2004. The scales for the three maps are the same as for the other areas, for comparison, but an extension to the scale has been added to the abundance of groups.

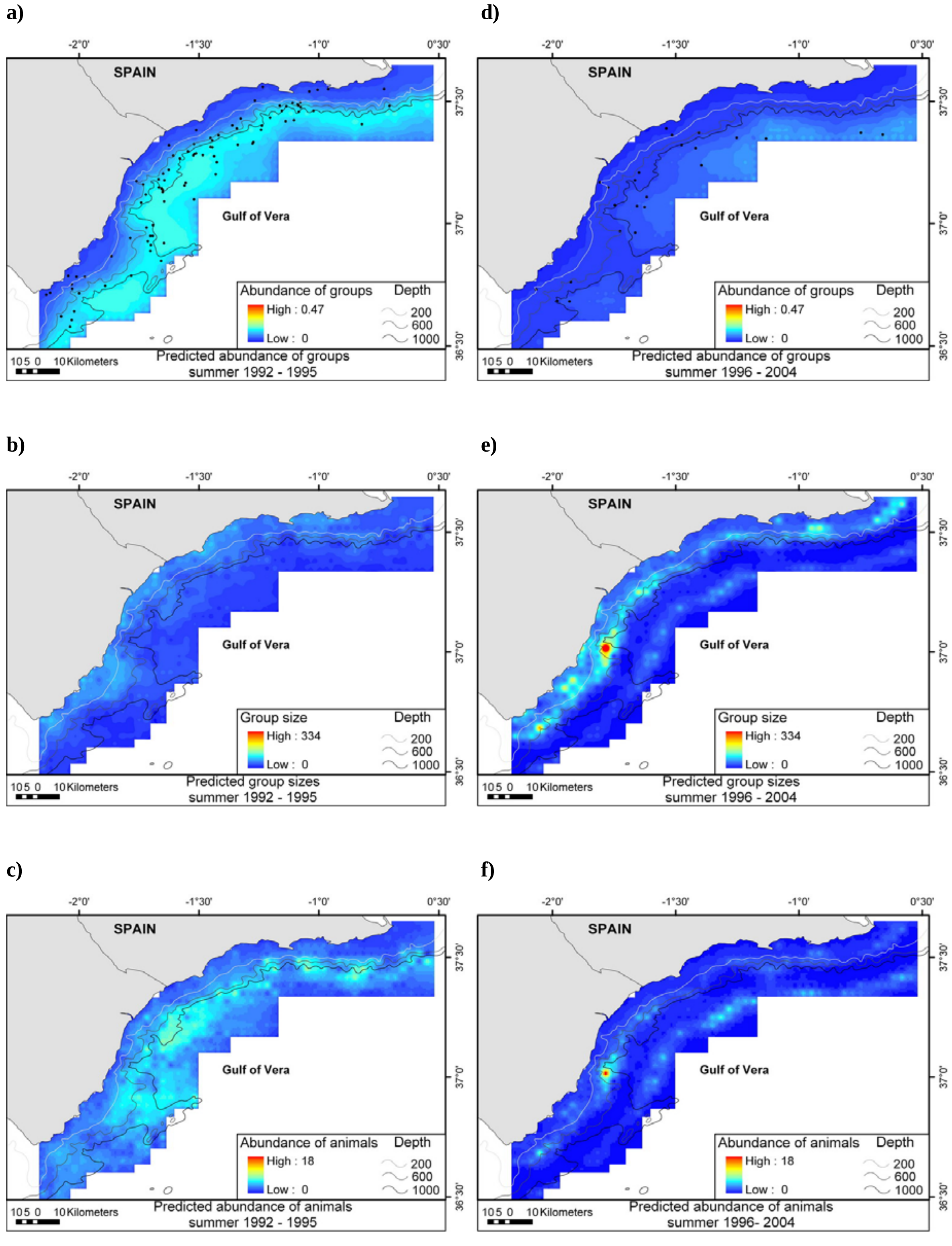
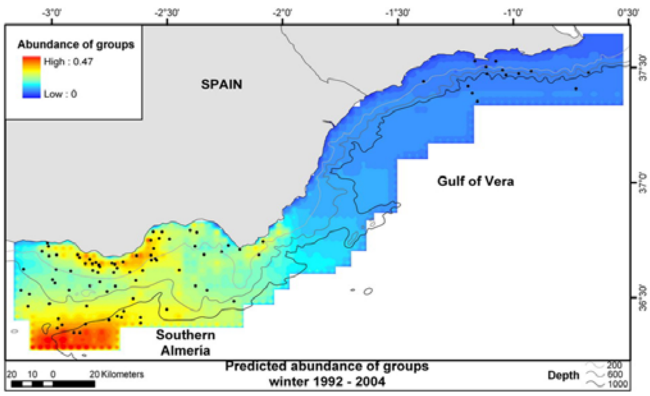


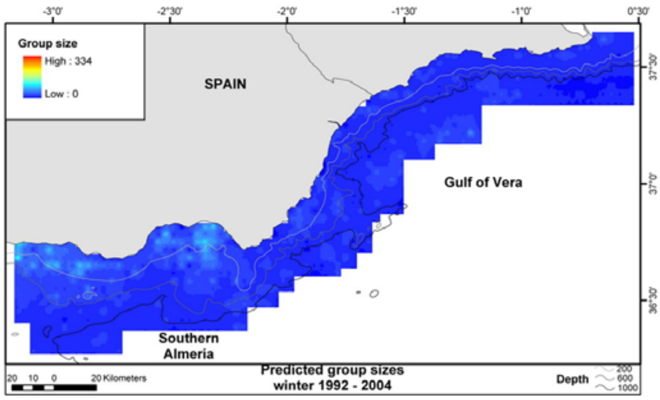
Figure 8.15. Surface maps of estimated abundance of groups, estimated group sizes and estimated abundance of animals for the area of the Gulf of Vera: (a, b and c) between 1992 and 1995, and (d, e and f) between 1996 and 2004. The scales for the three maps are the same as for the other areas, for comparison.

Density during the winter months was significantly lower than during the summer months in the Almería-Vera area ($d_{summer\text{-}winter}$ = 4.501, $p < 0.001$), considering all years together. This difference is mainly due to a much smaller average group size during winter (Table 8.4), while the encounter rate of groups remains similar (Table 8.3). There is also a shift in distribution, with higher density of groups towards deep waters (or lower latitude), but still with higher density in Southern Almería compared to the Gulf of Vera (Figure 8.16 at the end of the chapter). Despite the smaller group sizes in this season, larger groups still occur in shallower waters, where the chlorophyll concentration is higher (Figure 8.16). The encounter rates of animals were larger during the winter months than during summer in the Gulf of Vera after 2000 (Figure 8.2c and 8.3b). It was not possible to estimate abundance for that period in the Gulf of Vera due to the small sample size. Figure 8.17 shows the surface map of estimated winter abundance for the area of Almería-Vera for the whole period 1992-2004.

a)



b)



c)

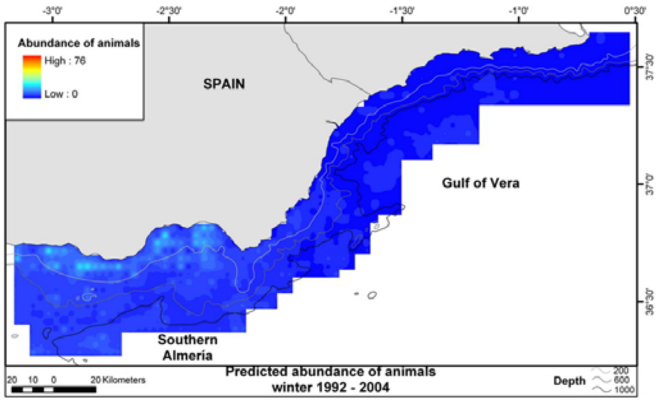


Figure 8.17. Surface map of (a) estimated abundance of groups, (b) estimated group size and (c) estimated abundance of animals for winter for the area of the Almería-Vera for the whole period: 1992 to 2004. The scales for the three maps are the same as for the other areas, for comparison.

8.4. DISCUSSION

8.4.1. Methodological considerations

The models of density of groups explained a low percentage of deviance. This could be for several reasons. First, the models may not be fitting the data very well. However, the surface maps, compared with the observed distribution of sightings, and the large similarities among datasets, suggest that the general distribution pattern of common dolphins in the area has been adequately captured by the models. A more plausible reason is that the very low proportion of positive observations in each segment of trackline, caused by the relatively low density and the small size of the segments, might be limiting the amount of variability that could possibly be explained with the available covariates. Even the most important areas with the highest densities, have very large proportions of segments with '0' observations. This could be partially addressed by using larger segments and, therefore, increasing the proportion of positive observations. But this would also mean losing much of the resolution of the environmental covariates, with a corresponding loss of explanatory power.

Another possibly very important reason for such a low percentage of deviance explained is the complexity of the species' ecology. Distribution and abundance might be influenced not only by environmental covariates (many of which are difficult to measure or unavailable), but also by their complex – and mostly unknown - social structure, behaviour, reproductive status, etc (referred to as 'intrinsic' factors in Chapter 9, where this is further explored). In particular, the covariates that most likely directly affect the distribution of the animals were not available for this study, namely the abundance and distribution of prey. The covariates used should be considered as proxies to help describe distribution rather than the reasons of it (i.e. these are predictive models, not explanatory models; MacNally 2000).

A third factor that could reduce the variability explained is the spatial scale of the study area, in relation to the habitat use of the species. If density varies little over the area modelled, spatial covariates will not be able to explain much variability. In this study the deviance explained in the larger datasets (Alborán-Vera) is higher than in the smaller datasets (Table 8.5).

The estimated density for a sub-area extracted from a larger dataset, and the density estimated by modelling the smaller datasets directly were very similar. However, the CV and 95% CI increased as the area modelled got smaller (Table 8.6). This was likely because density varied less over the smaller areas as well as the smaller sample size. For example, for the area of Southern Almería between 2000 and 2004, the estimated density modelling this dataset on its own was 1.02 (%CV = 30.8 – 31.3), when extracted from the model of the Almería-Vera dataset, it was 0.85 (%CV = 22.3 – 23.1), and when extracted from the model of the Alborán-Vera dataset, the estimated density was 0.97 (%CV = 14.9 – 16.1). The CV declined as the dataset became spatially larger. The conclusion is that larger study areas allow for contrasts in density that facilitate the modelling exercise and generate more precise estimates of abundance.

8.4.2. Abundance and trends

8.4.2.1. Possible bias

In this study, responsive movement before detection did not appear to be a big problem according to the tests done but strong attraction of common dolphins to the observation platform has been found in other studies (e.g. Cañadas *et al*. 2004). It is possible that in this study, the small size, low speed and quietness of the research vessel, combined with the typically large detection distance of common dolphin groups, resulted in no responsive movement before detection.

It was not possible to estimate g(0) as the double platform method was not implemented. Nevertheless, given the group sizes, travel speed and visibility conditions in this survey, g(0) was very likely to be close to 1. In the NASS95 surveys, the smaller group sizes, faster survey speed and worse conditions gave an estimated g(0) = 0.8 (Cañadas *et al*. 2004). The potential negative bias assuming g(0) = 1 is likely to be very small. Double platform data are being collected from 2005, so an adequate correction will be done in the near future.

8.4.2.2. Comparison with other areas

The Alborán Sea is a high density area for common dolphins, both neritic and oceanic, not only for the Mediterranean but for all European waters. This area has strong upwellings, complex topography and high productivity and biodiversity, and is considered the ‘hydrological motor’ of the Mediterranean Sea (Rodriguez 1982; Rubín *et al*. 1992; Chapter 2). There is a clear density gradient of common dolphins from West to East (i.e. from greater to lesser influence of the Atlantic inflow through the Strait of Gibraltar), dropping steeply in the Gulf of Vera, where the influence is predominantly Mediterranean (i.e. warmer sst, lower productivity, etc.). The oceanographic features of the Alborán Sea are therefore very different from those of the rest of the Mediterranean and Atlantic contiguous waters. The particular and intense oceanographic characteristics of the Alborán Sea create a habitat that can support high densities of common dolphins.

There exist very few studies giving an estimation of density or abundance for common dolphins in the NE Atlantic or the Mediterranean, all of them covering only a very small part of its distributional range. The estimated summer abundance obtained in this work for the northern Alborán Sea and Gulf of Vera is larger but not statistically different than that obtained by Forcada and Hammond (1998) after the 1991 and 1992 summer surveys in the whole Alborán Sea and Gulf of Vera. Comparisons between both studies are very difficult due to differences in survey and analytical methods and in sample size (28 *vs*. 762 sightings), so it is not profitable to explore possible reasons for any difference.

If there is only a small bias in this study, then the summer estimated density, particularly in Southern Almería, is comparable to that of the area to the west of Britain and Ireland from the NASS95 survey (Cañadas *et al*. 2004). In Western Alborán the estimated density is around double that from NASS95. If we assume a g(0) relatively close to 1 in the SCANS and MICA93 surveys, and that any responsive movement would lead to an overestimate in density, then the density of common dolphins is much higher in the NASS95 offshore area than in any of the other surveyed areas in the NE Atlantic. This area thus appears to be important habitat in the NE Atlantic, as is the northern Alborán Sea in the Mediterranean Sea.

8.4.2.3. Seasonal variations

A seasonal change in distribution and density was observed, characterised by lower estimated density in winter due to the groups being smaller, and a shift in high density of groups towards deeper waters in winter (Figure 8.17a) compared to summer (Figure 8.13d). A similar pattern has been observed in New Zealand (Neumann 2001), where common dolphins move offshore in autumn and winter and inshore in spring and summer. This author links this seasonal movement with changes in sst, suggesting that common dolphins prefer the warmer waters offshore during winter.

On the other hand, the opposite situation has been described for this species in the North-East Atlantic, where common dolphins are more abundant in offshore waters than over the continental shelf during summer (Cañadas *et al.* in press), but move towards shallower waters during winter (Pollock *et al*. 1997; Ó Cadhla *et al.* 2003; Northridge *et al.* 2004; Brereton *et al.* 2005). It has been suggested that this shift follows the migration movements of anchovies (Borja *et al*. 1998; Allain *et al*. 2001). In the Alborán Sea, sardines move towards deeper waters to hibernate when the sst drops in autumn, not returning to the epipelagic area until the end of spring or beginning of summer to feed (Lotina 1985b). In winter, common dolphins may adopt a different strategy for feeding, probably on different prey species, by spreading out towards deeper waters in smaller groups. The same change in pattern occurred during summer 1999, when a drop in sst was detected during some days. This could suggest that common dolphins reacted in the same way as they do in winter, possibly related to a similar change in the prey availability, yielding a lower density of animals in the study area. This is further discussed in Cañadas *et al*. 2002 (Chapter 5) and in Chapter 9.

8.4.2.4. Trends

No trend over time in the Alborán Sea as a whole was detected, since 1992 in Southern Almería and since 2000 in Western Alborán (Table 8.6 and Figure 8.11.a and b), suggesting that the northern Alborán sea population of common dolphins is stable in this area, at least during the time frame of this study.

On the other hand, the sharp drop in density of common dolphins in the Gulf of Vera after 1996, to less than half of that between 1992 and 1995 is a concern. To test whether the observed decline might be an artefact of lower effort in the area since 1995, especially between 1998 and 2002, the density of striped dolphins was estimated in the same area and periods, following the same methodology as for common dolphins. There was no change in striped dolphin density between the two periods (1992-1995: 1.08 dolphins per sq km, 95%CI = 0.80 – 1.23; 1996-2004: 1.17 dolphins per sq km, 95%CI = 0.92 – 1.39; see also Figure 8.2d for encounter rates of striped dolphins across the years in the Gulf of Vera). Therefore, the drop in common dolphin density seems to be real, and not an artefact of differences in effort.

8.4.3. Implications for conservation

The lack of trends in the abundance estimates for the northern Alborán Sea between 1992 and 2004 contrasts with the apparent decline of this species in the rest of the Mediterranean Sea (Bearzi *et al*. 2003) and with the reported high levels of by-catch in Moroccan drift-nets in the southern Alborán Sea (Tudela *et al*. 2005).

The decline of the common dolphin in the rest of the Mediterranean Sea (Bearzi *et al*. 2003), does not seem to have affected the situation in the northern Alborán Sea. This area has very special oceanographic characteristics, and common dolphins inhabiting this basin have proven to belong to a different population than that of the rest of the Mediterranean Sea (Natoli 2005).

According to Tudela *et al*. (2005), an estimated 1,500 to 2,000 common dolphins might be caught every year in Moroccan driftnets in the southern Alborán Sea. Simplistically extrapolating estimated density from the northern Alborán Sea to the rest of the basin, gives an abundance of around 95,000 common dolphins, and the by-catch estimate would represent about 2% of the population. Unfortunately there is no information on the distribution pattern of common dolphins outside our study area, and therefore no real inference can be made about the possible density in the Southern Alborán Sea. However, it seems plausible that density at least in the south-western portion must be relatively high, maybe comparable to that in the northern portion. In both years of the 1991-1992 survey of Forcada and Hammond (1998) there was an aggregation of sightings close to the South-western coast of the Alborán Sea, which could suggest that this might be an important area for common dolphins. This corresponds to the southern edge of the Western anticyclonic gyre, known for its high productivity (Rodriguez 1982; Rubín *et al*. 1992). But little information can be obtained from that study in terms of distribution, as the effort and number of sightings was very limited. The stranding records of the western coast of Algeria (Boutiba 1994) also shows a high presence of common dolphins in that area, which coincides with the southern end of the Almería-Orán front, where high productivity is enhanced (Tintoré *et al*. 1988). The oceanographic studies show, nevertheless, that the rest of the southern portion of the Alborán Sea is much poorer than the northern section in terms of nutrients and productivity (Parrilla and Kinder 1987; Rubín 1994). Thus common dolphin density in these areas might be lower than in the highly productive northern areas. Nonetheless, some opportunistic sightings around the area of Melilla (coast of Morocco, south of Almería) indicate relatively constant presence of common dolphins in these coastal waters (A. del Salto, pers. comm.).

The contrast between the estimated by-catch from Tudela *et al*. (2005) and the lack of trend in abundance in the Alborán Sea presented here could be due to several factors, or a combination of some of them:

a) The estimated by-catch rate comes from observations in one single port along the Mediterranean Moroccan coast and extrapolated to the other ports. Whilst acknowledging that this paper has highlighted that a serious by-catch problem exists in the area, the extrapolation could be misleading if it does not take into account (and it does not) differences in dolphin density and habitat use along the whole coast, and possible differences in the fleet from different ports;

b) There is a population structure within the Alborán Sea, with common dolphins from the southern portion being different from those in the northern portion. In this case, the by-catch could be depleting the southern 'population' and not affecting the northern one. This seems very unlikely given the size of the basin and the high mobility of the dolphins. Genetic analysis has shown that the common dolphins in the northern Alborán Sea and the Strait of Gibraltar are not different from those in the contiguous Atlantic waters, implying an important gene flow through the Strait (Natoli 2005). The same study shows, on the other hand, that these dolphins are genetically very distinct from those in the Central and Eastern Mediterranean Sea, with very limited gene flow. Unfortunately, not enough samples are available from the North African coast to explore population structure within the Alborán Sea;

c) The population is large enough (for example, density in the southern portion is higher) to sustain the by-catch. We do not know population size in the whole Alborán Sea, nor the whole by-catch, so it is quite possible that the population can sustain the bycatch and no trend would be expected.

Before these questions can be answered it is necessary to survey the whole Alborán Sea, and especially along the North African coast, to yield accurate abundance estimates of this area and the basin in general. It would also be of great interest to collect and analyse samples from the southern areas to assess the genetic identity and possible population structure of the dolphins inhabiting the Alborán Sea. It is also important to continue and extend to other ports the monitoring of the by-catch along the Moroccan coast. All this information is necessary to assess the impact of by-catch (and other threats) and therefore to develop adequate and effective conservation measures.

One reason for the decline of common dolphin density in the Gulf of Vera may be the exponential grow of aquaculture in the area since the mid 1990s (www.carm.es). Many aquaculture farms have been developed in the region of Murcia (northern Gulf of Vera) since then for gilthead seabream (*Sparus aurata*), European seabass (*Dicentrarchus labrax*) and especially Northern blue fin tuna (*Thunnus thynnus*). The main species caught to feed fish in these aquaculture farms is the round sardinella (*Sardinella aurita*). The catches of this fish, traditionally not a commercial species, went from almost no catches at the beginning of the 1990s to an average of 2,000 tons per year (www.carm.es) by 2003. In the Alborán Sea, there is not yet such a strong development of aquaculture, and the catches of round sardinella have remained stable at around 400 tons per year in the much larger region of Andalucía (Alborán Sea and Southern Gulf of Vera) since 1985 (www.juntadeandalucia.es). If common dolphins have declined in the northern Gulf of Vera because of the overexploitation of the round sardinella, on which they might be feeding there, they may have moved to deeper waters to feed on other types of prey (as they likely did in Southern Almería in 1999, and as occurs during the winter months), i.e. leaving an area that has became less suitable for them due to the lack of food resources.

However the decline in the Gulf of Vera could also be the product of other factors that have been proposed as reasons for the general decline in the rest of the Mediterranean (Bearzi *et al*. 2003). Those factors, including pollution, overfishing, by-catch, oceanographic changes, etc. are described in more detail in Bearzi *et al*. 2003. Even if these factors have not yet, apparently, affected the Alborán Sea dolphins to the point of producing a detectable negative trend, close monitoring should be kept on this population to be able to detect any adverse change, and on the human activities so they do not become out of control in terms of impact on the environment. The monitoring of the population should include not only the continuation of distribution, habitat preference and abundance studies, but also the development of investigations focussing on reproductive parameters and survival to inform a population viability analysis, thus developing a more complete understanding of the ecology, to better inform conservation efforts focussed on of common dolphins in the Mediterranean Sea. The control and close monitoring of the aquaculture activities and their effects on the fish stocks should be part of any attempt to develop conservation measures for common dolphin, probably not only in this area, but in the whole Mediterranean Sea.

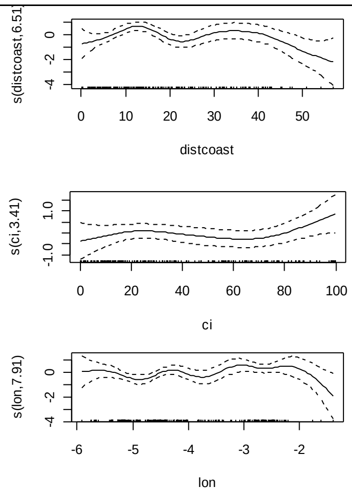
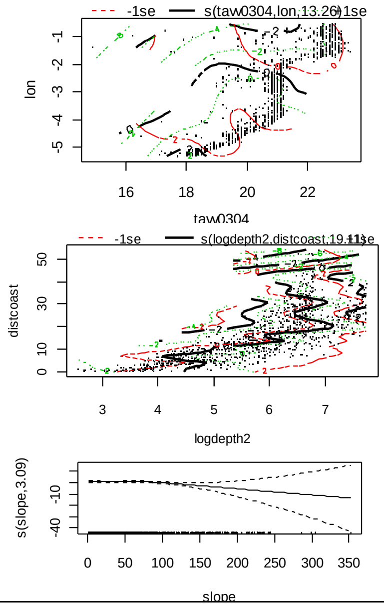
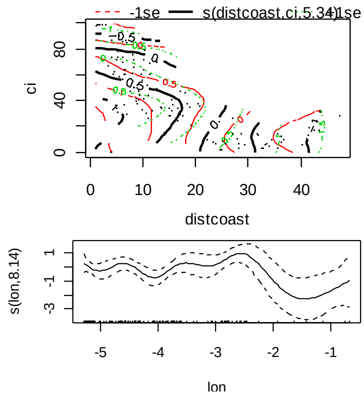
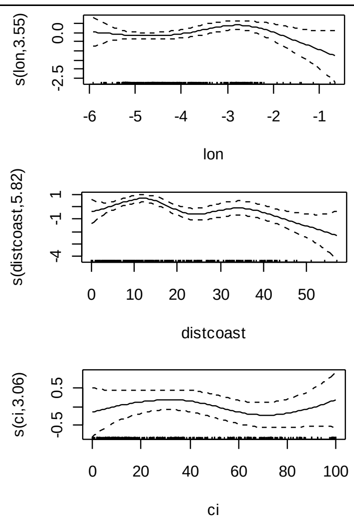
Subset	Groups	Group size
Summer Alborán-Vera		
Alborán-Vera 2000-2002	(plot not available for smooths with 3 variables)	
Alborán-Vera 2003-2004		
Alborán-Vera 2000-2004	(plot not available for smooths with 3 variables)	

Figure 8.6. Shapes of the functional forms for the smoothed covariates used in the models for Alborán-Vera in summer. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

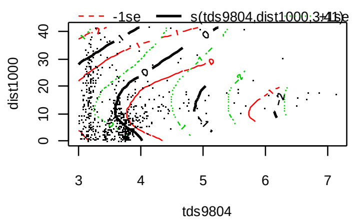
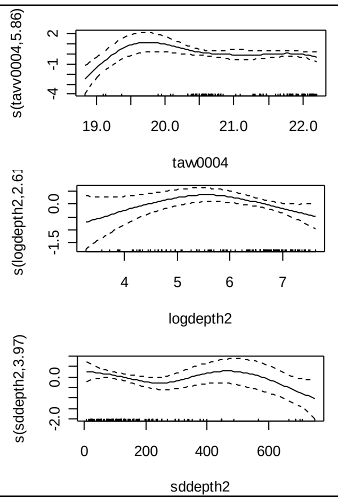
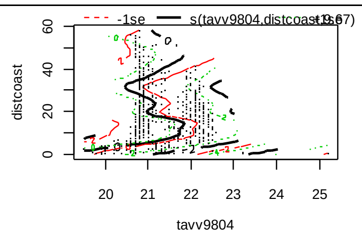
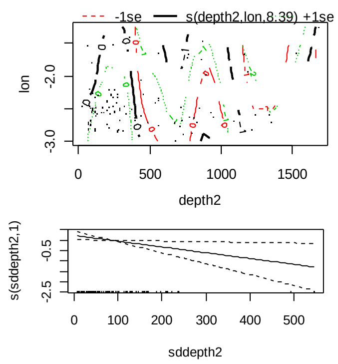
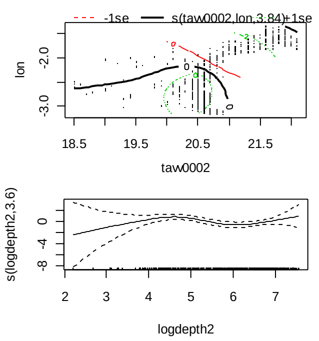
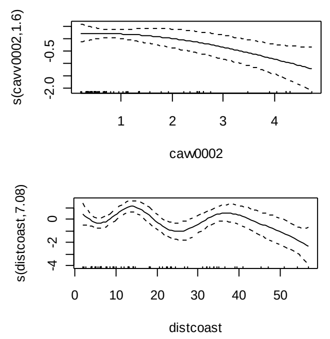
Subset	Groups	Group size
Summer Almería-Vera		
Almería-Vera 1992-1995		
Almería-Vera 1996-1998		
Almería-Vera 2000-2002		

Figure 8.7. Shapes of the functional forms for the smoothed covariates used in the models for Almería-Vera in summer. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

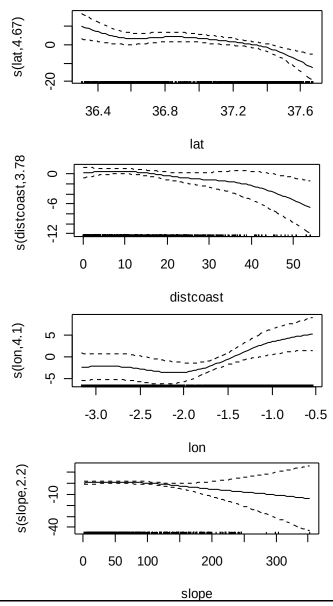
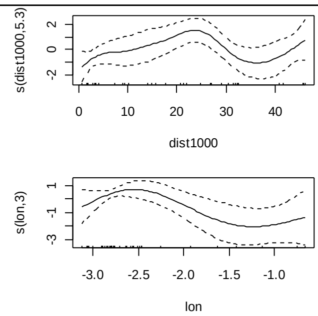
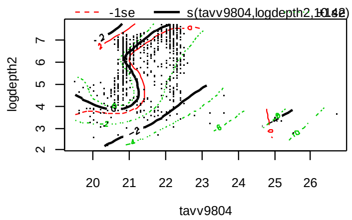
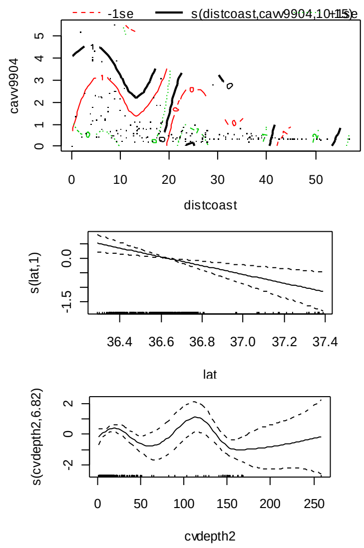
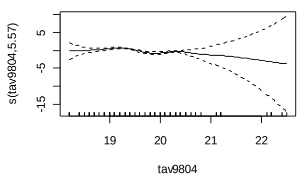
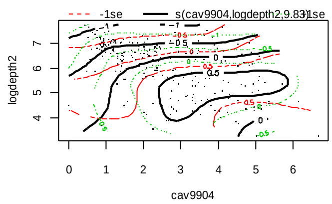
Subset	Groups	Group size
Summer Almería-Vera		
Almería-Vera 2003-2004		
Almería-Vera 1996-2004		
Almería-Vera 1992-2004		

Figure 8.7 (continuation). Shapes of the functional forms for the smoothed covariates used in the models for Almería-Vera in summer. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

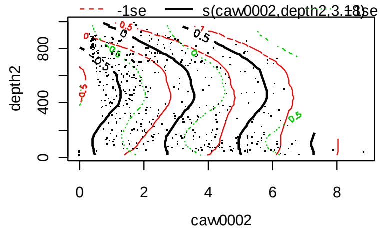
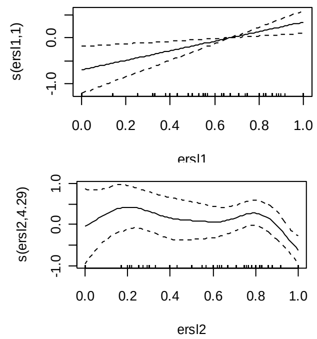
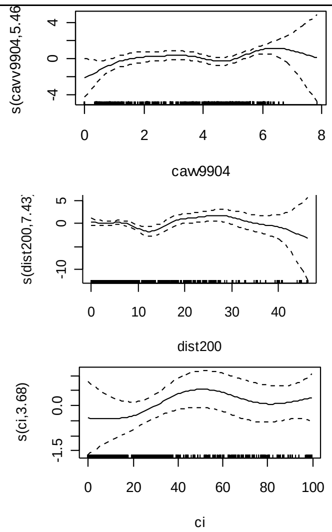
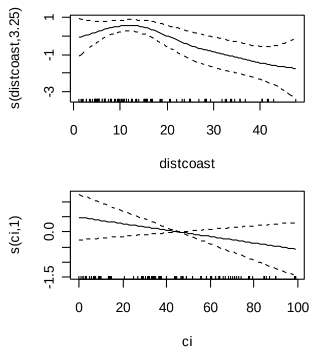
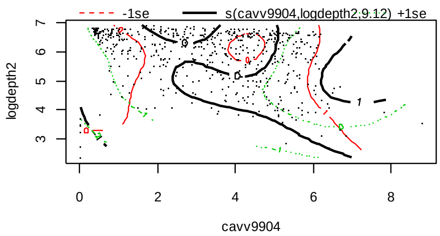
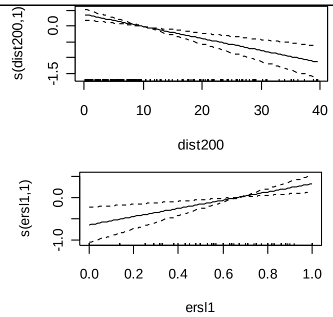
Subset	Groups	Group size
Summer Western Alborán		
Western Alborán 2000-2002		
Western Alborán 2003-2004		
Western Alborán 2000-2004		

Figure 8.8. Shapes of the functional forms for the smoothed covariates used in the models for Alborán in summer. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

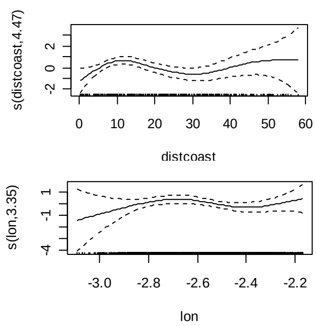
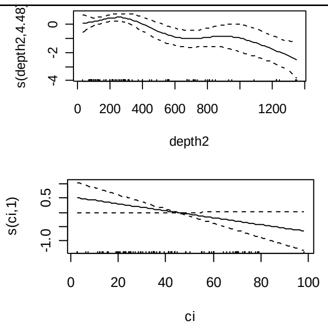
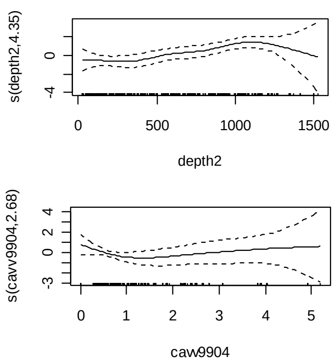
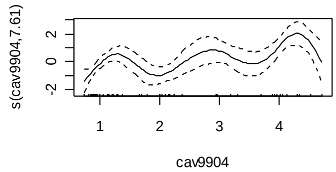
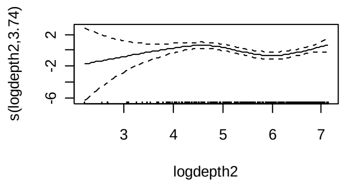
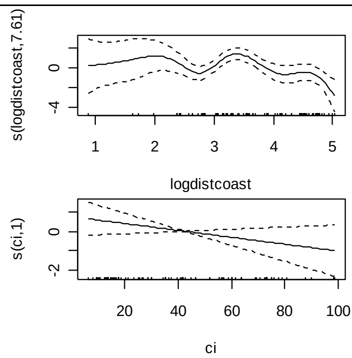
Subset	Groups	Group size
Summer Southern Almería		
Southern Almería 1996-1998		
Southern Almería 1999		
Southern Almería 2000-2004		

Figure 8.9. Shapes of the functional forms for the smoothed covariates used in the models for Southern Almería in summer. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

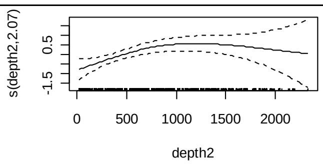
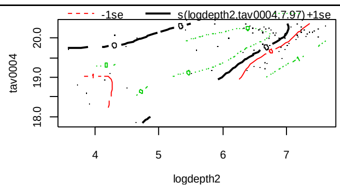
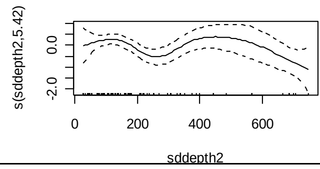
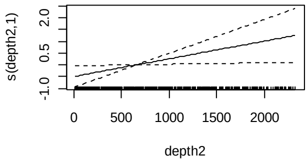
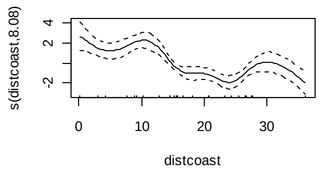
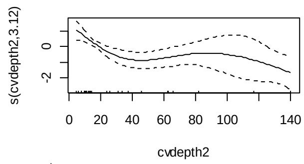
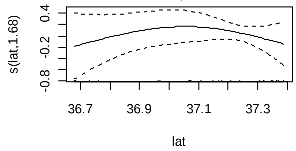
Subset	Groups	Group size
Summer Gulf of Vera		
Gulf of Vera 1992-1995		 
Gulf of Vera 1996-2004		  

Figure 8.10. Shapes of the functional forms for the smoothed covariates used in the models for Vera in summer. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

<table>
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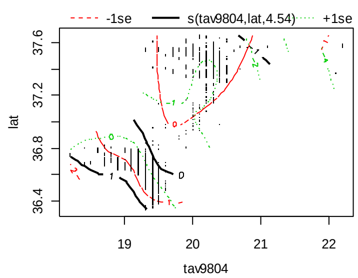
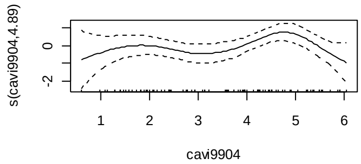
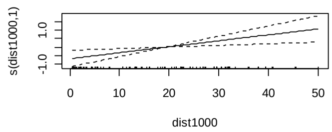
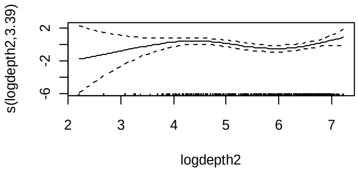
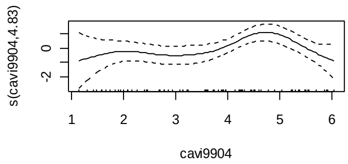
Vera
1992-2004</td><td>
</td><td>


</td></tr>
<tr><td>Almería
1992-2004</td><td>
</td><td>

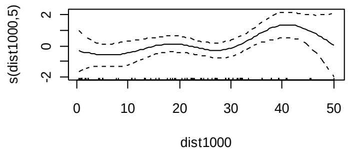

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Figure 8.16. Shapes of the functional forms for the smoothed covariates used in the models for winter. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

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CHAPTER 9

HABITAT PREFERENCE OF COMMON DOLPHINS

ABSTRACT

The distribution and habitat use of a species with complex ecology, social structure and behaviour, is very likely to be influenced not only by 'extrinsic' (i.e. abiotic and biotic environmental) factors, as explored in Chapters 6 and 8, but also by 'intrinsic' factors (e.g. reproductive status, feeding strategies, behaviour, interspecific relationships). Understanding these influences and the inter-relationships among them will greatly improve our understanding and interpretation of information on distribution and habitat use as well as improving our ability to develop targeted and more effective mitigation and conservation measures. This chapter begins to explore the habitat preferences of common dolphins in the study area, and in particular examines certain 'intrinsic' factors such as presence of calves, interspecific relationships and behaviour.

Groups with calves tended to prefer more coastal waters and groups without calves deeper waters. In both cases, however, a second smaller peak of density was observed in deep and coastal waters respectively. Single species groups followed the general pattern of higher densities around the shelf edge off Southern Almería but mainly towards the western end of the area, while there were higher densities of animals in mixed species groups (common and striped dolphins) in the deep waters off Southern Almería, and in the whole western part of the study area. In the westernmost section, however, the higher density occurs also around the shelf edge. Animals feeding showed the highest densities in shallow waters. Animals travelling followed the general pattern of higher densities towards the west and around the shelf edge, with a second smaller peak in deep waters. There was a strong contrast between the patterns of density of groups and of group sizes in socializing groups; there were more but smaller groups in deep waters, and fewer but larger groups in shallow waters. This bimodal pattern disappeared when stratifying socializing groups into single and mixed species groups. There was a higher density of socializing animals in single groups along the shallow waters of the shelf edge, and a higher density of socializing animals in mixed groups in deeper waters, mainly to the west.

This study has shown that introducing intrinsic factors in the analysis leads to a clearer picture of how common dolphins use their habitat in the Alborán Sea. This not only improves our understanding of the ecology of the species, but should also lead to more effective conservation.

9.1 INTRODUCTION

As discussed in Chapter 8, common dolphins in the Mediterranean were classified as ‘endangered’ by IUCN in 2003 (www.redlist.org) as they appeared to have suffered a serious decline (Bearzi *et al*. 2003), whilst the ACCOBAMS Conservation Plan for the Mediterranean Common Dolphin (Bearzi *et al*. 2004) identified the Alborán Sea as an ‘Area of Conservation Importance’ based on the high encounter rates there.

The absolute abundance of common dolphins in the study area was estimated in Chapter 8, and the most important (i.e. in terms of highest density) areas were identified in Chapters 6 and 8. This baseline information will enable detection of possible trends in abundance and/or shifts in population distribution - fundamental to conservation efforts. However, for a species with complex ecology, social structure and behaviour, its distribution and the way it uses its habitat is very likely to be influenced not only by ‘extrinsic’ (i.e. abiotic and biotic environmental) factors but also by ‘intrinsic’ factors (e.g. reproductive status, feeding strategies, behaviour, interspecific relationships). Understanding these influences and the inter-relationships among them will greatly improve our understanding and interpretation of any apparent trends as well as improving our ability to develop targeted and more effective mitigation and conservation measures.

There have been a number of studies looking at general habitat preference of common dolphins in several parts of the world, usually in terms of extrinsic factors such as oceanographic or bathymetric features. For example, in the eastern tropical Pacific, common dolphins have been shown to occupy the productive upwelling-modified waters of the region (Evans, 1982; Reilly, 1990; Reilly and Fiedler, 1994), whilst in the southern California Bight, distribution has been related with the bottom relief (Hui, 1979). In the North-East Atlantic, Forcada *et al*. (1990) related the distribution of common dolphins to cool waters, and reported a bimodal distribution in relation to depth. Only rarely has common dolphin habitat preference been considered in the context of ‘intrinsic’ factors. Cockroft and Peddemors (1990) linked the distribution and movements of common dolphins along the south-east coast of South Africa with their feeding on the annual Natal ‘sardine run’, suggesting that females may use the migration to wean their young and replenish reserves before their next pregnancy. An attempt to describe the distribution of common dolphins in relation with some environmental variables in the North-East Atlantic was recently carried out based on the data collected by the NASS, SCANS and MICA surveys (Cañadas *et al*. in press).

This lack of information on the habitat preferences and usage of common dolphins in the Mediterranean represents an important handicap for effective common dolphin conservation. Recent developments in spatial modelling provide a potentially powerful tool for examining habitat preferences (e.g. Cañadas *et al*. 2005, and see IWC, in press). However, as noted by Cañadas *et al.* (in press) who examined some aspects of the distribution of common dolphins (including school size as well as density) in relation to some geographical, oceanographic and bathymetric variables in the North-East Atlantic, such an approach (indeed any approach) is necessarily data hungry. Lack of appropriate data precluded them undertaking any rigorous spatial analysis.

The present dataset is probably the most extensive on common dolphins for any region of Europe. This chapter begins to explore the habitat preferences of common dolphins in the study area using the results from Chapter 8, and in particular further examines certain ‘intrinsic’ factors such as presence of calves, interspecific relationships and behaviour. It constitutes therefore a more in-depth investigation of the habitat preference of common dolphins in the study area than that presented in Chapter 6. This is the first time such an investigation has been carried out for a cetacean species using a spatial modelling approach. It is an exploratory study to examine whether these intrinsic factors may affect distribution, not to develop any cause-effect relationships.

9.2. METHODS

The methods for data collection and data analysis are the same as in Chapter 8. The same process was used to model the habitat use of common dolphins as for modelling the abundance, but the datasets were stratified in a different way, to explore the effect of ‘intrinsic’ parameters on the spatial-temporal distribution patterns of the dolphins. For this reason, spatial and temporal differences in group size, presence of calves and behaviour were explored as a previous step to the spatial modelling.

Differences were explored in terms of (a) geographic areas, (b) months, (c) seasons (summer = June to September; winter = October to May), (c) years, (d) behavioural categories (those defined in

Chapter 3, namely feeding/foraging (F), milling (M), socialising (S), resting (R) and travelling (T)), and (e) depth ranges (classified as: 0-200 m (continental shelf), 200-500 m (upper slope), 500-1000 m (medium slope), 1000-1500 m (lower slope) and more than 1500 m (plain)). Animals were classified as calves when their body size was equal or smaller than 75% the body size of the accompanying adults.

Non parametric tests (Kruskal-Wallis and Mann-Whitney) were used to investigate if there were significant differences in group sizes and presence of calves among different areas, seasons, and other parameters. A Kolmogorov-Smirnov two sample test was used to test differences between distributions.

For the spatial analysis, only summer months were used in order to avoid any confounding seasonal effect. All years were pooled together, and the following ten subsets were created: according to a) behaviour (as defined above); b) groups with or without calves; c) single species groups and mixed species groups with striped dolphins; and d) socialising single species groups and socialising mixed species groups.

9.3. RESULTS

9.3.1. Effort and sightings

A total of 37,385km was surveyed on effort between 1992 and 2004 in the study area during the summer. A total of 762 sightings of common dolphins within the truncation distance were made while searching on effort during these months. A total of 7,533km were surveyed on effort during the winter. A total of 96 sightings of common dolphins within the truncation distance were made during these months.

9.3.2. General patterns

9.3.2.1. Group sizes

A total of 897 sightings of common dolphins (including those discarded after right truncation for estimating the detection functions) were used for the analysis of group size. No significant differences in group size were found according to effort type. Overall mean group size was 65.7 (SE = 3.53, 95%CI = 58.8 - 72.6) with median=30, ranging from 1 to 1000 animals.

Over the whole area average group size was larger during summer than during winter (U=30,197.5 p<0.00001) (Table 9.1). Differences were significant among months (H=39.08, p<0.0001), July, August and September having larger median group sizes than the other months.

Average group size was significantly larger in summer then in winter (H=15.59, p=0.0036) in Southern Almería. There were no significant differences among areas during winter, although average group size was still larger in Almería (Table 9.2). Average group size was fairly consistent across years for each area during summer. Nevertheless, statistically significant differences in the median were found for two groups of years in the Gulf of Vera: 1992-95 against 1996-2004 ($median_{92-95}$=40, $median_{96-04}$=20, U=797.5, p=0.0013). No differences were found among years for the other areas. No differences were found for any area in winter.

Group size was generally larger in groups with calves, with significant differences, both during the summer (U=17,298, p<0.00001) and winter (U=1,736.5, p<0.00001) (Table 9.3). Table 9.4 shows the summary statistics for the group sizes by behavioural category and by season. During summer, average group size was larger when the animals were socializing (H=43.2721, p<0.00001). Group size when feeding was significantly larger than when milling (U=2,932.5, p<0.001) and when travelling (U=14,421, p<0.01). During winter, no differences were found in group size between different behavioural categories, except that groups feeding were significantly larger than groups travelling (U=367.5, p<0.01). No socialising was observed during winter.

Group size differed over depth ranges in summer (H=27.17, p<0.0001), with larger groups in shallower waters (0-200 and 201-500 m) than in deeper waters (Table 9.5). No significant differences were found either between the two shallower ranges or among the three deeper ones. Smaller differences were observed in winter, with group sizes larger also in shallower waters (0-200m) (H=11.76, p<0.02).

Group size did not vary by time of day, in any season, depth range or behavioural category.

Table 9.1. Summary statistics for group size by month and season (S = summer, W = winter).

	Month							Season	
	1	4	6	7	8	9	11	S	W
N	17	40	96	285	196	207	56	784	113
Median	10	15	20	30	37.5	30	20	30	15
Minimum	1	1	1	1	1	1	1	1	1
Maximum	50	80	400	600	1000	500	500	1000	500
Mean	13.3	22.7	39.0	73.4	87.6	63.5	50.7	70.1	35.1
Standard Deviation	14.28	20.39	59.52	105.96	144.51	87.79	96.24	109.27	70.51
Standard Error	3.46	3.23	6.08	6.28	10.32	6.10	12.86	3.90	6.63

Table 9.2. Summary statistics for group size by area and season.

	Summer				Winter			
	Gibraltar	Alborán W	Almería	Vera	Gibraltar	Alborán W	Almería	Vera
N	28	260	291	105	3	40	126	35
Median	37.5	25	40	30	9	15	20	15
Minimum	2	1	1	1	8	1	1	1
Maximum	200	600	1000	300	12	140	500	120
Mean	59.6	59.1	99.4	48.2	9.7	23.6	44.4	27.1
Standard Deviation	64.48	87.15	146.31	52.63	2.08	25.81	81.07	26.67
Standard Error	12.19	5.40	8.58	5.14	1.20	4.08	7.22	4.51

Table 9.3. Summary statistics for group size in groups with presence or absence of calves by season.

	Summer		Winter	
	CALVES	NO CALVES	CALVES	NO CALVES
N	311	409	26	77
Median	60	15	30	12
Minimum	3	1	6	1
Maximum	1000	200	500	70
Mean	112.4	23.4	76.9	18.0
Standard Deviation	141.94	26.79	132.40	17.11
Standard Error	8.05	1.33	25.97	1.95

Table 9.4. Summary statistics for group size by behaviour and season. F=feeding, M=milling, S=socialising, T=travelling, R=resting.

	Summer					Winter				
	F	M	S	T	R	F	M	S	T	R
N	73	116	85	505	5	17	14	0	75	4
Median	50	24.5	80	26	25	30	21		15	8
Minimum	2	1	3	1	3	6	1		1	4
Maximum	350	400	600	1000	200	500	200		200	35
Mean	67.4	42.2	129.5	66.1	59.0	88.8	46.4		23.2	13.8
Standard Deviation	66.56	65.71	131.81	115.07	81.97	156.77	59.30		59.30	14.66
Standard Error	7.79	6.10	14.30	5.12	36.66	38.02	15.85		6.85	7.33

Table 9.5. Summary statistics for group size by depth ranges (m) and season.

	Summer					Winter				
	0-200	200-500	500-1000	1000-1500	1500-2500	0-200	200-500	500-1000	1000-1500	1500-2500
N	283	177	239	70	15	52	24	25	9	3
Median	40	40	22	27.5	20	25	15	15	6	12
Minimum	1	1	1	1	1	1	1	1	3	1
Maximum	1000	600	400	250	80	500	500	80	50	12
Mean	84.9	97.7	43.8	41.0	21.4	46.4	40.2	17.2	15.3	8.3
Standard Deviation	128.70	132.64	63.32	49.00	20.18	76.25	99.82	17.87	17.55	6.35
Standard Error	7.65	9.97	4.10	5.86	5.21	10.57	20.38	3.57	5.85	3.67

9.3.2.2. Spatial analysis

Abundance of groups

The most important covariate for the abundance of groups in the models (Table 8.5) for the large datasets (Alborán-Vera and Almería-Vera), both during summer and winter, was sea surface temperature (sst), with a clear preference for cooler waters (Figure 8.5). The other important covariate in these datasets was one of the depth group. Very often these covariates were selected as an interaction term between both. The general trend was for larger abundance of groups towards the West and for bimodality, with a peak around the shelf break and another one in deep waters around 1000 m depth (Figures 8.11 and 8.12). The same pattern was observed in winter for the Almería-Vera area (Figure 8.17).

In the models of abundance of groups for the smaller datasets, sst was not selected. Nevertheless, average chlorophyll concentration was selected in the three models of the Western Alborán dataset, with a strong increase in abundance towards areas of higher chlorophyll concentrations. It was also selected in the model for Southern Almería in 1999. In this case, this covariate was not significant according to the p-value, but its inclusion increased the percentage of deviance explained and reduced the GCV, and therefore it was retained. The commonest covariate selected in the model of abundance of groups for all three small areas, including winter, was one from the depth group. Again the trend was for bimodality (Figures 8.5 and 8.13), except in the Gulf of Vera (Figure 8.14) and in Southern Almería in 1999 (Figure 8.15d), where only one peak of higher density was predicted in deep waters in both cases.

Group sizes

When modelling the group sizes, the commonest covariate selected was one from the depth group, usually distance from coast (Table 8.5). In all surface maps of estimated group size, there was invariably a clear trend for larger group sizes at the edge of the continental shelf, and especially in the Southern Almería area (Figures 8.11 to 8.10), as was already described in Cañadas *et al*. (2005). There is also sometimes a second peak, much smaller than the first one, around depths of 1000 m, giving a bimodal shape to the predicted distribution of group size, as for the density of groups. In the two datasets for Western Alborán, the first scattering layer was selected in the models of group size, with increasing group size towards areas of increasing detected presence of scattering layer.

Abundance of animals

In general, the bimodal pattern is also reflected in the predicted distribution of abundance of animals, with higher densities around the shelf edge, and a second peak in deep waters. The exceptions are Southern Almería in 1999 (Figure 8.13f) and the Gulf of Vera (Figures 8.14c and f), where there is a higher abundance of animals in deep waters. The tendency for there to be higher abundance towards the west, and a second peak in Southern Almería, is clearly reflected in most cases. There is very low density predicted in the Gulf of Vera, decreasing northwards from Almería (Figures 8.11 to 8.17)

9.3.3. 'Intrinsic' factors

9.3.3.1 Presence of calves

Calves were observed in 41% of the groups in which the presence or absence of calves could be determined (Figure 9.1). The proportion of groups with calves was significantly larger during the summer months than during the winter months (χ^2=10.4, df=1, p=0.0013). On the other hand, no differences were observed among the areas in any season. There were no differences in the proportion of groups with calves among years. The proportion of groups with calves varied with depth, with the highest proportion in shallower waters (0-200 m) (χ^2=26.5, df=4, p<0.0001). The proportion of groups with calves also varied with behaviour. There were significantly more groups with calves in feeding and socialising groups (χ^2=25.4, df=4, p<0.0001), while there were no differences in travelling, milling or resting groups.

The variables retained in the two steps of the model for each dataset are shown in Table 9.6.The shapes of the functional forms for the smoothed covariates retained by the final models for each dataset are plotted in Figure 9.2 at the end of the chapter. Figure 9.3 shows the surface maps of group size, abundance of groups and abundance of animals for groups with and without calves. Groups with calves clearly tend to prefer more coastal waters and groups without calves deeper waters. In both cases, however, a second smaller peak of abundance can be observed in deep and coastal waters respectively (Figures 9.3a and d respectively). The model of abundance of groups with calves selected the interaction between depth and longitude, while the model for abundance of groups without calves selected the sst (with a strong increase towards the coolest waters), the depth (its logarithm) and one of the variables of the bottom physiography group (CI -contour index-). These last two variables are negatively correlated; even so, the inclusion of both covariates improved the model fit.

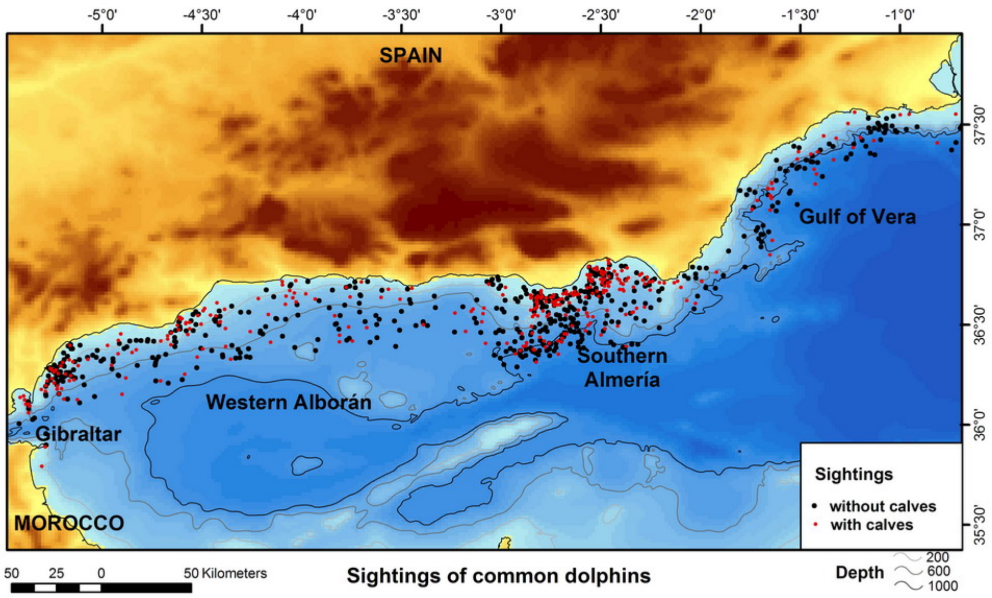


Figure 9.1. Sightings of groups with (red dots) and without calves (black dots).

In the models of group size for groups with no calves, none of the explanatory variables were significant. For groups with calves, sst, depth (its logarithm) and CI were again selected, favouring depths around the shelf edge (with moderate CI) and moderate sst, which are found in the central part of the study area (mainly in Southern Almería and Málaga) (Figure 9.3b).

The abundance of animals in groups with calves was highest around the shelf edge in the western half of the Alborán Sea, with a second smaller concentration off Southern Almería (Figure 9.3c). The abundance of animals in groups without calves obviously follows the same pattern as the abundance of groups, with higher density in deep waters and towards the west (Figure 9.3e).

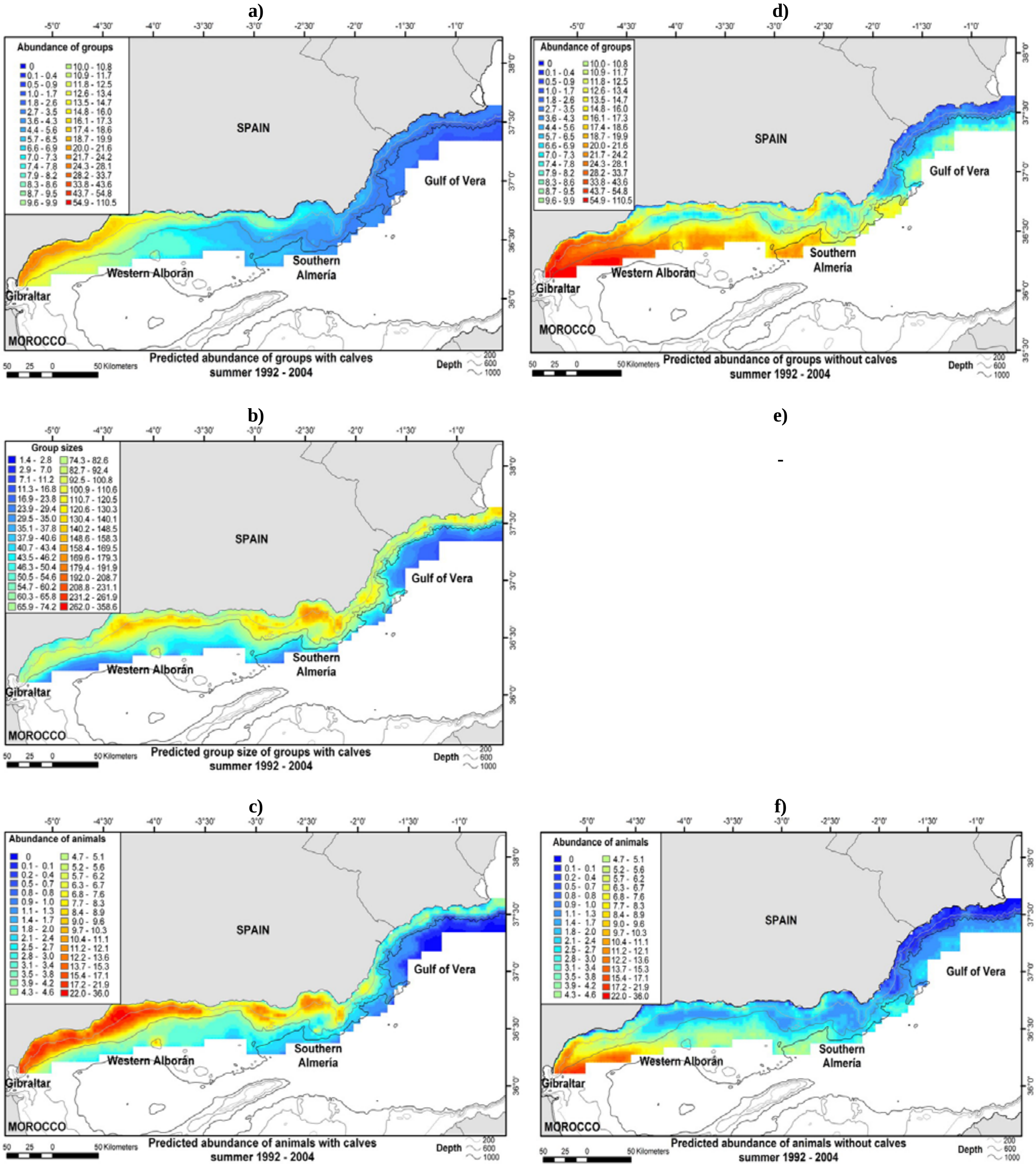


Figure 9.3. Surface maps of estimated abundance of groups, estimated group sizes and estimated abundance of animals for groups with calves (a, b and c respectively) and groups without calves (d, e and f respectively). The predicted values for abundance of groups are multiplied by 100 to facilitate the plotting.

9.3.3.2. Single and mixed species groups

Common dolphins were found in mixed species groups with striped dolphins in 22% of the sightings (Figure 9.4). There were no differences in the proportion of mixed groups encountered by month (χ^2=12.4, df=6). On the other hand, there were highly significant differences depending on behavioural category (χ^2=35.6, df=3, p<0.001), with a much larger proportion of mixed species groups when socialising and smaller when feeding. There were no differences in the proportion between Gibraltar, W Alborán, Southern Almería and Vera (χ^2=1.4, df=3). There were highly significant differences in the proportion of mixed groups with respect to depth (χ^2=64.3, df=4, p<0.001), with a clear increase towards the deeper ranges. The average group size of common dolphins was not significantly different between single and mixed groups, neither considering all sightings together nor stratified by areas, months or depth ranges, except for significantly larger group sizes in mixed groups in shallow waters (0 – 200 m). There were no differences in the proportion of groups with calves for single or mixed groups.

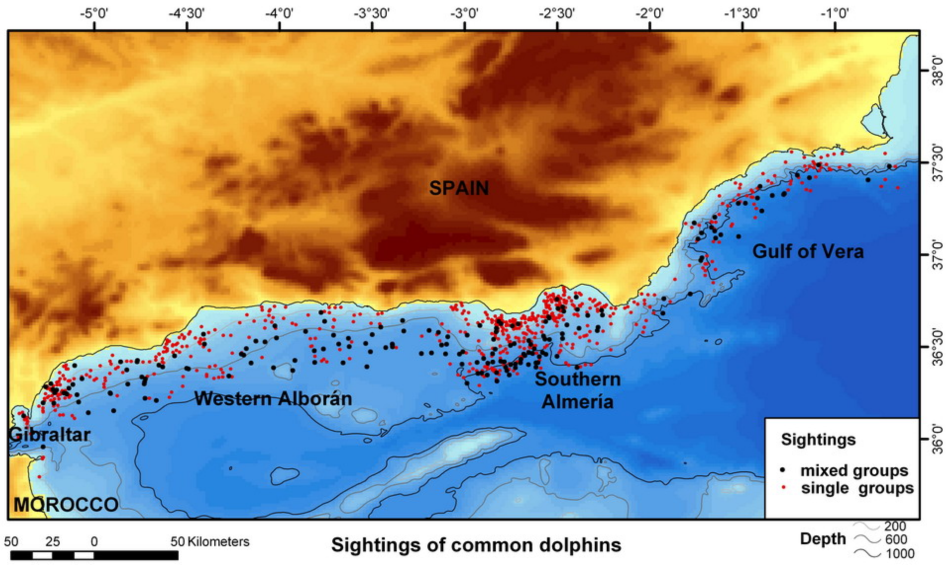


Figure 9.4. Sightings of single (red dots) and mixed (black dots) species groups.

The variables retained in the two steps of the model for each dataset are shown in Table 9.6.The shapes of the functional forms for the smoothed covariates retained by the final models for each dataset are plotted in Figure 9.5 at the end of the chapter. Figure 9.6 shows the surface maps of abundance for single and mixed species groups. A clear difference is observed when comparing the surface maps of abundance of groups (Figures 9.6a and d respectively). There is a higher density of single species groups in the western part of the study area, and some bimodality in the rest of the area, being more abundant in coastal waters and secondarily in the deepest ones. This pattern was the most similar to the general one counting only with 'extrinsic' factors. Mixed groups, on the contrary, showed a marked tendency of higher density towards the deepest waters in the whole study area.

The surface maps of group size are more similar, with larger predicted group sizes around the shelf edge in both cases, but more concentrated off Southern Almería and with a lighter second peak in deeper waters in the case of single species groups (Figures 9.6b and e). In both models the selected variables were: the CI (with intermediate values, corresponding to the shelf edge, favouring larger group sizes) and one of the group of depth (depth and distance from coast), with increasing group sizes towards shallower waters (closer to the coast). But in the model of single species groups, longitude was also selected, favouring larger group sizes for the longitudes corresponding to Southern Almería (Figure 9.5).

In the resulting surface maps of abundance of animals (Figures 9.6c and f), single species groups followed the general pattern of higher densities around the shelf edge off Southern Almería but mainly towards the western part of the area, while there were higher densities of animals in mixed species groups in the deep waters off Southern Almería, and in the whole western part of the study area. In the westernmost section, however, the higher density occurs also around the shelf edge. In the mixed species groups, there was a strong contrast between the patterns of density of groups and of group sizes. The proportion of common dolphins in the mixed species groups decreases towards deep waters (Figure 9.6g).

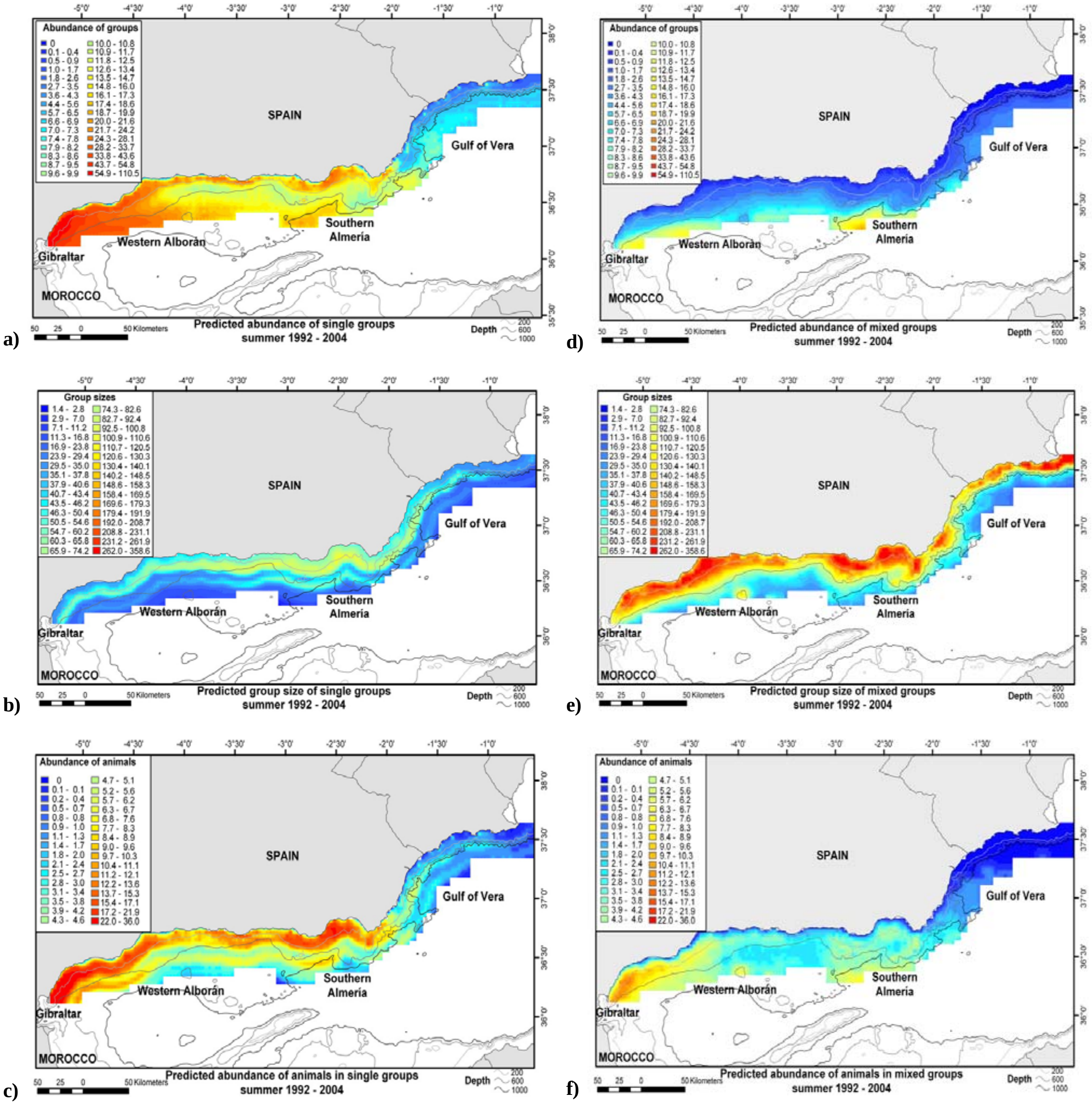
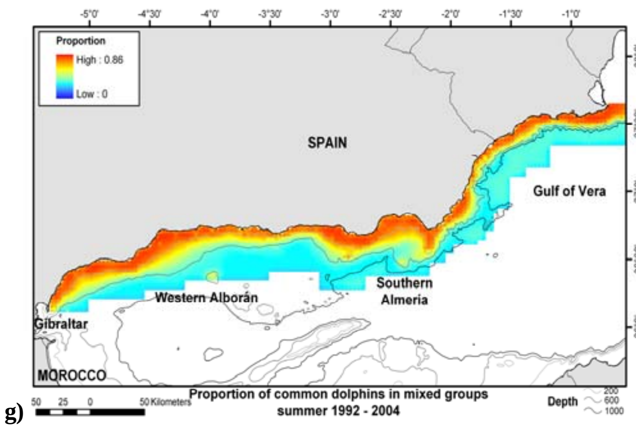


Figure 9.6. Surface maps of estimated abundance of groups, estimated group sizes and estimated abundance of animals for (a, b and c) single species groups and (d, e and f) mixed species groups with striped dolphins and (g) surface map of proportion of common dolphins in mixed groups. The predicted values for abundance of groups are multiplied by 100 to facilitate the plotting.



9.3.3.3. Behaviour

In 66% of the groups encountered, the animals were travelling, while in 9.2% of the groups the animals were feeding, in 9.8% they were socialising, in 15% they were classified as milling, and in 1% they were resting (Figures 9.7 and 9.8). This last category was excluded from the spatial analysis due to its small sample size. 'Milling' was also excluded because it is a very loose category, in which we do not really know what the dolphins are doing or the purpose of their behaviour. In some cases it may mean that they are feeding or foraging (even if prey are not observed) or socialising (underwater, with no specific aerial behaviour), making it possibly a mixture of several behavioural states, and therefore much more difficult to interpret. There were significant differences in the proportion of the different behavioural categories amongst months (χ^2=51.1, df=18, p<0.0001). These differences were due mainly to the lack of socialising behaviour during the winter months. Highly significant differences were found in the proportion of behavioural categories with respect to depth (χ^2=81.1, df=12, p<0.0001). Travelling increased towards deeper waters, whilst feeding decreased. The largest differences were due to the large proportion of feeding behaviour in shallow waters (0 – 200 m), and the lack of it in the deeper areas (more than 1500 m).

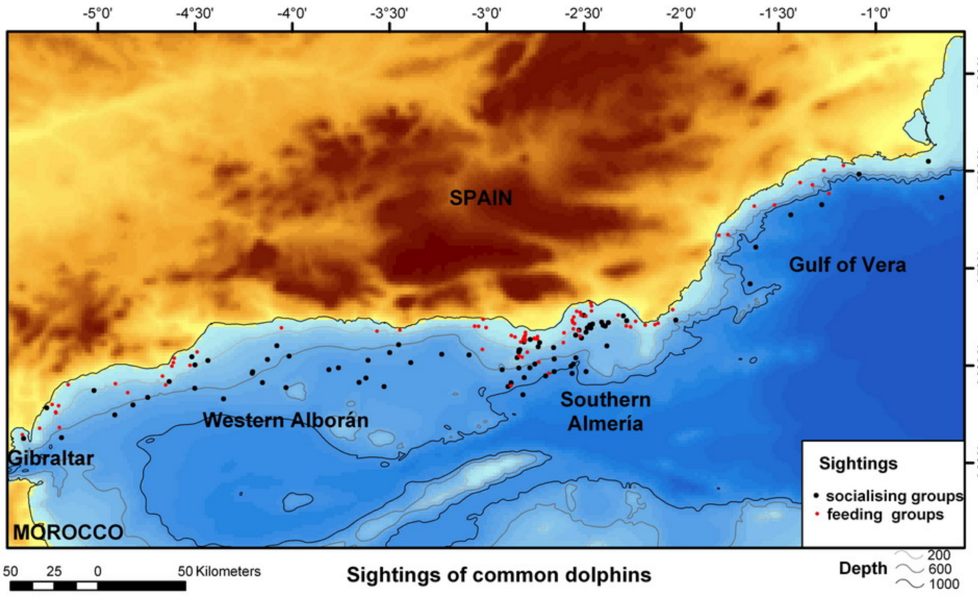


Figure 9.7. Sightings of feeding (red dots) and socialising (black dots) groups.

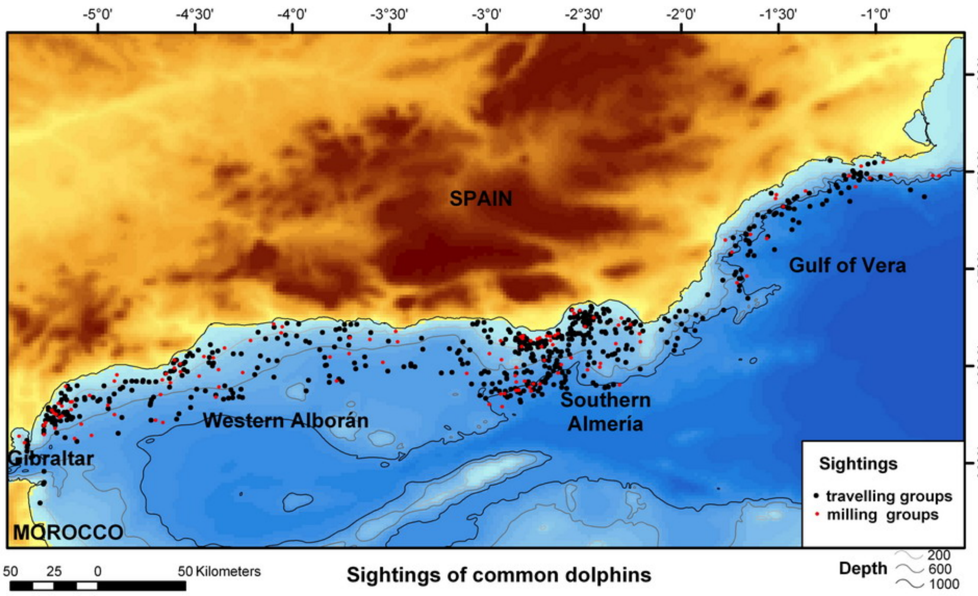


Figure 9.8. Sightings of milling (red dots) and travelling (black dots) groups.

The variables retained in the two steps of the model for each dataset are shown in Table 9.6.The shapes of the functional forms for the smoothed covariates retained by the final models for each dataset are plotted in Figure 9.9 at the end of the chapter. Figure 9.10 shows the surface maps of abundance for different types of behaviour. The largest difference was observed between groups feeding and groups socialising (Figures 9.10a and f respectively). While the largest abundance of groups feeding occurred in the most coastal areas, groups socialising occurred mainly in the deep waters, although a second much weaker concentration is shown around the shelf edge. Groups travelling (Figure 9.10c), had typical distribution patterns as when dealing only with 'extrinsic' factors, with the highest densities towards the western portion, and some bimodality, although with higher density towards deep waters. All models selected the same variables: sst (with increasing density towards cooler waters) and one of the depth group, as an interaction term (Figure 9.9). In the functional form for groups feeding, the uni-modal pattern can be observed, while the bimodal pattern is reflected in the plots for the other categories (Figure 9.9).

Figure 9.11 shows the surface maps of predicted abundance for single and mixed species groups socialising. There are no large differences, although socialising mixed groups are predicted with extremely low density close to the shore (except in the westernmost end) while the prediction for socialising single groups extends towards the coast in the area of Malaga. In both cases there is no bimodality (Figures 9.11 a and d respectively). Both models selected similar variables: depth (its logarithm) and sst or longitude (Figure 9.9).

In the models of group size for groups feeding, none of the variables were significant. In the other models, a variable of the depth group was selected (Figure 9.9) predicting larger group sizes around the shelf edge in both cases (Figures 9.10d and g). A second variable was also selected: sst for groups travelling and longitude for groups socialising, in both cases predicting larger group sizes in the area off Southern Almería, extending towards the west. In the cases of single and mixed species group socialising, both models selected distance from the 200 m depth contour (with larger groups sizes closer to this contour) and also longitude in the case of single species groups socialising, predicting again larger group sizes off Southern Almería and Granada towards the west (Figure 9.9).

For the dataset of groups feeding, the abundance of groups was multiplied by the mean group size of that dataset to give a surface map of abundance of animals, which is, therefore, identical in shape to the map of abundance of groups (Figure 9.10b). Animals travelling followed the general pattern of higher densities towards the west and around the shelf edge, with a second smaller peak in deep waters (Figure 9.10e). As in the case of mixed species groups, there was a strong contrast between the patterns of abundance of groups and of group size in socialising groups, yielding an even stronger bimodal pattern (Figure 9.10h), with more groups but smaller in deep waters, and less groups but larger in shallow waters. This bimodality in socialising groups was not apparent when stratifying them into single and mixed species groups, although the differences between both maps are not too strong: higher density of socialising animals in single groups along the shallow waters of the shelf edge, and higher density of socialising animals in mixed groups in deeper waters but mainly to the west (Figures 9.11c and f).

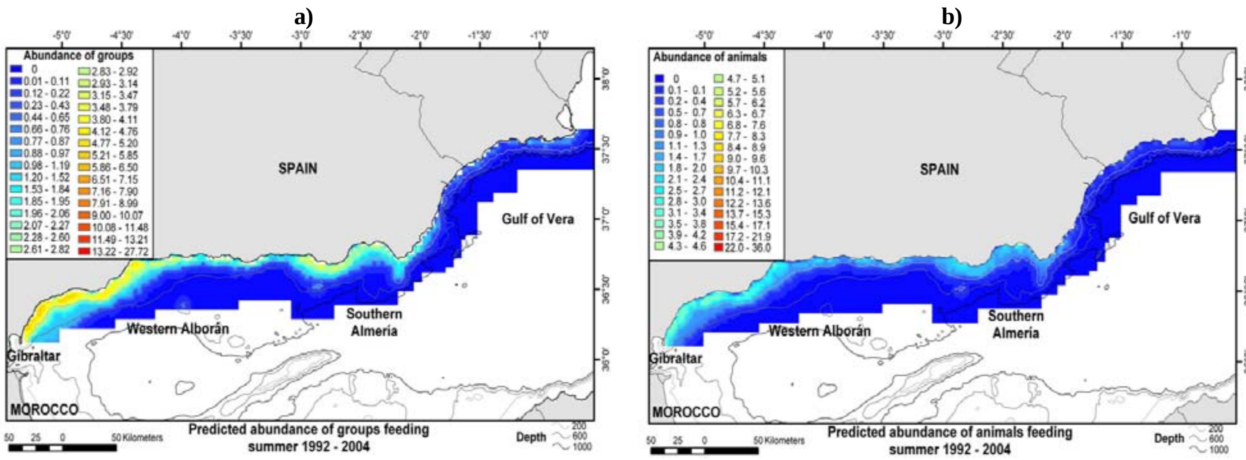


Figure 9.10. Surface maps of (a) estimated abundance of groups and (b) estimated abundance of animals for groups feeding. The predicted values for abundance of groups are multiplied by 100 to facilitate the plotting. The scale for the predicted abundance of groups travelling is different than for the other behavioural categories.

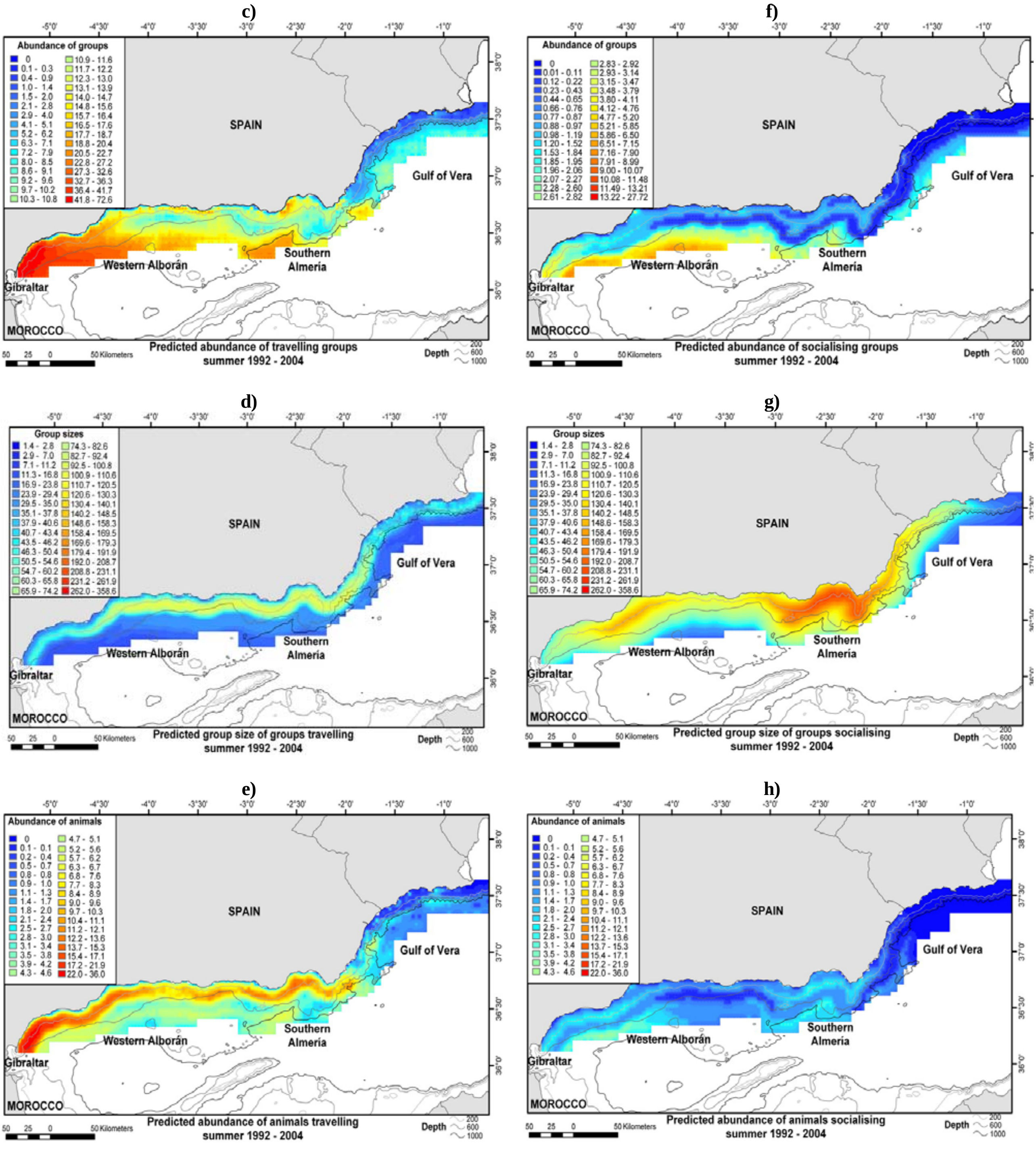


Figure 9.10 (continuation). Surface maps of (c and f) estimated abundance of groups, (d and g) estimated group sizes and (e and h) estimated abundance of animals for groups travelling (c, d and e) and groups socialising (f, g and h). The predicted values for abundance of groups are multiplied by 100 to facilitate the plotting. The scale for the predicted abundance of groups travelling is different from the other behavioural categories.

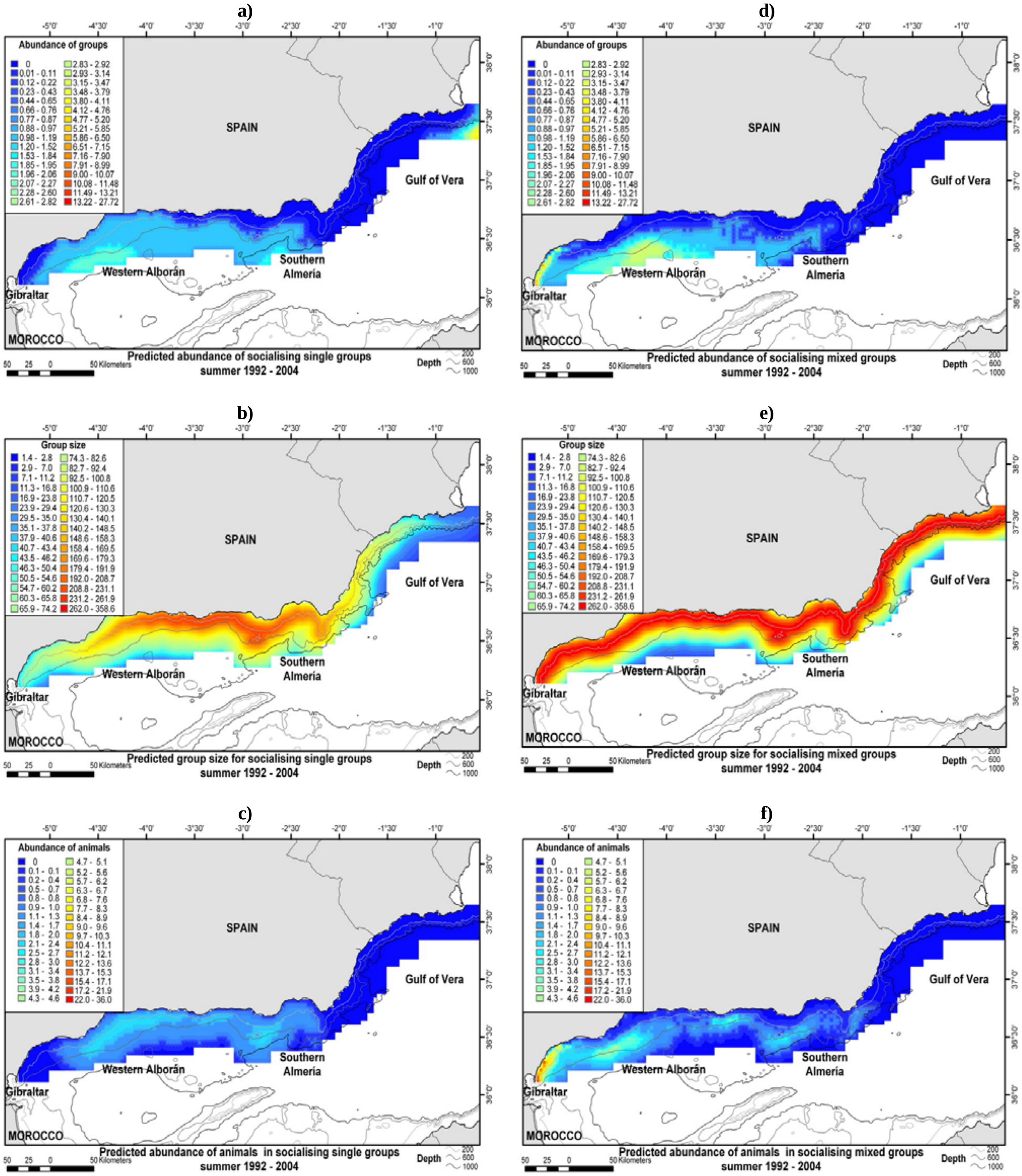


Figure 9.11. Surface maps of (a and d) estimated abundance of groups, (b and e) estimated group size and (c and f) estimated abundance of animals for single species groups socialising (a, b and c respectively) and mixed species groups socialising (d, e and f respectively). The predicted values for abundance of groups are multiplied by 100 to facilitate the plotting.

Table 9.6. Model results for all the datasets analysed. For each row, the two models are shown (abundance of groups and group size), indicating the variables (':' indicates an interaction between two variables) retained in the best model (estimated degrees of freedom in parentheses: 1 means a linear relationship), and the percentage of deviance explained by the model. The variables are abbreviated as follows: lon = longitude, lat = latitude, depth = depth of the sea floor, logdepth = logarithm of depth, slope = slope of the sea floor, dist200 = distance to the 200 m depth contour, dist1000 = distance to the 1000 m depth contour, distcoast = distance to the coast, sddepth = standard deviation of depth, cvdepth = coefficient of variation of depth, ci = contour index, tav = annual sst average, tavv = summer sst average, cavv = summer chlorophyll concentration average, cavi = winter chlorophyll concentration average (numbers behind all sst and chl variables indicate years on which the average was calculated, e.g. 0004 = 2000 to 2004), g(y,v) = conditional probability of detection (always as a linear predictor). Variables are ordered from more to less significant according to their p-value in the final model.

Subset	Model	Variables	% Deviance explained
Presence of calves			
With calves	Groups	depth:lon (4.8)	4.5
	Group size	distcoast (5.5) + tavv9804 (3.3) + g(*y*,*v*)	18.8
With no calves	Groups	tavv9804 (1.7) + logdepth (4.3) + ci (3.3)	7.6
	Group size	-	
Single and mixed groups (with striped dolphins)			
Single groups	Groups	tavv9804:logdepth (11.6)	7.4
	Group size	distcoast (7.6) + lon (2.1) + ci (3.6) + g(*y*,*v*)	17.2
Mixed groups	Groups	logdepth:lat (5.1)	9.1
	Group size	depth (2.2) + ci (2.3) + g(*y*,*v*)	25.6
Proportion of common dolphins in mixed groups	Proportion	depth (2.7)	29.4
Behaviour			
Travelling	Groups	tavv9804:logdepth (11.3)	7.2
	Group size	distcoast (5.5) + tavv9804 (3.3) + g(*y*,*v*)	18.8
Feeding	Groups	tavv9804:logdepth (5.0)	9.4
	Group size	-	
Socialising	Groups	tavv9804:dist200 (5.6)	5.2
	Group size	lon (4.9) + dist200 (1) + g(*y*,*v*)	28.1
Socialising single groups	Groups	lon (5.3) + depth (1)	5.2
	Group size	lon (3.0) + dist200 (1) + g(*y*,*v*)	32.5
Socialising mixed groups	Groups	tavv9804:logdepth (10.8)	13.0
	Group size	dist200 (1) + g(*y*,*v*)	21.2

9.4. DISCUSSION

9.4.1. General patterns

In the models for the large datasets (Alborán-Vera and Almería-Vera) there is a clear strong gradient in abundance of groups towards the west, following the negative gradient in sst (Figure 9.10), especially around the shelf edge. In the models of the smaller datasets, sst was not selected probably due to a smaller contrast in mean sst within such small areas. In the Western Alborán, the chlorophyll concentration shows strong contrasts due to the presence of the Western Alborán gyre, an anticyclonic current of cooler and more productive waters coming from the Atlantic (Figure 9.10; see Chapter 2 and references within), which can explain the strong increase in density towards areas of higher chlorophyll concentrations in the three models of the Western Alborán dataset. In the other small areas (Southern Almería and Gulf of Vera), the contrast in chlorophyll concentration within the area is small. Group sizes were in general larger around the shelf edge, and especially off Southern Almería, despite the higher productivity in Western Alborán. This is probably due to different distribution patterns of the prey. It is believed that the formation of large groups would benefit predation on large patches of prey, where prey is abundant enough for each member of the group to profit (Neumann 2001). If the prey is distributed in many small patches, it is probably more efficient for the dolphins to split in smaller groups. Unfortunately, no information is available on the level of 'patchiness' of possible prey in Western Alborán and Southern Almería, in order to test if this could be a main reason for the presence of large number of groups with moderate average group size in Western Alborán, and the smaller number of larger (on average) groups off Southern Almería. The scattering layer, selected in the models of group size for Western Alborán, is an indication of high density of biomass (either zooplankton or small fish), which is especially intense in Western Alborán due to its very high productivity. It is not surprising then, that common dolphins concentrate in areas with more biomass under the surface.

There is no information on the diet of common dolphins in the study area, except for direct observations of feeding behaviour by the research team. During these observations, when the target prey species could be identified, it was either common sardine (*Sardina pilchardus*), round sardinella or guilt sardine (*Sardinella aurita)* or needle fish (*Belone belone*). According to other studies around the world, this species appears to be an opportunistic feeder (Klinowska, 1991; Young and Cockcroft, 1994; Gannier, 1995), targeting mainly small, neritic, epipelagic fish, especially of the Clupeidae family and some of the Gadidae family, as well as a small amount of cephalopods (Young and Cockcroft, 1994; Kenney *et al*., 1995; Cordeiro, 1996; Santos *et al*., 1996). Most of the small epipelagic fish, but especially the sardines, have distribution patterns strongly linked to high productivity areas, as they feed mainly on zooplankton (Lotina 1985a). In the study area, the inflow of Atlantic water and its associated currents create important upwellings of high productivity (with higher chlorophyll concentrations and cooler sst), especially along the coastal waters of the Western Alborán area and, at a lesser extent, in Southern Almería (Rubín *et al*. 1992; see Chapter 2). Furthermore, there is an area of very high productivity off Southern Almería, north of the sea mount "Seco de los Olivos", which is apparently not caused by the Atlantic inflow but by an *in situ* effect due to the topography (Rubín *et al*. 1992; Rodriguez *et al*. 1994). The type of fish mentioned above tend to aggregate in these high productivity areas (Gil 1992). The variables selected in the models, and their functional forms, seem to go to in accordance with this. The strong influence of these oceanographic features on the distribution patterns and relative density of common dolphins in the area is discussed in more detail in Cañadas *et al*. 2005 (Chapter 5).

In the Gulf of Vera both the density of groups and the predicted groups sizes were much smaller than in the neighbouring area of Southern Almería. The influence of the inflow of Atlantic water is much smaller here (Díaz del Rio 1991), as most of it runs along the so-called Almería-Oran front towards the Algerian coast of North Africa (Millot 1985; Tintoré *et al*. 1988), leaving the Gulf of Vera with most typical 'Mediterranean' oceanographic characteristics, much poorer than the Alborán Sea (Díaz del Rio 1991). On the other hand, the continental shelf in this area is extremely narrow. The density of sardines in this area is lower than in the Alborán Sea (Abad *et al*. 1987; Gil 1992), probably mostly due to the reasons mentioned above. Therefore, it is possible that common dolphins in this area rely more on prey species other than sardines, or other neritic epipelagic small fish, and hence show a different distribution pattern with the peak of density of groups in deep waters. When the density of common dolphins declined in this area, their distribution pattern also moved towards even deeper waters (Figure 8.15 in Chapter 8). Unfortunately, there are no data available on distribution and density in the areas outside the study area, except for the known extremely low density of the species north of the Gulf of Vera (Universidad de Barcelona 2002; Universidad de Valencia 2002). Densities may be high in even deeper waters, as happens in the NE Atlantic, where the higher densities of common dolphins during summer occur in deep waters (Cañadas et al. 2004, Cañadas *et al*. in press; Northridge *et al*. 2004; Brereton *et al*. 2005). No information is available either on where these animals moved to and moving towards deeper water is just one option. They could also have moved to the Alborán Sea. Given the previous low density of dolphins in Vera, an 'increase' in the Alborán Sea with dolphins coming from Vera would have possibly passed unnoticed. Or they may have moved to the African coast. In any case, there has been a clear displacement of common dolphins from the Gulf of Vera, which may represent a significant adverse change in the habitat quality. This is discussed further in Chapter 8.

In 1999 there was a clear change in the distribution pattern of groups in Southern Almería. This change towards deep waters (Figure 8.14d in Chapter 8) was described and discussed in Cañadas *et al*. 2002 (Chapter 5). That specific year, a drop in sst occurred during a few days in summer, probably causing the displacement of sardines out of the area. During that summer fishermen reported that they were not catching sardines close to shore, but that they had to go to deeper waters to catch them. This is consistent with the displacement of common dolphins towards deep waters This illustrates the value of a long-term study, in which it can be seen that 1999 was an 'odd' year in comparison with the most typical situation before and after 1999. Had a short-term survey occurred just in 1999, wrong conclusions about the habitat use of common dolphins in this area could have been drawn.

The estimated density in winter is almost three times lower than that of the summer months (Chapter 8). This difference in density is because of a much smaller group size during the winter months; the density of groups is similar to that in summer. However, there is a drift in the distribution pattern during the winter months, with higher densities of groups towards deep waters, at the edge of the study area. Both common sardine and round sardinella move towards deeper waters in autumn and winter (Compán Vázquez 1984; Lotina 1985b), when the sst drops, to hibernate close to the sea bed. In spring they move again to more coastal areas to spawn, and remain over the continental shelf during summer feeding (Compán Vázquez 1984; Lotina 1985b). It is very plausible that common dolphins change their behaviour during winter, with smaller groups and moving towards deeper waters to feed on different prey. A seasonal change in group size has also been described for the southern California Bight, where mean group size drops from around 250 in summer, when anchovies are largely available, to about 40 in winter when they are not (Hui 1979). The drop in sst during summer of 1999 could have had the same effect on the sardines as the sst drop in autumn and hence the same effect on the dolphins. Both winter group size models selected the winter chlorophyll concentration and a variable from the group of depth, with larger group sizes in high chlorophyll levels, which means close to the shore, as happened during summer 1999. It is possible that the higher productivity near the coast still allows the gathering of relatively larger groups to feed in these areas when sardines are less available.

This seasonal drift in distribution is opposite to that reported for the NE Atlantic, where it has been documented that common dolphins move inshore during winter and offshore during summer (Pollock *et al*. 1997; Ó Cadhla *et al*. 2003; Northridge *et al*. 2004; Brereton *et al*. 2005). In this case it is believed that the dolphins follow the seasonal movements of the anchovy (Borja *et al*. 1998; Allain *et al*. 2001).

It has been suggested that the bimodal distribution of common dolphins observed in the North East Atlantic, could occur due to the existence of two different populations, one neritic and one oceanic (Forcada *et al*. 1990), although an age / sex segregation has also been suggested (Silva and Sequeira 2003; López 2003; V. Martin, pers. com). We explored some of the possible sources of the bimodality with respect to depth / distance from coast also observed in our study area, through the stratification of some ‘intrinsic’ parameters. This possibility of exploring not only the ‘extrinsic’ but also the ‘intrinsic’ factors that may be affecting the distribution patterns of the animals is another advantage of spatial analysis. This is discussed further below.

The variables related to human activities (level of acoustic pollution, and trawling areas) were never significant in any of the models. Common dolphins were observed around trawlers, but there does not seem to be an important interaction between them, as there is between bottlenose dolphins and trawlers (Cañadas *et al*. in press). As mentioned above, common dolphins seem to feed mainly on small epipelagic fish, while trawlers target demersal species, and in particular shrimps, so the lack of an interaction is not unexpected. Data on purse seiners targeting small pelagic fish were not available from this study because they fish at night. It would be of great interest to explore the possibilities of surveying at night (maybe by means of acoustic methods) or to obtain data on purse seine fishing effort from another source. This would allow the influence of this type of fishery on common dolphins to be investigated using spatial analysis.

The lack of significance of the acoustic pollution variable is perhaps more surprising given its reported negative effect on cetacean populations (Richardson *et al*. 1995; Gordon and Moscrop 1996). This could be for several reasons, for example: a) the acoustic pollution is not affecting the distribution of the animals because they have habituated to it; b) the noises recorded are not in the frequencies and/or intensities that disturb the dolphins strongly enough to exclude them from areas that otherwise have the appropriate qualities for them; c) the disturbance produced by the noise occurs at a scale and distances from the source that is too small to be detected by the models; d) the type of data recorded is not the appropriate to investigate the possible effect of man-made noise on the habitat use of the dolphins. More work is needed to investigate this further.

9.4.2. Effect of ‘intrinsic’ factors

When stratifying according to ‘intrinsic’ factors, more information on habitat use became available. The higher density of groups with calves nearshore could be due, at least partly, to the higher densities of small epipelagic fish in these areas. Lactating females may be concentrating on the highly nutrient prey available in this area. In the case of mixed species groups, striped dolphins are usually in deep waters, and therefore it is unsurprising that mixed groups occur with higher frequency where there are more possibilities to find striped dolphins.

The type of behaviour in which the group was engaged when encountered also seemed to influence the selection of the habitats. The largest difference was observed between groups feeding and groups socialising. As mentioned above, the main source of prey for common dolphins in this area during daylight are believed to be small epipelagic fish, the main concentrations of which are over the continental shelf and shelf edge. The lack of observations of feeding behaviour in deep waters does not mean that common dolphins do not feed on more oceanic fish or squid species as they have been reported to do in other parts of the world (Young and Cockcroft 1994, 1995: Scott and Cattanach 1998). Thismay occur during night time, when those types of prey undergo vertical migrations towards the surface. The reasons for a higher number of groups socialising in deep waters are unclear. The fact that groups travelling have the same distribution patterns as when dealing only with ‘extrinsic’ factors, is consistent with the fact that travelling must be done everywhere. For the same reasons explained above, it also makes sense that socialising mixed species groups occur mainly in deep waters, where striped dolphins are more abundant.

When stratifying according to ‘intrinsic’ factors, the most common variable selected when modelling group sizes was one from the depth group as it was without stratification. In all these models, the resulting surface maps of estimated group sizes show again a strong tendency for larger group sizes to occur in shallow waters and especially around the shelf edge. Only in the model of single groups a second slight peak appears in deeper waters. Further stratification of single species groups would probably help clarify this bimodality. In general, the larger group sizes occur in the area of Southern Almería, as determined by the variables selected in the models (longitude or sst), extending sometimes westwards towards Granada. A second longitudinal peak appears in the area of the Bay of Málaga (Western Alborán) (Figures 9.6 to 9.9). It seems that these two areas around the shelf edge off Southern Almería and off Málaga have special characteristics that favour the aggregation or large group sizes there. The reasons for such a clear and constant pattern of larger group sizes in these areas are not clear. If it only happened under certain circumstances (e.g. when feeding), then it could be suggested that there might be advantages in gathering for feeding due to the presence of large schools of fish on those areas and depths. But as it happens in all circumstances, there must be other factors, or a mixture of several, leading to the advantage of gathering into large groups around the shelf edge, regardless of activity or social structure. It would be worth exploring this issue in more depth. The sharp contrast between the distribution of abundance of groups and group sizes in mixed species groups (Figures 9.7d and e), is probably explained by the strong pattern in the proportion of common dolphins within mixed species groups (Figure 9.7g), with the largest proportions in the shallow waters, decreasing steadily towards deep waters. As common dolphins are more abundant over the continental shelf and shelf edge, and striped dolphins in deep waters (Cañadas *et al*. 2002, Cañadas *et al.* 2005; see Chapters 5 and 6), the proportion of each species in the total group size simply seems to be a function of relative density.

In general, the shelf edge areas, and especially off Málaga and off Southern Almería, seem to be the preferred habitat for this species in most situations, but mainly when feeding and when there are calves in the groups. This is so most probably because it is the main habitat for their apparently main prey species in the study area. Nevertheless, the distribution patterns and especially the bimodal situation would be worth investigating further, for example by exploring with further stratification.

Another possible cause of the observed bimodality in the abundance of groups and animals with respect to depth, besides the effect of the ‘intrinsic’ factors, could be the wind regime. As explained in Chapter 2, the wind regime alters the location of the upwellings in the Alborán Sea. Due to the Coriolis force, the wind creates a current in the surface waters, not in the same direction of the wind, but with an angle of about 45º to the right of the wind direction (Medina 1974; see Chapter 2). In the Alborán Sea, the main wind regimes are either from the West (‘Poniente’) or from the East (‘Levante’), blowing usually quite parallel to the coast. With ‘Poniente’, the current created by the wind pushes the coastal superficial waters far from the coast, creating upwellings close to the shore where the cooler and nutrient rich waters from the bottom replace the superficial waters displaced. With ‘Levante’ the opposite phenomenon occurs. The wind pushes the superficial waters towards the coast, where they sink, and the upwellings are created several kilometres away from the coast. It would not be surprising, therefore, if the wind regime affected the distribution pattern of a dolphin species whose density is so much dependent on the presence of high productivity areas, of which upwellings are one of the clearest sources. It would be interesting to explore this issue and analyse the dolphin distribution with both regimes, taking into account a possible time lag needed between the start of the winds, the creation of the upwellings and the possible reaction of the dolphins. This will be the subject of future work.

This study has shown that introducing intrinsic factors in the analysis leads to a clearer picture of how common dolphins use their habitat in the Alborán Sea. This not only improves our understanding of the ecology of the species, but should also lead to more effective conservation. Even if some patterns have been found in this work that help clarify the habitat preference of common dolphins in this area, many questions remain unanswered in terms of the reasons for such patterns. Why are there systematically larger group sizes around the shelf edge, even when the animals are not feeding? Why is there always a ‘gap’ in intermediate waters (around 300 to 600m depth) where density is lower? Why is there a larger density of groups travelling and socialising in deep waters? Why are there more but generally smaller groups in Western Alborán, and fewer but usually larger groups off Southern Almería? Why do groups with calves prefer shallower waters and groups without calves deeper waters?

9.4.3. Implications for conservation

The identification of the Alborán Sea as an 'Area of Conservation Importance' within the Mediterranean basin by the ACCOBAMS Conservation Plan for the Mediterranean Common Dolphin (Bearzi *et al*. 2994) serves mainly two purposes: (a) to promote the investigation of the relationships between the distribution and abundance of this species with its environment in this area as a case study to understand better the ecology of the species and its distribution patterns in the rest of the Mediterranean basin; and (b) to promote the development and implementation of adequate and efficient management measures aimed at maintaining a favourable conservation status of this species in this area, both to avoid a future impoverishment of the most important concentrations in the basin, and as a possible future source of recruitment for the rest of the Mediterranean when/if the causes of the negative trend are mitigated.

A large amount of knowledge has been gained on the distribution patterns of this species through the work carried out during the last 14 years in the study area. However, it is not advisable to extrapolate the results obtained for this area to other unsurveyed areas where different environmental characteristics and processes may be occurring. When comparing the Alborán Sea and the Gulf of Vera distribution patterns, it is clear that dolphins are using these two areas in a different way, even though they are geographically so close, probably due to their very different environmental features. Nonetheless, robust information obtained from one area could be used as an initial indication of the situation in other relatively similar areas. These new areas should then be studied to confirm whether similar patterns occur or not. For example, consider the recent decline in common dolphins in the area of Kalamos, in the Ionian Sea (Bearzi *et al*. 2003). This is a very shallow area where intensive surveying has been going on for more than a decade. Knowing from our study that common dolphins can have a bimodal distribution, with large number of groups in deep waters, it would be advisable to survey the deep waters (up to more than 1000 m depth) in the waters surrounding Kalamos to investigate if the decline is more a shift in distribution rather than a real decrease in total numbers. This could be a similar situation to what might be happening in the Gulf of Vera in recent years.

Based on molecular analysis, common dolphins in the Alborán Sea seem to belong to an Atlantic population, with gene flow maintained through the Strait of Gibraltar, rather than to the Mediterranean one (Natoli 2005). It seems very unlikely therefore that common dolphins from the Alborán Sea would move eastwards to 'refill' the Mediterranean basin if the conditions become adequate.

The Alborán population (or at least the common dolphins that inhabit its Northern section) have not declined during the time-frame of this study in contrast to what seems to be happening in the rest of the Mediterranean basin (see Chapter 8). Comparative studies between the Alborán Sea and other Mediterranean areas, in terms of differences and similarities of environmental features, might prove useful to help understand what has led common dolphins in the Mediterranean areas to decline or to redistribute to other unstudied areas.

Knowledge of preferred habitats for common dolphin, especially with respect to their different needs such as feeding or reproduction, is absolutely essential for effective conservation. Knowing the areas mostly used by the dolphins for feeding or with calves could lead to specific management measures for those areas, which may need special or different treatment than other areas. In this case, it seems clear that, despite the high densities of common dolphins predicted also for deep waters, the most critical areas for this species within the study area are the waters around the shelf edge, where they concentrate to feed and where the large majority of the calves are encountered. Unfortunately, this is also the area with the strongest impact from human activities: pollution from land sources, overfishing and disturbance by the intense maritime traffic of small to medium size ships. The continental shelf and shelf edge of the Alborán Sea are vulnerable in two ways: this is where the common dolphin population seems to be more vulnerable (feeding and calving grounds), and also where the marine environment is more vulnerable (stronger human impact). Therefore, despite the attempts to develop adequate management strategies for the whole Alborán Sea, some specific and priority measures should be taken targeting the conservation or restoration of the marine environment from the coast up to beyond the shelf edge (e.g. up to 400-500m depth) if conservation of the common dolphin population is to be achieved.

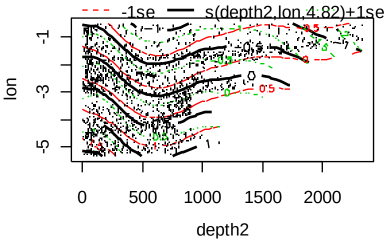
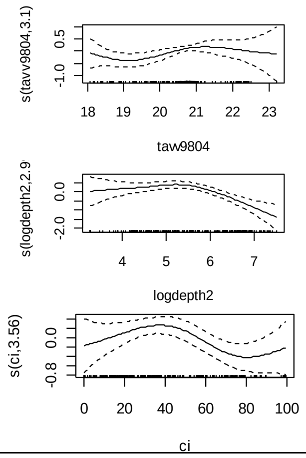
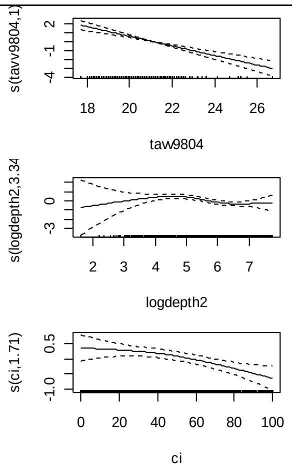
<table>
<tr><th>Subset</th><th>Abundance of groups</th><th>Group size</th></tr>
<tr><td></td><td>Presence of calves</td><td></td></tr>
<tr><td>Groups with calves</td><td>
</td><td>
</td></tr>
<tr><td>Groups with no calves</td><td>
</td><td>-</td></tr>
</table>

Figure 9.2. Shapes of the functional forms for the smoothed covariates used in the models of habitat use for groups with and without calves. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

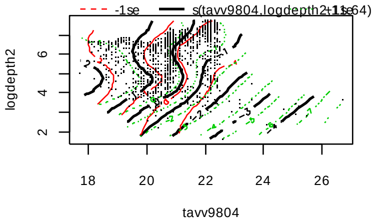
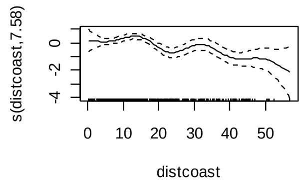
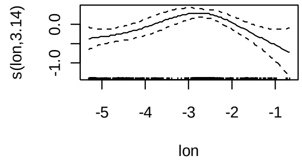
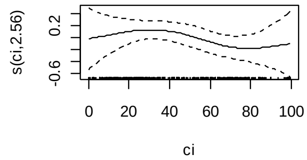
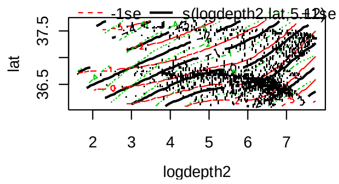
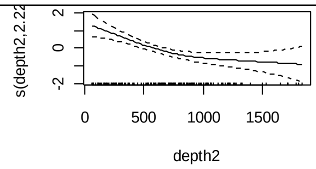
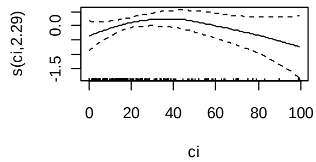
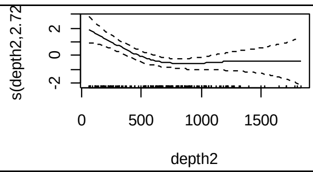
Subset	**Abundance of groups**	**Group size**
Single and mixed groups (with striped dolphins)		
Single groups		  
Mixed groups		 
Proportion of common dolphins in mixed groups		

Figure 9.5. Shapes of the functional forms for the smoothed covariates used in the models of habitat use for single and mixed species groups. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

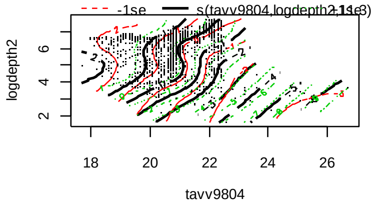
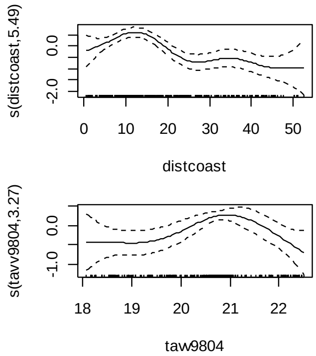
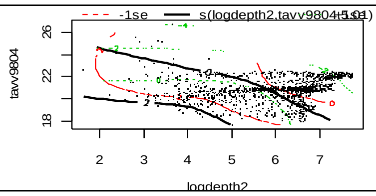
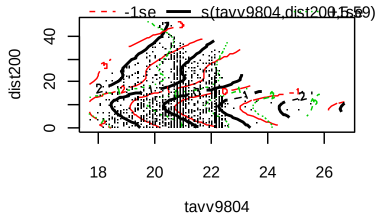
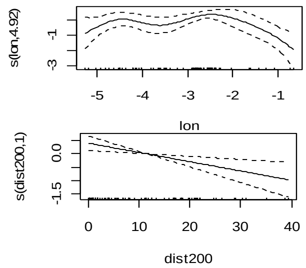
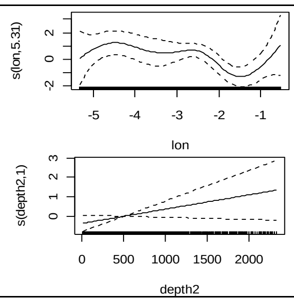
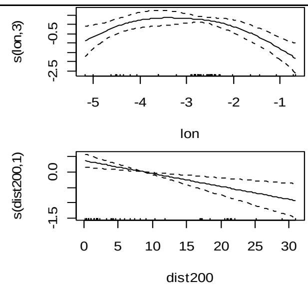
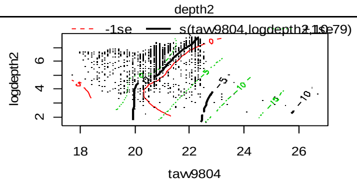
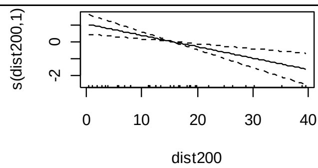
Subset	Abundance of groups	Group size
Behaviour		
Groups travelling		
Groups feeding		-
Groups socialising		
Single species groups socialising		
Mixed species groups socialising		

Figure 9.9. Shapes of the functional forms for the smoothed covariates used in the models of habitat use for different categories of behaviour. Zero on the vertical axes corresponds to no effect of the covariate on the response (group density on the left and group size on the right). The dashed lines represent twice the standard error of the estimated curve (95% confidence band). The locations of the observations are plotted as small ticks along the horizontal axes. The interactions between two variables are shown as two-dimensions plots. In these cases, the locations of the observations are plotted as small dots.

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CHAPTER 10

CONSERVATION PLAN FOR BOTTLENOSE DOLPHINS

10.1. THE CONSERVATION PLAN

One of the main objectives of this thesis was to aid the development of a Conservation Plan for bottlenose dolphins in Andalusia and Murcia, one of the main actions of the LIFE-Nature Project ‘Conservation of cetaceans and sea turtles in Andalusia and Murcia’ (LIFE02NAT/E/8610). The foundation of the Plan is the scientific information obtained during the time frame of this study on the target species (Chapters 5 to 7), and the information on human activities and possible threats in the region (Chapter 4).

It is not the aim here to develop the Conservation Plan itself as part of this thesis, but to describe the process through which it is being developed and the contribution of the work presented here. This will serve as the basis for the final development of the Plan, which must be submitted to the competent authorities (European Commission, Spanish Ministries of Environment and of Fisheries and regional governments) during the second half of 2006.

The development of a plan, either a Conservation Plan for a species, a Management Plan for an area, or any other kind of Plan, must follow a logical process taking into account all the necessary aspects for its success, from scientific information to an effective management regime. This process must take into account specified conservation objectives, the status of the animals, actual and potential threats and threats to those animals, mitigation measures to reduce or eliminate those threats, management measures, and effective monitoring and compliance schemes. The Conservation Plan for bottlenose dolphins in Andalusia and Murcia should therefore be developed according to a process which takes us from the science to the management following the steps outlined below. Some of these points are included in the Management Plans for the UK SAC in Moray Firth (Moray Firth cSAC Management Group 2003) and Cardigan Bay (Ceredigion County Council *et al*. 2001). The terms are defined later in the Chapter and, while not intuitive, follow those used in the Habitats Directive and other European Legislation.

1. **Analysis** of the situation
2. Establishment of the **Overall Conservation Objectives**
3. Definition of the **Attributes** of the target feature of the Conservation Plan
4. Definition of the **Specific Conservation Objectives** for these attributes
5. Definition of the **Indicators** and **Targets** for the attributes with respect to the conservation objectives
6. Identification of the **Threats** to the conservation objectives
7. Definition of the **Baselines** for the attributes
8. Establishment of a **Monitoring Plan**
9. Establishment of the **Actions** to be undertaken
10. Establishment of an **Action Follow-up** process
11. Establishment of how the Conservation Plan will **Function**

Although the process should try to follow the established steps in this logical order, in practice it is also necessary to consider point 6 from the beginning taking human activities one by one and establishing potential threats resulting from these activities.

10.1.1. Analysis of the situation

Before developing the main body of the Conservation Plan, it is necessary to perform a diagnosis of the situation. This analysis should be done at various levels:

- Characteristics and requirements of the species
- The conservation status of the population(s)
- The habitat of the species
- Main threats to the population(s)
- Socio-economic aspects
- The legal framework in which the Conservation Plan might be placed

- Geographic scope of the application of the Conservation Plan

10.1.2. Establishment of the Overall Conservation Objectives

Establishing overall conservation objectives is the first and most fundamental step in the process of developing a Conservation Plan.

In the present case of a Conservation Plan for bottlenose dolphins, the framework is the European Union's Habitats Directive, in which this species is listed under Annex II. While the Habitats Directive does not expressly require the establishment of conservation objectives, it 'assumes' that there will be conservation objectives for each Natura 2000 site. Not only does the Directive not require objectives, it does not specify what form they should take, or the precise role they play in the management of sites (EN *et al*. 2001). However, three general aims for the Habitat Directive have been established as statutory requirements:

(a) conservation of biodiversity (Article 2.1);

(b) maintenance or restoration of favourable conservation status of the habitats and species in Annexes I and II of the Directive (Article 2.2); and

(c) Natura 2000 network to enable the achievement of favourable conservation status (Article 3.1).

According to the *Guidelines for Developing Conservation Objectives for Marine SACs* (EN *et al*. 2001), this implies that for Natura 2000 sites 'Conservation objectives must represent a site's appropriate contribution to the achievement of favourable conservation status, and the wider goal of biodiversity conservation, based on the features for which it has been selected'.

Since this conservation plan is being developed within the Habitats Directive framework, even if the geographic scope of application is much wider than a single Natura 2000 (SAC) site, for the purpose of the Conservation Plan for bottlenose dolphins, (b) above, to *maintain* or *restore* a *favourable conservation status*, is the most appropriate.

According to Article 1(i) of the Habitat Directive, the *conservation status of a species* means the sum of the influences that act over it, and which can affect the natural abundance and distribution of its populations, in the long-term, within the European territories of the member States. According to the same Article 1(i), the conservation status will be assumed as '*favourable*' when:

- the data on the species population dynamics indicate that it is being maintained in the long-term as a viable component of its natural habitat, and
- the natural range of the species is not being reduced, and it is not probable that it will be reduced in the near future, and
- there is, and probably there will be in the future, a sufficiently large habitat to maintain its populations in the long-term

From this, we can establish two Overall Objectives for this Conservation Plan:

- to maintain, at least, the abundance of the species in the entire area covered by the Plan; and
- to maintain, at least, the distribution or level of usage of the species in the area.

These objectives must necessarily work from a baseline (see step 7 below). In most cases this will be the current situation, because of the lack of historical data to allow estimation of the distribution or abundance of the species in this region, prior to possible changes as a result of anthropogenic impacts. Thus the minimum objective is to maintain at least the present situation and, if possible, to improve it.

10.1.3. Definition of the 'Attributes' of the target 'Feature' of the Conservation Plan

Following the terminology used in previous Conservation Plans for marine species and habitats in the European Union (Ceredigion County Council *et al*. 2001; Moray Firth cSAC Management Group 2003), the 'Feature' of a plan is the species or habitat for which the plan has been developed; in this case the bottlenose dolphin.

The term ‘Attribute’ is a standard term defined by the UK Joint Nature Conservation Committee (JNCC 1998) as: ‘a characteristic of a habitat, biotope, community or population of a species which most economically provides an indication of the interest feature to which it applies’. For our purposes, then, the attributes are those characteristics of the bottlenose dolphin that provide an indication of its conservation status within the geographical scope (‘region’ from now on) of the Conservation Plan.

The “*Guidelines for Developing Conservation Objectives for Marine SACs*” (EN *et al*. 2001), states that the attributes can include ‘a combination of (a) quantitative characteristics (such as abundance or viability of a population and related characteristics such as its distribution or if its spatial occurrence is discrete or continuous); (b) qualitative characteristics (e.g. age / sex structure, reproductive rate or even certain health aspects of individuals); and (c) processes that maintain or affect the species, as physical environmental factors (e.g. hydrological processes, water quality, sedimentation processes, etc.). All attributes used should be quantifiable in one way or other to allow for their monitoring and evaluation’. The use of the term “qualitative” under (b) is misleading; the examples given by EN *et al*. 2001 under ‘qualitative characteristics’ are quantitative measures.

In finally choosing appropriate attributes, one must take into account the practicality of (a) measuring them and (b) being able to detect changes in them within a reasonable time. Given the identified overall objectives in section 10.1.2, the following potential attributes have been identified for the Conservation Plan for bottlenose dolphins:

a. Genetic structure of population

This includes establishing whether there is one or more population or subpopulations within the region, the genetic variability within them and relationships with adjacent populations.

b. Abundance

Unless the region contains all of the animals from the population(s) of interest, then this attribute will have to be the mean number of animals that use the area, rather than the absolute abundance. This is certainly the case for bottlenose dolphins. The animals that are using this region frequently use also areas outside the region.

c. Distribution and habitat use

This refers to the extent of the region used by the population(s) as well as the frequency, intensity and manner of usage (feeding, breeding, migrating, etc.).

d. Health and nutritional status

These are a number of characteristics of the health and nutrition of individuals that may give an indication of the health and nutritional status of the population(s).

e. Prey (attribute of the habitat)

The availability of food resources may be a key factor in the overall status of the population(s).

10.1.4. Definition of the Specific Conservation Objectives for the attributes

For each Attribute there must be at least one associated Specific Conservation Objective, derived from the Overall Conservation Objectives of the Plan. These objectives must be prioritized according to their usefulness and the feasibility of measuring whether they are being met. The Specific Conservation Objectives proposed for the Attributes defined in section 10.1.3 are:

a. Genetic population structure

Specific Conservation Objective 1: To maintain the genetic variability of the population(s)

Specific Conservation Objective 2: To avoid the fragmentation of the population and the genetic isolation of any sub-units (maintain or increase gene flow between population nuclei).

b. Abundance

Specific Conservation Objective 3: To maintain, or increase in the long term the abundance of the species in the region.

c. Distribution and habitat use

Specific Conservation Objective 4: To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas suitable for the species (areas that offer the conditions / characteristics necessary for usage by the species in one way or another).

d. Health and nutritional status

Specific Conservation Objective 5: To avoid deterioration in the health and nutritional status of animals in the population(s).

e. Prey

Specific Conservation Objective 6: To maintain or increase the availability of food resources for the animals.

10.1.5. Definition of the Indicators and Targets for the attributes with respect to the conservation objectives

Each Attribute must have a Target that can be defined in a quantitative way, representing the desirable condition of the Attribute with regard to its specific conservation objectives. In order to verify where we stand with respect to these targets, a series of indicators need to be established, on which the monitoring plan (see step 8 below) will provide information to assess how far the present situation is from the Target. These indicators therefore need to be quantitative or at least be able to be expressed as a range of values. A priorization of the targets of the conservation objectives should be done based on their importance to maintaining a favourable conservation status of the population(s). The process can be simplified in table format (Table 10.1).

10.1.6. Identification of the Threats to the conservation objectives

The threats to the bottlenose dolphin in the region have been identified in Chapter 4.

In the first step of the Conservation Plan, the analysis of the situation, a general overview of the main threats that affect or can potentially affect bottlenose dolphins in the region is provided. Nevertheless, in this step a more exhaustive and structured review of the threats should be done, classifying them with regard to which Attributes and associated Conservation Objectives are or are potentially being affected.

It is important to take into account that threats are very varied and can have an effect either only at the individual or also at the population level. All threats have impact individuals from simple disturbance to causing the death or negatively affecting the health or life history parameters (such as reproductive success) of particular individuals. But if an animal's fitness is not affected, the threat will not impact on the population. In a conservation plan, we should focus on those threats that affect the status of the population, despite the legitimate concerns on the individual animal's welfare.

For each possible threat the following are identified:

- *Cause of threat*

  Main human activities that are known or suspected of being a source of the threat considered

- *Indicator of threat*

  Variable that indicates that the identified activity (source of the threat) is taking place

- *Attribute affected*

  Attribute on which the identified threat is having or may likely have an effect

- *Conservation objective threatened*

  Specific conservation objective for the Attribute on which the identified threat is having or may likely have an impact

- *Possible impact of the threat on the Attribute*

  Possible effect or impact of the identified threat on the Attribute and its specific conservation objective

- *Indicator of possible impact*

  Variable that indicates if the identified activity (source of threat) is producing an impact on the conservation objective of the Attribute, and if so, at what level

- *Intensity / occurrence of cause of threat*

  Relative intensity or level of occurrence at which the identified activity (source of threat) is taking place in the area (low – medium – high)

- *Severity of impact on the conservation objective*

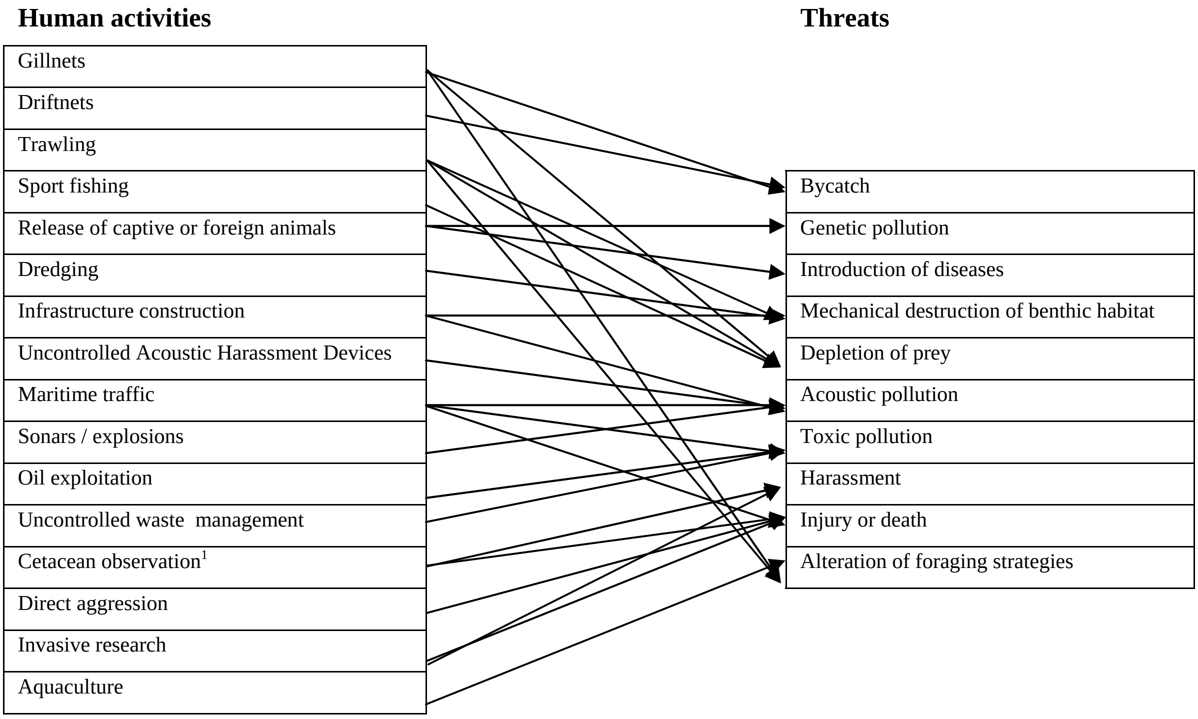
  Severity that the threat may have on the conservation objectives of the Attribute if it occurs

- *Impact level on Attribute*

  Level of impact of the effect that the threat may have on the conservation objectives of the Attribute, which is a combination of the intensity and the severity of the threat.

  The last three items inform the priorization process of the actions (see step 9 below).

Table 10.2 shows the main threats to the population, and all the items listed above. Some human activities may cause several threats, and some threats may be caused by several human activities. Therefore, Figure 10.1 represents a flow chart showing the synergies and links between different human activities and threats.



[1] Includes whale-watching, approach by pleasure yachting and research activities

Figure 10.1. Links between human activities and threats

10.1.7. Defining the baselines for the Attributes

In this step of the process, an exhaustive analysis of the information available on the bottlenose dolphin and its habitat should be done, to determine the status of each Attribute with respect to its Conservation Objectives. This constitutes the baseline information, the need for which is presented in

Chapter 1. In some cases there is information available from the studies carried out in this thesis (e.g. abundance in the study area, trends and fluctuations in recent years, distribution and habitat preferences; Chapters 5, 6 and 7). But in other cases the information will be very limited or nonexistent, which means that the necessary mechanisms to ensure the collection of such information should be established.

Table 10.3 shows an outline of the baseline information that should be available for each Attribute of the population(s) and habitat and their present availability. This table links up to the associated monitoring requirements and tools (see below). The same scheme is applied for the human activities level, defining in the first place what are the human activities for which it is necessary to have baseline information.

10.1.8. Establishing a Monitoring Plan

The need for a Monitoring Plan as an integral part of the Conservation Plan is outlined in Chapter 1. It is of fundamental importance to develop a feedback mechanism to the Conservation Plan; the results of monitoring periodically inform the Plan. In this way, the Actions can be adapted to new situations. As described in Chapter 1, the requirement for baseline information is at two levels: monitoring of the population (the Attributes defined in step 3) and of the human activities (those identified in step 6). In all cases it is necessary to prioritize the monitoring actions according to their usefulness and feasibility.

The Monitoring Plan must include the specific conservation objective established with respect to an attribute, the selection of an indicator value, the selection of a monitoring tool (including data collection and analysis) and finally the outcome which is to serve as feedback to the Conservation Plan. Table 10.3 shows the Monitoring Plan for the population in a schematic way, together with the baseline information required.

As with the collection of baseline information, it is also important to consider here the synergies between monitoring methods. Some methods for collecting data or for analysis are the same or very similar for monitoring several Indicators of Conservation Objectives. This should be an important aspect to consider when prioritizing monitoring actions. For example, the sampling methods could be summarised, in general, into two and can provide data for a variety of analytical methods, both for the monitoring of the populations (see Table 10.3) and for the human activities:

Data collected from sampling from line transect survey:

- Distribution and habitat preference
- Abundance estimates
- Human activities
- Additionally, with surveys with flexible design:
    - Photo-identification
    - Biopsies (genetics, toxicology, stable isotopes)

Data collected from strandings and by-catches

- Pathology
- Genetics
- Causes of mortality
- Stable isotopes
- Toxicology
- Diet

10.1.9. Establishment of the Actions to be undertaken

The main tool of a Conservation Plan is the programme of Actions. These Actions are the necessary actions to be undertaken in order to reach the Conservation Objectives. They are designed to minimise the impact of the threats on the species and its habitat. Therefore, the programme of Actions should be the result of a careful analysis of the threats, their possible effects on the population(s), and the possible palliative or preventive measures that could be taken in a realistic way.

The Actions can be classified in several categories, following to large extent those established in the ACCOBAMS Conservation Plan of the Mediterranean common dolphin (www.accobams.org).

1. Monitoring Actions

   Actions involving lines of research on specific aspects of the species, the habitats or the human activities and their impact on the species. These research actions focus on filling the scientific information gaps that are essential for effective conservation. Monitoring Actions also ensure that there is a systematic recording of those essential values that have been identified as indicators for the analyses of trends in the conservation status of the species and their habitats and in the threats and human activities that cause them. These Actions will assess, therefore, if the conservation objectives are being accomplished.

2. Research Actions

   These Actions are established where there is an urgent need for data to solve a specific problem (i.e. testing bycatch mitigation measures) or to obtain essential baseline data.

3. Management Actions

   Actions designed to manage human activities such as fisheries, whale-watching, pollution, etc.

4. Legislative Actions

   Actions that involve the creation or modification of laws, regulations, guidelines, etc. and the creation or ratification of agreements, conventions, etc. This also refers to certain actions to allow the better implementation of existing regulations.

5. Capacity building Actions

   Actions that contribute to the monitoring, legislative and management actions through the better involvement of stakeholders in the process, both at an institutional and at an individual scale. Institutional capacity building actions would be designed to promote the appropriate activities towards the Conservation Objectives by the institutions (administrative, education, research, etc. both governmental and non-governmental), providing them with the necessary information and/or mechanisms for it. Individual capacity building actions would be designed to provide adequate information and training to individual persons (teachers, press, managers, researchers, etc.) so they can reach the necessary capacity to act in favour of the Conservation Objectives of the Plan.

6. Public Awareness Actions

   Actions that link the Conservation Plan and in general the regional, national and international biodiversity conservation strategies with the general public (students, fishermen, managers, etc.) providing them with attractive and educational information.

All the Actions included in the Conservation Plan should describe:

- IDENTITY including: a) Type of action; b) Name of action and c) Level of priority

- DESCRIPTION including: a) Specific objectives it is developed for; b) Specific threats it is aimed to mitigate; c) Target; d) Method and materials; e) Expected results; f) Implementation; g) Timeline; and h) Cost

- LEGAL FRAMEWORK

- ACTORS including: a) Relevant authority; and b) Executers (operators – receivers)

- EVALUATION including: a) Indicator values; and b) Monitoring tool

10.1.10. Establishment of an Action Follow-up process

It is fundamental to establish a follow-up, surveillance and review mechanism for all the planned Actions to ensure their implementation and verify their effects. This is different from the monitoring of the populations and the human activities, although in some cases they might be closely linked especially with some human activities monitoring actions, and therefore a synergy could be established between some monitoring and follow-up mechanisms. But in this step the objective is to track the Actions themselves to verify if they are being carried out properly. Each action should have, therefore, an associated process or mechanism of follow-up as part of the Action itself. The contents of this mechanism are included in the description of the contents of the Actions under the previous step.

10.1.11. Establishment of how the Conservation Plan will function

Finally, it is necessary to establish the functioning of the Conservation Plan through the development of a strategy. This should include:

- the legal and administrative competences in relation to the Plan,
- the mechanisms for the coordination of the Plan including aspects of cooperation among different entities,
- the temporal plan and working agenda, and
- financial and human resources needed for the implementation of the Plan

10.2. MANAGEMENT ACTIONS

The official designation of a MPA or the ratification of a conservation plan is typically a slow process due mainly to the associated bureaucracy. Both should be considered as steps in the process towards conservation, not targets by themselves. The last and effective conservation tools will be the actions (legislative, management, capacity building, public awareness, monitoring) that will be implemented either within the framework of a Management Plan of a protected area or of a Conservation Plan.

An MPA without a plan of concrete actions will be ineffective. Conversely, the implementation of concrete actions even if there is no MPA designated or a ratified Conservation Plan can be an important step towards the conservation of the species and/or its habitat. A clear example of this is some of the actions carried out during the development process of the Conservation Plan for bottlenose dolphins. During the phase of identification and implication of the stakeholders and competent authorities for some of the actions planned, the first meetings allowed the highlighting of synergies that led, in turn, to concrete actions. The relocation of the “Off Cabo de Gata” Traffic Separation Scheme (see below) is a clear example of this: a tangible action with important implications for the target species, taken well before the existence of a legal framework for a MPA or a Conservation Plan.

Another example that illustrates the advantages of pursuing management actions in the face of the unavoidable bureaucratic slowness in the administrative and legislative processes is the whale-watching industry in the region. The involvement in the development process of a national law regulating whale-watching has promoted, in the main area of this activity in the Strait of Gibraltar, a sustainable exploitation of this resource and the development of educational and research activities that constitute at present one of the main supports for the conservation of the marine environment in this region. Meanwhile, the law, the final draft of which was accepted in 2001, continues its slow progress.

For marine species, the investigation of which involves serious logistic and economic challenges, it is often necessary to use the ‘precautionary principle’ due to the lack of basic scientific data. In this study, however, a large amount of information has been collected on human activities, threats on the cetacean populations (Chapter 4) and the most important areas for the conservation of these species (Chapters 6 to 9). Thanks to this information, and within the framework of the LIFE-Nature project “Conservation of cetaceans and sea turtles in Murcia and Andalusia” (LIFE02NAT/E/8610), some concrete management actions have been already developed and even implemented in some cases, constituting important steps towards an effective conservation. This has happened before the proposed MPAs are officially designated and with the Conservation Plans still under development.

Some examples are: a) commitment for the non-use of military sonars in the Oceanic Area by the Hydrographic Institute of the Spanish Navy in 2003 as a precautionary measure to avoid their negative effects on beaked whales (C. Gamundi, pers. comm.), based on information provided in Chapter 6; b) displacement of the Cabo de Gata Traffic Separation Scheme 20 nmi southwards, accepted by the Spanish General Directorate of the Merchant Navy and the I.M.O. (International Maritime Organization) in 2005, to displace maritime traffic outside the proposed SAC for bottlenose dolphins off Southern Almería, based on information provided in Chapters 6 and 7 (Figures 10.3 and 10.4); c) development of “Pesca Turismo”, a project on traditional fishing tourism involving the development of a new perception of dolphins by fishermen, the creation of an alternative livelihood for traditional fishermen, the establishment of fluid communication between them and the competent authorities, and the restoration of the coastal areas used by these fishermen including an effective waste management system; and d) establishment of a system for the collection of plastic debris by trawlers and long-liners and batteries and chemical lights by long-liners and a pilot scheme to establish selective waste management centres for debris collected by the fishing boats.

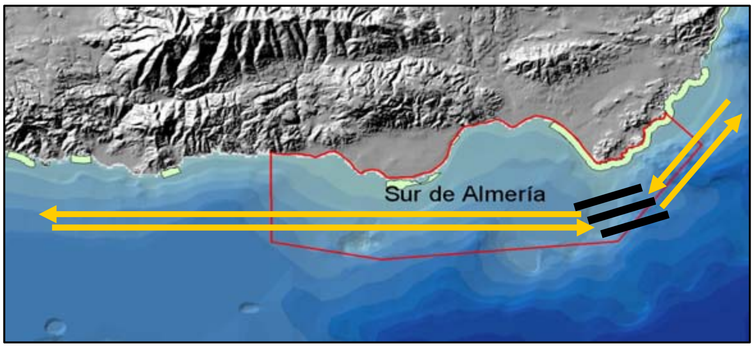


Figure 10.3. Present location of the DST (black lines) and main maritime routes (yellow lines). Red lines show the proposed SAC.

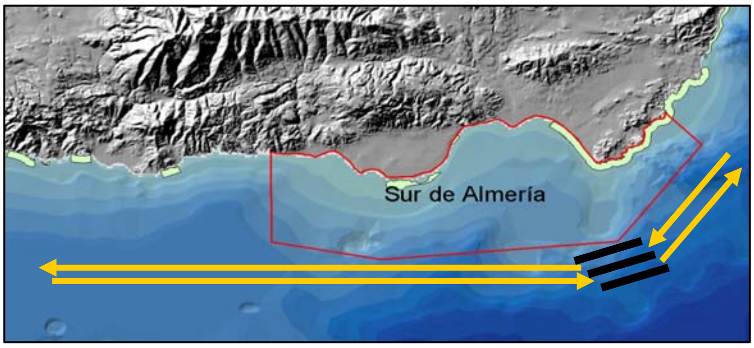


Figure 10.4. Proposed relocation of the DST (black lines) and main maritime routes (yellow lines). Red lines show the proposed SAC.

Table 10.1. Indicators and Targets of the Attributes

Attribute	Conservation Objective	Indicator	Target	Priority
Genetic structure of the population	To maintain the genetic variability of the population	Level of genetic diversity: - Deviances form the Hardy Weinberg equilibrium - Allelic richness - Nucleotidic diversity	To be defined, based on the present values (information available in autumn 2006)	Medium
	To avoid fragmentation of the population and the genetic isolation of its sub-units (maintain or increase gene flow between population nuclei)	Genetic structure of the population: - Level of intrapopulation differentiation - Level of interpopulations differentiation - Migration rate	To be defined, based on the present values (information available in autumn 2006)	High
Abundance	To maintain or increase in the long term the abundance of the species in the region	Abundance of dolphins and trends	Lower limit of abundance: 278 – 744 animals (95%CI of abundance estimate for the study area between 2000and 2003, as defined in Chapter 6), taking into account natural fluctuations	High
Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas necessary for the species	Size of the areas used by the dolphins and shifts in time	To maintain at least the extent of the important areas used by the dolphins as defined by the surface maps in Chapter 7	High
		Frequency of use of the areas and trends	Minimum frequency of usage of the important areas by the dolphins to be determined	High
		Site fidelity of the animals	Minimum level of site fidelity to be determined	Medium
Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Thickness of the blubber layer	Minimum to be determined	Medium
		Level of pollutants in the animals tissues	To minimize to ‘natural levels’ (maximum level to be determined)	Medium
		Levels of pathologies in the animals	To minimize to ‘natural levels’ (maximum level to be determined)	Medium
		Percentage of time used in searching for food	To be determined	Low
		Number of mortalities which cause is identified as ‘human activity’	Maximum level to be determined	Low
		Composition of the diet of the animals	To avoid reduction in variety, quality and quantity of prey in the diet (to be determined)	Medium
Prey	To maintain or increase the availability of food resources for the animals	Abundance of the main prey species for bottlenose dolphins	To maintain or increase the abundance of the main prey species for bottlenose dolphins (to be determined)	High

Table 10.2. Threats to the population, their causes, their impacts, indicators and priority levels.

Threat	Cause	Indicator of threat	Attribute affected	Conservation Objective threatened	Possible impact on Attribute	Indicator of possible impact on Attribute	Priorization		
							Severity of impact on conservation objective	**Intensity / occurrence of cause of threat**	**Impact level on Attribute**
Bycatch	- Gillnets - Driftnets	Bycatch rate	Genetic structure of the population	To maintain the genetic variability of the population	Imbalances in Hardy-Weinberg equilibrium and loss in variability if bycatch is selective		Medium	Suspected low (bycatch rate to be determined)	Suspected low (depending on bycatch rate)
			Abundance	To maintain or increase in the long term the abundance of the species in the region	Death of individuals	Proportion of animals by-caught in the population	High		
					Disruption of the age/sex structure if bycatch is selective	Decreased reproductive rate	High		
Genetic pollution	Release of captive or foreign dolphins	Number of releases of captive dolphins	Genetic structure of the population	To maintain the genetic variability of the population	Genetic pollution		Low	None at present, but plans	Low
Introduction of diseases	Release of captive or foreign marine mammals	Number of releases of captive or foreign marine mammals	Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Pathologies	Increase of 'new' pathologies	Medium	None at present, but plans	Medium (to be determined if occurring)
Injury or death	Direct aggression	Dolphins found (dead or alive) with signs of aggression	Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Injury (slight to severe) or death	Num. of dolphins found (dead or alive) with signs of aggression	Medium	Low	Low
	Maritime traffic (collision)	Dolphins found (dead or alive) with signs of collision				Num. of dolphins found (dead or alive) with signs of collision			
	Cetacean observation (collision)								
	Invasive research (involving direct contact or capture)	Dolphins found (dead or alive) with signs of mishandling				Num. of dolphins found (dead or alive) with signs of mishandling			

Table 10.2. **(continuation)** Threats to the population, their causes, their impacts, indicators and priority levels.

Threat	Cause	Indicator of threat	Attribute affected	Conservation Objective threatened	Possible impact on Attribute	Indicator of possible impact	Priorization: Severity of impact on conservation objective	Priorization: Intensity / occurrence of cause of threat	Priorization: Impact level on Attribute
Mechanical destruction of prey aggregating benthic habitat	Trawling	Trawling effort (spatial and temporal)	Abundance	To maintain or increase in the long term the abundance of the species in the region	Increased mortality rate by reduction of availability of food resources in the area	Reduction in abundance of animals	High	High	High
					Reduction in reproductive success by reduction of availability of food resources in the area	Reduction in reproduction rate			
			Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of availability of food resources in the area	Reduction (spatial or temporal) on the usage of the important areas			
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Malnutrition by reduction of availability of food resources in the area	Increase in number of emaciated animals			
			Prey	To maintain or increase the availability of food resources for the animals	Reduction of availability of food resources in the area	Reduction in abundance of food resources			
	Dredging	Num. and extent of dredging operations	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of availability of food resources in the area	Reduction (spatial or temporal) on the usage of the important areas	Low	Low	Low
	Infrastructure construction (e.g. ports, wind farms)	Num. and extent of infrastructure constructions	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of availability of food resources in the area	Reduction (spatial or temporal) on the usage of the important areas	Low	Medium	Low

Table 10.2. **(continuation)** Threats to the population, their causes, their impacts, indicators and priority levels.

Threat	Cause	Indicator of threat	Attribute affected	Conservation Objective threatened	Possible impact on Attribute	Indicator of possible impact	Priorization		
							Severity of impact on conservation objective	**Intensity / occurrence of cause of threat**	**Impact level on Attribute**
Depletion of prey	Trawling	Trawling effort and catches (spatial and temporal)	Genetic structure of the population	To avoid the fragmentation of the population and the genetic isolation of its sub-units	Longer distances between sub-units and decreased migration rate due to reduction in abundance	Decreased gene flow	High	High	High
			Abundance	To maintain or increase in the long term the abundance of the species in the region	Increased mortality rate by reduction of availability of food resources in the area	Reduction in abundance of animals			
					Reduction in reproductive success by reduction of availability of food resources in the area	Reduction in reproduction rate			
			Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of availability of food resources in the area	Reduction (spatial or temporal) on the usage of the important areas			
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Malnutrition by reduction of availability of food resources in the area	Increased number of emaciated animals			
			Prey	To maintain or increase the availability of food resources for the animals	Reduction of availability of food resources in the area	Reduction in abundance of food resources			
	Sport fishing	Sport fishing effort and catches (spatial and temporal)	Abundance	To maintain or increase in the long term the abundance of the species in the region	Increased mortality rate by reduction of availability of food resources in the area	Reduction in abundance of animals	Medium	Medium	Medium? (to be determined)
					Reduction in reproductive success by reduction of availability of food resources in the area	Reduction in reproductive rate			
			Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of availability of food resources in the area	Reduction (spatial or temporal) on the usage of important areas			
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Malnutrition by reduction of availability of food resources in the area	Increase in number of emaciated animals			
			Prey	To maintain or increase the availability of food resources for the animals	Reduction of availability of food resources in the area	Reduction in abundance of food resources			

Table 10.2. **(continuation)** Threats to the population, their causes, their impacts, indicators and priority levels.

Threat	Cause	Indicator of threat	Attribute affected	Conservation Objective threatened	Possible impact on Attribute	Indicator of possible impact	Priorization: Severity of impact on conservation objective	Priorization: Intensity / occurrence of cause of threat	Priorization: Impact level on Attribute
Depletion of prey	Gillnets	Gillnets effort and catches (spatial and temporal)	Abundance	To maintain or increase in the long term the abundance of the species in the region	Increased mortality rate by reduction of availability of food resources in the area	Reduction in abundance of animals	Medium	Low	Suspected low (to be determined)
					Reduction in reproductive success by reduction of availability of food resources in the area	Reduction in reproductive rate			
			Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of availability of food resources in the area	Reduction (spatial or temporal) on the usage of the important areas			
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Malnutrition by reduction of availability of food resources in the area	Increase in number of emaciated animals			
			Prey	To maintain or increase the availability of food resources for the animals	Reduction of availability of food resources in the area	Reduction in abundance of food resources			
Alteration of foraging strategies	Aquaculture	Proportion of dolphins foraging around aquaculture farms	Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Dependence and laziness	Proportion of dolphins foraging around aquaculture farms	Low	Low to Medium (area dependant)	Low
	Gillnets	Proportion of dolphins foraging around gillnets				Proportion of dolphins foraging around gillnets		Medium	
	Trawling	Proportion of dolphins foraging behind trawlers				Proportion of dolphins foraging behind trawlers		High	

Table 10.2. **(continuation)** Threats to the population, their causes, their impacts, indicators and priority levels.

Threat	Cause	Indicator of threat	Attribute affected	Conservation Objective threatened	Possible impact on Attribute	Indicator of possible impact	Priorization		
							Severity of impact on conservation objective	**Intensity / occurrence of cause of threat**	**Impact level on Attribute**
Acoustic pollution	Uncontrolled use of AHD	Num. and technical characteristics of AHD used in the area	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas imoprtant for the species	Exclusion by reduction of acoustic quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	High	Low at present but increase foreseen	Medium? (to be determined)
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Ear damage up to lethal injury	Indicators of ear damage in stranded animals	Medium		
	Maritime traffic	Num. and type of vessels	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas imoprtant for the species	Exclusion by reduction of acoustic quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	Low	High	Low to Medium? (to be determined)
	Sonars and explosions from military and oceanographic / geological activities	Num. and type of military and oceanographic / geological activities	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas imoprtant for the species	Exclusion by reduction of acoustic quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	Medium	Medium	Medium? (to be determined)
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Ear damage up to lethal injury	Indicators of ear damage in stranded animals	Medium		
	Infrastructure construction	Num. and type of infrastructure constructions	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas imoprtant for the species	Exclusion by reduction of acoustic quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	Low	Low but increase foreseen	Low? (to be determined)
Harassment	Cetacean observation (whale-watching, research, pleasure boats, jet skis)	Num. and severity of reported cases of harassment	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas imoprtant for the species	Exclusion by increased perturbation	Reduction (spatial or temporal) on the usage of the important areas	Low	Low / medium (area dependant)	Low
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Stress and associated effects	Increased indicators of stress in stranded animals	Medium		
	Invasive research (involving direct contact or capture)	Num. and severity of reported cases of harassment	Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Stress and associated effects	Signs of stress in animals	Medium	Low	Medium

Table 10.2. **(continuation)** Threats to the population, their causes, their impacts, indicators and priority levels.

Threat	Cause	Indicator of threat	Attribute affected	Conservation Objective threatened	Possible impact on Attribute	Indicator of possible impact	Priorization		
							Severity of impact on conservation objective	**Intensity / occurrence of cause of threat**	**Impact level on Attribute**
Toxic pollution	Oil exploitation	Num. and extent of oil spills	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	Medium? (to be determined)	Low but increase foreseen	Medium? (to be determined)
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Pathologies, immunosuppression, disruption of reproduction	Levels of toxic pollutants in dolphin samples			
	Uncontrolled waste management	Waste management control reports	Abundance	To maintain or increase in the long term the abundance of the species in the region	Increased mortality rate	Reduction in abundance of animals	Medium? (to be determined)	High	High? (to be determined)
					Reduction in reproductive success	Reduction in reproductive rate			
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Pathologies, immunosuppression, disruption of reproduction	Levels of toxic pollutants in dolphin samples			
	Maritime traffic	Num. of oil spills from maritime traffic	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	Medium? (to be determined)	High	Medium? (to be determined)
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Pathologies, immunosuppression, disruption of reproduction	Levels of toxic pollutants in dolphin samples			
		Num. of maritime accidents with toxic substances spills	Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Exclusion by reduction of quality of the habitat	Reduction (spatial or temporal) on the usage of the important areas	Medium? (to be determined)	Low	Medium? (to be determined)
			Abundance	To maintain or increase in the long term the abundance of the species in the region	Increased mortality rate	Reduction in abundance of animals			
					Reduction in reproductive success	Reduction in reproductive rate			
			Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Pathologies, immunosuppression, disruption of reproduction	Levels of toxic pollutants in dolphin samples			

Table 10.3. Baseline information required and scheme of Monitoring Plan for the population and habitat attributes

			Baseline information			**Monitoring Plan**						
Attribute	**Conservation Objective**	**Indicator**	**Information required**	**Current data availability**	**Current analysis availability**	**Data requirement**	**Data collection methods requirements**	**Analytical methods requirements**	**Output**	**Sampling temporal plan**	**Feasibility**	**Priority**
Genetic structure of the population	To maintain the genetic variability of the population	Level of genetic diversity of the population	Genetic diversity of the population: - Deviances from the Hardy Weinberg equilibrium - Allelic richness - Nucleotidic diversity	Partially available (more samples needed)	Not available yet, but foreseen for 2006	Skin biopsies or skin swabbing of animals from the region and from adjacent areas	Ship-board surveys	- Molecular analysis of mitochondrial DNA and microsatellites - Statistical analysis	- Deviances from the Hardy Weinberg equilibrium - Allelic richness - Nucleotidic diversity	Every 5 years	High	High
						Skin or other tissues from stranded or by-caught animals in the region and in adjacent areas	Strandings and by-catches			All stranded and by-caught animals	Low (low rate of strandings and by-catches)	High
	To avoid the fragmentation of the population and the genetic isolation of its sub-units (maintain or increase gene flow between population nuclei)	Genetic structure of the population	Genetic structure of the population: - Level of intrapopulation differentiation - Level of interpopulations differentiation) - Migration rate	Partially available (more samples needed)	Not available yet	Skin biopsies or skin swabbing of animals from the region and from adjacent areas	Ship-board surveys	- Molecular analysis of mitochondrial DNA and microsatellites - Statistical analysis	- Level of intrapopulation differentiation - Level of interpopulations differentiation - Migration rate	Every 5 years	High	High
						Skin or other tissues from stranded or by-caught animals in the region and in adjacent areas	Strandings and by-catches			All stranded and by-caught animals	Medium	High

Table 10.3. (continuation). Baseline information required and scheme of Monitoring Plan for the population and habitat attributes

Attribute	Conservation Objective	Indicator	Baseline information			Monitoring Plan						
			Information required	Current data availability	Current analysis availability	Data requirement	Data collection methods requirements	Analytical methods requirements	Output	Sampling temporal plan	Feasibility	Priority
Distribution and habitat use	To avoid the reduction (spatial and temporal) on a long term basis of the usage of areas important for the species	Size of areas used by dolphins and shifts in time	Size of the areas used by the dolphins	Available	Available for the Alborán Sea through spatial analysis. For the rest of the areas foreseen for 2006	Effort and sightings data	Ship-board surveys	Spatial analysis	Surface maps of habitat preference	Seasonal and yearly	High	High
		Frequency of use of the important areas and trends	Frequency of use of the adequate areas	Available	Not available			Statistical analysis	Seasonal and annual frequency of use of the areas	Seasonal and yearly	High	High
		Site fidelity of animals	Site fidelity of animals	Available	Not available	Photo-identification		Mark-recapture	Levels of site fidelity of individual animals	Seasonal and yearly	Medium	Medium

Table 10.3. (continuation). Baseline information required and scheme of Monitoring Plan for the population and habitat attributes

Attribute	Conservation Objective	Indicator	Baseline information			Monitoring Plan						
			Information required	Current data availability	Current analysis availability	Data requirement	Data collection methods requirements	Analytical methods requirements	Output	Sampling temporal plan	Feasibility	Priority
Abundance	To maintain or increase in the long term the abundance of the species in the region	Abundance of dolphins and trends	Current abundance in southern Spanish Mediterranean	Available	Available for Alborán Sea. Rest of the areas foreseen for 2006	Line transect data in southern Spanish Mediterranean	Ship-board surveys in southern Spanish Mediterranean	Spatial analysis	Abundance estimate and trends and surface maps of density	Seasonal and yearly	High	High
						Photo-identification		Mark-recapture	Abundance estimate and trends	Seasonal and yearly	Medium	Medium
									Catalogue of identified animals			
			Current abundance of population (as informed from genetics) in Mediterranean Sea	Not available. Basin-wide survey being planned within the ACCOBAMS framework	Not available	Line transect data in Mediterranean Sea	Ship-board surveys in Mediterranean Sea	Distance sampling	Abundance estimate and trends	Every 10 years	Low	High
								Spatial analysis	Abundance estimate and trends and surface maps of density			
			Viability of the population (including reproductive rates and survival)	Not available	Not available	Reproduction rates (sightings data and photo-identification)	Ship-board surveys	Population Viability Analysis	Prediction of the viability of the population	Every year	Low	Medium
						Survival (photo-identification)						

Table 10.3. (continuation). Baseline information required and scheme of Monitoring Plan for the population and habitat attributes

Attribute	Conservation Objective	Indicator	Baseline information			Monitoring Plan						
			Information required	**Current data availability**	**Current analysis availability**	**Data requirement**	**Data collection methods requirements**	**Analytical methods requirements**	**Output**	**Sampling temporal plan**	**Feasibility**	**Priority**
Health and nutritional status of the population	To avoid a deterioration of the health and nutritional status of the animals	Level of pathologies in animals	Level of pathologies in animals	Not available	Not available	Stranded or by-caught animals	Strandings and by-catches	Clinical and pathological examinations	Description and levels or proportions of pathologies	All strandings and by-catches	Low	Low
		Level of pollutants in animal tissues	Level of pollutants in animal tissues	Not available	Not available	Skin, blubber and other tissues	Strandings and by-catches	Toxicological analysis	Quantitative levels of pollutants in the tissues of the animals	All strandings and by-catches	Medium	Medium
						Skin biopsies of animals	Ship-board surveys				High	Medium
		Thickness of blubber layer	Nutritional status of animals	Not available	Not available	Stranded or by-caught animals	Strandings and by-catches	Measure of the blubber thickness	Blubber layer thickness	All strandings and by-catches	Low	Low
		Percentage of time used in searching for food				Sightings and behavioural data	Ship-board surveys	Statistical analysis	Proportion of time spent searching for food	Seasonal and yearly	High	Medium
		Number of mortalities the cause of which is identified as 'human activity'	Number of injuries and mortalities the cause of which is identified as 'human activity'	Not available	Not available	Number of injuries and mortalities the cause of which is identified as 'human activity'	Strandings and by-catches	Analysis of the causes of mortality	Estimated number and proportion of injuries and mortalities caused by different types of human activities	All strandings and by-catches	Low	Medium
							Observations at sea	Statistical analysis		All visual surveys	High	Medium
							Inquiries to fishermen			Yearly	Medium	Low
							Observers on fishing boats			Seasonal and yearly	Medium	High
		Composition of the diet of animals	Diet	Partially available through stable isotopes (not to species level)	Partially available through stable isotopes (not to species level)	Potential prey samples	Markets, fishing boats, etc.	Stable isotopes	Stable isotopes profiles for dolphins and prey	Seasonal and yearly	High	High
						Biopsy samples	Ship-board surveys				High	
						Skin, blubber and other tissues	Strandings and by-catches	Stable isotopes		All strandings and by-catches	Low	High
								Stomach contents	Stomach contents		Low	Low

Table 10.3. **(continuation).** Baseline information required and scheme of Monitoring Plan for the population and habitat attributes

Attribute	Conservation Objective	Indicator	Baseline information			Monitoring Plan						
			Information required	Current data availability	Current analysis availability	Data requirement	Data collection methods requirements	Analytical methods requirements	Output	Sampling temporal plan	Feasibility	Priority
Prey	To maintain or increase the availability of food resources for the animals	Abundance of the main prey species for bottlenose dolphins	Spatial distribution of potential prey	Partially available (IEO)	Partially available (IEO)	Spatial distribution of CPUE (catch per unit effort) of potential prey species	Oceanographic surveys	Spatial analysis	Surface maps of distribution of potential prey	Yearly	Low	High
			Abundance of potential prey	Partially available (IEO)	Partially available (IEO)	CPUE of potential prey species	Oceanographic surveys	Statistical analysis	Abundance of potential prey	Yearly	Low	High

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CHAPTER 11

GENERAL DISCUSSION: TOWARDS CONSERVATION OF CETACEANS IN THE ALBORÁN SEA

The conservation status of the Mediterranean marine environment is of concern (EAA 1999), and it is reflected to some extent in the conservation status of cetaceans inhabiting this basin (e.g. high levels of pollutants in the blubber, high levels of bycatch in fishing gear in some areas, declining of the common dolphin population(s), fragmentation of bottlenose dolphin population(s)). Therefore, there is an increasing interest in the conservation of cetaceans and their environment in the Mediterranean. Rigorous science is needed to provide basic support for conservation action that has some guarantee of success. Any Conservation Plan and management measures must be based on a basic scientific knowledge of the species, its ecology and its habitat.

The general objective of this thesis was, therefore, to contribute to the conservation of cetaceans in general, and bottlenose and common dolphins in particular, in the Alborán Sea. For this, two parallel paths were followed: (a) the investigation about aspects of the ecology of the species in this region, and (b) the proposal of management and conservation measures based on this scientific information.

11.1 APLICABILITY OF THE METHODS USED IN THIS STUDY

The study carried out in Chapter 6 illustrated the value of habitat preference modelling as a tool to help identify potential MPAs. In summary, 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. Another feature of this approach is that areas with apparently good habitat but few sightings can be identified where this is due to low searching effort, which 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.

The work done in Chapter 9, furthermore, suggests that the more we can introduce to the models those intrinsic factors that are likely to be influencing the density and habitat use, the clearer the picture we can get about the distribution patterns of the animals, improving our understanding of the ecology of the species and therefore providing information for conservation efforts.

In Chapters 7 and 8, the spatial analysis used in Chapter 6 was combined with line transect data, yielding abundance estimates. This method, known as model-based abundance estimation is an alternative technique to conventional design-based abundance estimation, suitable for estimating abundance from surveys that have not been designed to achieve equal coverage probability. This is a relatively new method that has not yet been widely applied and some technical issues remain unresolved. Nevertheless, it has been shown to be a good approach for describing cetacean distribution and estimating abundance using the data collected in this study.

When using this method, careful attention must be paid to its requirements and limitations, including: a) although a systematic design is unnecessary, reasonable coverage across the range of values for the explanatory variables used is required; b) the relatively large number of observations needed to allow modelling means that the method may not work very well in areas of low density without a large amount of effort, and t it may not be always possible to make the desired stratification (e.g. annual, seasonal, by behaviour); c) a potentially large number of variables can be involved, some known or suspected and quantifiable but others unknown or very difficult to quantify and not possible to be used, which decreases the power of the models and makes their interpretation more difficult; d) there is a risk of overfitting the data or creating an 'edge-effect' yielding unrealistic densities and surface maps; and e) models for species with low density (large proportion of 'absences') and wide distribution (low contrast in spatial density) become difficult to apply and a low percentage of the deviance gets explained. An added difficulty found during the work of this thesis was the novelty of the methods applied, especially on marine species such as cetaceans.

But it has some important advantages, including: a) using features of the environment to predict abundance may increase precision; b) abundance can be estimated for any subarea within the study area;

and c) this method does not require a randomised or systematic sampling scheme, and is therefore suitable for data collected from platforms of opportunity or dedicated surveys that did not follow a systematic design. This last point is very important because much of the data on cetacean distribution and density in Europe, and particularly in the Mediterranean Sea, is being collected through non-systematically designed surveys similar to those presented here. This method constitutes, therefore, a promising way to analyse these large collections of data.

11.2. ECOLOGY OF DOLPHINS IN THE ALBORÁN SEA

11.2.1. General overview

As highlighted in Chapter 1, almost no research on cetaceans had been done in the study area before this work began in 1992. Knowledge of species diversity, relative density, habitat preference and, in general, any aspect of cetacean ecology in the study area was practically non existent or, at best, extrapolated from other geographical areas. This study has contributed substantially to an increase in the knowledge of several cetacean species in the Mediterranean and especially in the Alborán Sea and the Gulf of Vera.

This area proved to be of great interest for cetaceans from the very beginning of this study, both because of its high diversity and because of their relatively high densities. Nine species have been seen regularly (fin whale, sperm whale, orca, long-finned pilot whale, Risso's dolphin, Cuvier's beaked whale, stripe dolphin, common dolphin and bottlenose dolphin), another three more rarely (harbour porpoise, northern bottlenose whale and false killer whale) and there are records of at least one more (not observed by us: minke whale). The long-finned pilot whale here has the highest encounter rates of those recorded in the whole Mediterranean Sea (Cañadas and Sagarminaga 2000). The bottlenose dolphin here has group sizes much higher than in other areas of the Mediterranean, and their density is comparable or higher than in other areas of this basin, with frequent incursions of large immigrant groups (Cañadas and Hammond in press; Chapter 7). The highest recorded densities of common dolphins in the whole Mediterranean basin are in the Alborán Sea (Bearzi *et al.* 2003; Chapter 8). All this is due mainly to the special oceanographic characteristics of this region, as transition area between the Atlantic Ocean and the Mediterranean Sea, with a highly dynamic hydrology and very important productivity (see Chapter 2).

The first phase of this work, focussed on the study of the distribution of 7 odontocete species in waters off Southern Almería, indicated that local physiography can play a significant role in their distribution (Chapter 5). Two distinct groups of species were identified according to their different distribution with respect to depth. Striped dolphins, Risso's dolphins, pilot whales, beaked whales and sperm whales, all had a preference for deep waters. Common and bottlenose dolphins were more frequently found in shallower waters.

The most obvious characteristic common to all species in the deep water group was their feeding habits. The five species included in this group have been frequently reported as teutophagic (Mercer 1975; Clarke and Pascoe 1985; Würtz *et al.* 1992; Blanco *et al.* 1995; Kenney *et al.* 1995; Santos *et al.* 1996; Gannon *et al.* 1997; Pauly *et al.* 1998; Blanco and Raga 2000), although some species like striped dolphins have a wider spectrum of target prey (Hassani *et al.* 1995; Santos *et al.* 1996; Pauly *et al.* 1998). In contrast, common and bottlenose dolphins (shallow water group), despite being considered as opportunistic species with a wide range of target prey, have shown in many dietary studies to have preference for fish over squid (Collet *et al.* 1981; Evans 1987; Barros and Odell 1990; Young and Cockcroft 1994; Berrow and Rogan 1995; Boutiba and Abdelghaní 1995; Kenney *et al.* 1995; Cordeiro 1996; Santos *et al.* 1996; Salomón 1997). Hence, the classification of odontocetes in the Alborán Sea according to their depth preference seemed to match a broad classification according to feeding habits. In Chapter 5 a more detailed analysis of these feeding habits and their depth-related distribution gradients is made, showing an even larger coincidence between both parameters.

In the second phase, a more in-depth analysis of the habitat preference of the odontocete species was made using spatial analysis (Chapter 6). The study area was extended towards the west (whole northern section of the Alborán Sea) and towards the east (Gulf of Vera). The results of these new analyses confirmed those of the first phase, but with greater robustness.

All species were observed in all seasons. Their presence in the study area cannot be considered seasonal, therefore, but permanent, independent of seasonal fluctuations in density or variations in habitat use.

Bottlenose and common dolphins are still the most common encountered species along the continental shelf and shelf edge throughtout the extended study area.The other five species are distributed mainly in deep waters, avoiding the continental shelf. These general distribution patterns of these species in the area have been identified as a result of the studies described here. The findings can be summarised as follows:

The striped dolphin is the most abundant species (as it is in most of the Mediterranean basin - Notarbartolo di Sciara 1993; Ganier 1995; Forcada and Hammond 1998; Gaspari 2004). Its larger group sizes occur towards the West (Málaga and Granada). The highest density of this species was found in the deep watersof the Alborán Sea, followed by the Strait of Gibraltar and finally by the Gulf of Vera. It seems to have preference for warmer waters than the common dolphin, coinciding with observations in other geographic areas such as the NE Atlantic (Forcada *et al*. 1990), and for deep waters with little presence over the continental shelf, as has also been described for other areas of the Mediterranean Sea (Notarbartolo di Sciara 1993; Gannier 1995; Gaspari 2004; Gómez de Segura in prep.). Their preferred area in the Strait of Gibraltar is slightly narrower and closer to the center of the channel than for the common dolphin.

The highest relative densities of long-finned pilot whale are in the Strait of Gibraltar and the deep waters south of Granada and Almería up to south-east from Cabo de Gata, although it is also frequently found in the deep waters of the Gulf of Vera, always beyond the 500m isobath. This area has the highest encounter rates of this species in the Mediterranean (Cañadas and Sagarminaga 2000). There are very few studies on the long-finned pilot whale, and most deal with their feeding habits (Gannon *et al.* 1997), or with acoustics or behaviour (Baraff 1998; Rendell and Gordon 1999; Baird *et al*. 2002; Ottensmeyer and Whitehead 2003). The distribution and habitat preferences of this species has only been thoroughly investigated, as far as we know, in waters of the Faroe Islands (NE Atlantic) – due to the hunting of this species there (Bloch *et al.* 1989; Buckland *et al*. 1993) and in Nova Scotia and north-eastern coast of US (Payne and Heinemann 1993; Ottensmeyer, comm. pers.). There are only occasional references to the presence of this species in the Mediterranean, sometimes with very brief descriptions of their general distribution (e.g. Di Natale 1982; Notarbartolo di Sciara *et al.*1993; Gannier 1995). This work presented here provides, therefore, valuable information on a very poorly studies species in terms of habitat preference.

Risso's dolphins are found only on the eastern half of the northern Alborán Sea and in the Gulf of Vera, increasing its density and group sizes from West to East. Its distribution is very similar to that of the pilot whale (except for its absence in the Strait of Gibraltar), although slightly more reduced and towards deeper waters, especially beyond the 800 m isobath. The habitat preference of this species in the study area coincide with those described in some of the few studies carried out in other geographic areas, such as the Gulf of Mexico (Baumgartner 1997) or the Ligurian Sea in the Mediterranean (Gaspari 2004), but are very different from others in which this species is frequently observed over the continental shelf (Leatherwood *et al*. 1980; Gill *et al.* 1997). The total absence of sightings in the western section of the Alborán Sea and in the Strait of Gibraltar suggests that the Mediterranean population of this species could be isolated from that in the North Atlantic, with a minimal or non-existant flow through the Straits.

Beaked whales have the most restricted distribution in the study area, mainly confined to the deep waters (around 1000 m depth) off Southern Almería, with a few sightings in the Gulf of Vera. As for Risso's dolphin, there are no recordings of these species in the western end of the Alborán Sea nor in the Strait of Gibraltar. This could also indicate in this case that the Mediterranean population could be relatively (or totally) isolated from the Atlantic, although the possibility of animals passing undetected across the Strait due to being very inconspicuous should not be discounted. The identification of the area with the highest denisty of this species off Southern Almería triggered the proposal for the protection for this area (the 'Oceanic Area', described below), especially in relation to potentially dangerous acoustic sources for these species.

Sperm whales are not encountered very often in the study area, except in the Strait of Gibraltar, and their distribution in the eastern section of the Alborán Sea is very similar to that of Risso's dolphins and beaked whales (deep waters off southern Almería).

11.2.2. The bottlenose dolphin

The common bottlenose dolphin was encountered throughout the whole study area and in all seasons (Chapters 5, 6 and 7). The highest densities occurred in the southern section of the Strait of Gibraltar, the areas south of Almería (especially around the Seco de los Olivos sea mount) and the island of Alborán. Relative density declines northwards from Cabo de Gata, but increased again towards Murcia.

Bottlenose dolphins appear to have a preference for waters between 200 and 600 m depth and a steep sea bottom (especially around the Seco de los Olivos). This agrees with this species' most common feeding habits reported in the western Mediterranean (mainly demersal fish prey; Gannier 1995, Blanco *et al*. 2001, Cañadas *et al*. 2002).

The point estimate of abundance for 2000 to 2003 in the Alborán area was 584 dolphins (95%CI = 278 – 744), mainly concentrated in southern Almería, the coastal areas of Granada and south of Punta Calaburras in Málaga. In the area of Almería, estimated abundance for the first period studied (1992 to 1997) was 111 animals (95%CI = 54 - 234). In the second period (1998 to 2000), after the arrival of the "immigrant" animals, estimated abundance increased markedly by a factor of four. In 2001-2003, estimated abundance decreased by a factor of two (Chapter 7). Despite the differences in estimated abundance over time, the core area was the same in the three periods: around the Seco de los Olivos sea mount. This is an important area of upwelling induced by the topography, which has been highlighted as having the highest concentrations of ichthyoplankton in the northern half of the Alborán Sea (Rubín *et al*. 1992). As highlighted in Chapter 7, these abundance estimates are potentially underestimated, but probably not by much.

This study has provided the first abundance estimate of bottlenose dolphins for the SW Mediterranean (and one of the first of the whole Mediterranean basin), and the first analysis of its habitat preference in this basin, identifying the 'hot spots' in the study area. It is also the first time that a robust analysis of trends in density over more than 10 years has been carried out in a portion of the Mediterranean Sea. All this has important implications for conservation (see below).

11.2.3. The common dolphin

The short-beaked common dolphin was also found throughout the whole research area and in all seasons. There was a preference for areas with cooler waters than the overall average. The area with the highest predicted occurrence included the Bays of Málaga and Estepona, especially off Punta Calaburras, coinciding with the northern branch of the western anticyclonic gyre of the Alborán Sea (Gascard and Richez 1985; Parrilla and Kinder 1987). However, larger numbers of dolphins were predicted in southern Almería, where the average group size was much larger than in the other areas. Combining the results from both models (groups and school size), these two areas were predicted to have the highest relative density, especially at depths between 100 and 400m.

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 southeast 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 Alborán Sea.

The total abundance for the whole study area from Gibraltar to the Gulf of Vera between 2000 and 2004 was estimated as 19,428 animals (95%CI= 15,277-22,804). Seasonal variation in density was detected off Southern Almería, with higher average density in summer than in winter (Chapter 8). There were also geographical differences when considering the whole study area (from 2000 to 2004) during summer, with much higher density in the west than in the east, and intermediate density off Southern Almería in the middle (Chapter 8).

In the Alborán Sea, summer density kept fairly stable over time, since 1992 in Southern Almería and since 2000 in Western Alborán. This suggests that the Alborán Sea (or, more precisely, the northern Alborán Sea) population of common dolphins is currently doing well in this area. On the other hand, the drastic drop in density of common dolphins in the Gulf of Vera after 1996, to around a third of that between 1992 and 1995, is of concern (Chapter 8).

A consistent pattern was seen in the results from all models, irrespective of the area or the years modelled (except for 1999): a higher density of animals towards the western end of the Alborán Sea with a second peak off Southern Almería, and higher densities around the shelf edge (100-400m), with a second weaker peak in deep waters (800-1200m).

There was a seasonal change in distribution and density during the winter months (October to May). This change took the form of lower density for the winter months due to the groups being smaller, and a higher density of groups towards deeper waters. The same change in pattern occurred during summer 1999, when a drop in sea surface temperature was detected during some days. These changes are possibly related to changes in prey availability, as discussed in Chapters 8 and 9.

Groups with calves tended to prefer more coastal waters and groups without calves deeper waters. In each case, however, a second smaller peak of density was seen in deep and coastal waters, respectively. Single species groups followed the general pattern of higher densities around the shelf edge off Southern Almería but mainly towards the western end of the area, while there were higher densities of animals in mixed species groups in the deep waters off Southern Almería, and in the whole western part of the study area. In the westernmost part, however, the higher density occurred also around the shelf edge. Animals feeding showed the highest densities in shallow waters. Animals travelling followed the general pattern of higher densities towards the west and around the shelf edge, with a second smaller peak in deep waters. There was a strong contrast between the patterns of density of groups and of group sizes in socialising groups, yielding a strong bimodal pattern, with more but smaller groups in deep waters, and fewer but larger groups in shallow waters. This bimodality in socialising groups disappeared when stratifying them into single and mixed species groups, although the differences were not strong: a higher density of socialising animals in single species groups along the shallow waters of the shelf edge, and a higher density of socialising animals in mixed species groups in deeper waters but mainly to the west.

In general, it can be concluded that the shelf edge areas, and especially off Málaga and off Southern Almería, seem to be the preferred habitat for this species in most situations, but mainly when feeding and when there are calves in the groups. This is most probably because it is the main habitat for what is apparently their main prey species in the study area.

This constitute the first abundance estimate of common dolphins in the Mediterranean Sea and, furthermore, the first in-depth analysis of their habitat preference in Europe. Our knowledge has therefore substantially improved, which constitutes an important baseline for the conservation efforts of this species.

11.3. TOWARDS THE CONSERVATION OF CETACEANS IN THE ALBORÁN SEA

The work carried out throughout this study has significantly contributed to the conservation of cetaceans in the Alborán Sea and the Mediterranean Sea in general. Several MPAs have been proposed based on the information presented here. In particular, four SAC (one already approved in Murcia and other 3 proposed in Andalucía) and one SPAMI. The basis for the development of a Conservation Plan for bottlenose dolphins in Andalucía and Murcia has also been established, and there has been an active collaboration in the development of the ACCOBAMS Conservation Plan for Mediterranean common dolphins. Furthermore, some management measures have already been taken, and much work has been done, both actively and passively, on public awarness; being this a fundamentally important factor when trying to implement conservation actions.

11.3.1. Proposals for Marine Protected Areas

On the basis of the results obtained during this study, several MPAs have been proposed. Each of them was proposed under the appropriate category of protection according to its particular characteristics or needs: SAC (for areas important for bottlenose dolphins), SPAMI (when there were important and representative areas for the entire Mediterranean biogeographic zone), or others.

Since one of the objectives of the “Mediterranean Project” (Raga and Pantoja 2004) was to fulfill the objectives of the Bern Agreement, the Habitat Directive of the European Union, the Barcelona Agreement, the Protocol on special protected zones and the biological diversity in the Mediterranean and ACCOBAMS, the requirements of these conservation frameworks were considered when selecting the areas (Chapter 6).

This study has therefore 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.

This study 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. Furthermore, our results have brought to the attention of several government administrations and international conservation organizations the importance of the Alborán Sea for the conservation of cetaceans and biodiversity in general, not only for Spain but also for the Mediterranean Sea as a whole. The draft ACCOBAMS Conservation Plan for the Mediterranean short-beaked common dolphin includes the Alborán 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 Alborán Sea MPA for the conservation not only of the cetacean species, but of the whole biodiversity and ecological processes of this area.

It is essential that sound science provides the basis for area designation and monitoring goal attainment. The work presented here 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.

The next step will be the development of Management Plans for these MPAs. For this, two parallel processes have been initated. First, a process for the establishment of conservation objectives, analysis of the situation and of the potential threats and priorization of mitigation actions was initiated. Second, a series of coastal tours was made with the aim of identifying the people and groups that should be involved in management actions, with the purpose of implicating them in a process whose aim is the development of a Management Plan based on scientific data and with the consensus of all parties. This process that at first was anticipated to proceed slowly to avoid mistakes, has gone faster for some actions when synergies and common positions were detected, allowing significant advances in concrete aspects of cetacean conservation. These Management Plans will be elaborated in detail during the first half of 2006.

An important consideration for cetacean conservation in the Alborán Sea is that some management actions could and should be implemented whether or not specific MPAs are designated. Some examples of this are given in Chapter 6.

11.3.1.1 SAC proposals

At present, one SAC for common bottlenose dolphins in the region of Murcia was accepted by the Spanish Government in 2000 (ES6200048 Medio Marino) as a result of a proposal by SEC, the Spanish Cetacean Society, based on the data collected during this study from 1992 to 1998 (Figure 11.1). The presence of bottlenose dolphin is not taken into account in any of the proposed SAC at the moment by the Autonomous Community of Andalusia. Therefore, the present situation is obviously insufficient.

A brief description of the three new proposals for SAC made within the framework of the "Mediterranean Project" is given in Chapter 6: Straits of Gibraltar, Southern of Almería and the Island of Alborán (Cañadas *et al.* 2005) (Figure 11.1). A summary of some proposed management measures to mitigate the detected threats in each one is also given.

The new three proposed areas are those with the highest estimated densities of bottlenose dolphin, representing the habitats of most interest for the conservation of this species. The designation of these areas as MPAs, and especially their adequate management, will be a positive step towards maintaining a favourable conservation status for this species. Although SAC are only directly relevant to bottlenose dolphins and harbour porpoises, many of the real and potential threats to them are shared by other cetacean species. Therefore, the Management Plans developed for the SAC can indirectly benefict other species present in the same areas.

It is important to highlight, as mentioned in Chapter 1, that it is absolutely fundamental to elaborate adequate and efficient Management Plans for each of the MPAs. These Plans may have a very similar process and structure as a Conservation Plan (described below), but focussing on the specific characteristics of the area were the SAC is proposed.

In summary, due to the results of this work, a SAC was proposed for Murcia, which is already approved, and three others have been proposed in Andalucía (Figure 11.1). These three proposed SAC are currently waiting for the clarification of whether the local government of Andalucía and the Spanish Ministry for the Environment has competence. Meanwhile, the Spanish Ministry of Environment has recently (November 2005) included the bottlenose dolphin in the alredy proposed SAC around the Island of Alborán (ES6110015 - "Isla de Alborán") and in the Spanish coastal areas of the Strait of Gibraltar (ES6120012 – "Frente litoral del Estrecho de Gibraltar") as a result of the studies presented here.

11.3.1.2. SPAMI proposal

For the Mediterranean, the SPAMI instrument represents a potentially important complementary measure to the Habitat Directive to aid the conservation of cetacean populations and their habitats in the Mediterranean Sea.

A series of potentially important threats were highlighted in (Chapter 4), which require the implementation of management measures at a larger scale to those that could be covered by a network of SAC. Therefore, a proposal for a SPAMI (Specially Protected Area of Mediterranean Importance) was presented to the competent authorities. The area proposed as a SPAMI covers the northern half of the Strait of Gibraltar (but including the waters of the Autonomous Community of Ceuta) and the Alborán Sea (including the Island of Alborán), and the Gulf of Vera including Southern Murcia (Figure 11.1). The proposed SPAMI includes both inshore and offshore areas (including the proposed SACs). Based on the analyses presented here, it contains preferred habitats for several cetacean species and meets all the important specific SPAMI criteria for cetaceans as well as the wider (non-cetacean) criteria (Chapter 6).

The results of the analysis clearly showed the particular relevance of the Alborán Sea and the Straits of Gibraltar for the conservation of cetaceans, not only for Spain but for entire Mediterranean biogeographic zone. The importance of the region for migration and feeding of these species turns it into an essential spot for any possible recovery of the most vulnerable and fragmented populations in Mediterranean waters at the moment.

For example, the proposed SPAMI has the highest encounter rate for long-finned pilot whales within the whole Mediterranean basin (Cañadas and Sagarminaga, 2000) and would link the population nuclei of this species in the Strait of Gibraltar and the Almería-Gulf of Vera area. The Alboran Sea is at present the most important remaining habitat for the common dolphin in the Mediterranean Sea (Bearzi *et al*., 2003). Predicted areas of importance for the short-beaked common dolphin not covered by the proposed SACs include the coastal waters off Málaga and Granada. In the deep waters south of Almería, there is a high diversity of cetaceans and the analysis 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. This SPAMI can also play an important role connecting the different proposed SAC for bottlenose dolphin among them and with the existing SAC in Murcia. Finally, it seems to be an important passage area for the migrations of fin whales between the Mediterranean and the Atlantic (Guinet *et al*. in press).

The important productivity and biodiversity of the Alborán basin is without doubt the main explanation for the great diversity of cetacean species and for the present conservation status of these populations. This situation is just a normal reflection of a maritime region whose relevance goes beyond the exclusive conservation of emblematic species such as cetaceans and turtles. Its function as hydrological motor of the western Mediterranean, its geographic characteristics and the diversity and richness of its trophic webs clearly shows the importance of Alborán for the conservation of the Mediterranean Sea as a whole.

The spatial requirements of marine pelagic species such as cetaceans are large scale and clearly show the importance of an adequate MPA design. This also means moving away from an approach too focussed on certain prioritiry species forgetting that they only constitute one more element of complex trophic webs.

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 SACs. Even if management plans are successfully developed and implemented for small MPAs, without some connectivity amongst them their conservation objectives might not be fully accomplished.

11.3.1.3. Proposal of an Oceanic Area

A proposal for protection of a so-called 'Oceanic Area' was submitted to the Ministry of Environment within the framework of the "Mediterranean Project" (Raga and Pantoja 2004) (Figure 11.1). The innovative character of this proposal should be highlighted, being an oceanic area far from coast. In general, offshore areas of importance to cetaceans have received little conservation attention, although a few precedents exist in the northwest Atlantic (e.g. the Stellwagen Bank, off Massachussets – Ward 1995 -, and the Gully Canyon, in Nova Escotia – Hooker *et al*. 1999) and the Ligurian Sea Pelagos Cetacean Sanctuary in the Mediterranean (www.cetaceansanctuary.com). The problems of designing areas for protection outside territorial waters (exclusively oceanic, little available knowledge), has prevented up to now the designation of this type of areas. But the Spanish National Strategy for Biodiversity and Sustainable Development already states the importance of creating strictly marine categories of protection and the importance of marine areas that do not need to be necessarily linked to the coast. Therefore, this is a problem to be solved and should not prevent a proposal for protection of a marine area with these characteristics if the importance of the site requires it.

As shown in Chapter 6, there is a large diversity of cetacean species in the deep waters south of Almería, and the models clearly show its special relevance for the conservation of some of them that concentrate in this area. It is an area of interest for beaked whales, Risso's dolphin, long-finned pilot whales, sperm whales and striped dolphins, with the added presence of bottlenose dolphins (outside the proposed SAC) and common dolphins.

Even though beaked whales are not included in the National Cataogue of Endangered Species, mainly due to the lack of scientific data, it is important to highlight the relevance of this area for them, with the aim of proposing management measures with respect to the use of sonar and underwater explosions both military and scientific. This is especially important for beaked whales, which are vulnerable to certain military activities (Frantzis 1998; Jepson *et al.* 2003). These species have the most restricted distribution in the study area, and overall their distribution is mainly confined to the oceanic area south of Almería. The 'precautionary principle' should prevail in order to avoid events of mass mortalities of these species. For this reason a communication channel was established with the Ministry of Defence to make all the necessary scientific data, to help avoid or reduce the impact of the potentially dangerous acoustic activities, available to the Spanish Navy, NATO and the Spanish General Directorate of Merchant Navy.

This area constitutes, furthermore, a link between the proposed SAC of Southern Almería and Island of Alborán, being a corridor for the movements of bottlenose dolphins between both areas.

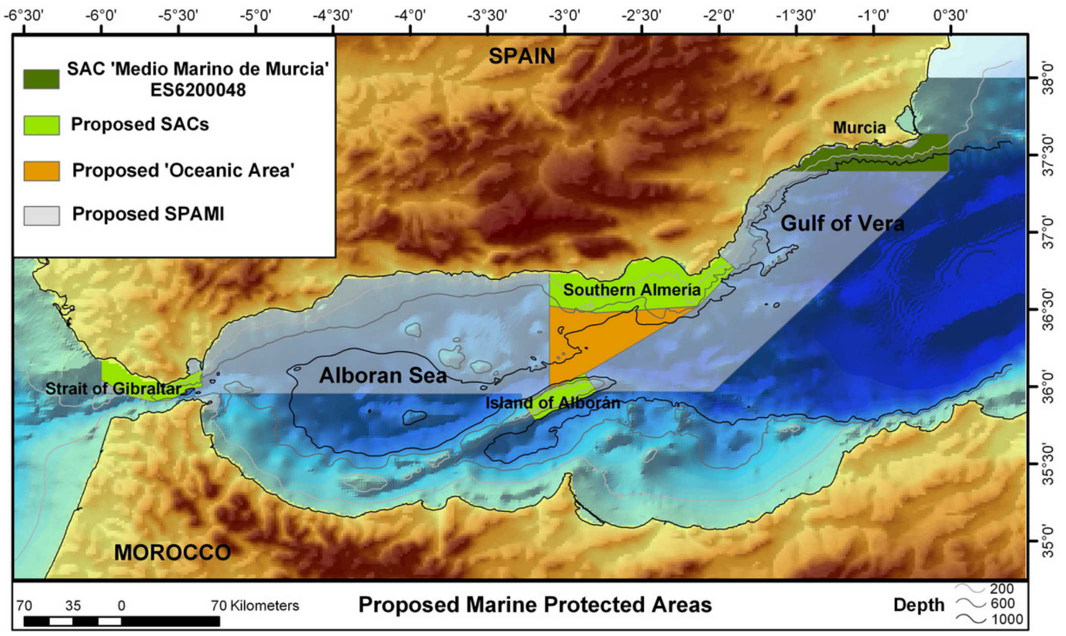

Figure 11.1. Proposed marine protected areas.

11.3.2. Conservation Plan for common dolphins

The revision of the status of the common dolphin in the Mediterranean has been one of the priorities of ACCOBAMS ever since its first Meeting of the Parties in 2002. Data collected in the Alborán Sea and Gulf of Vera throughout the work of this thesis was part of a first step in this direction through its contribution to the publication of an article focusing on the ecology, status and conservation of Mediterranean common dolphins (Bearzi *et al*., 2003). This article provided the scientific background for the inclusion of the Mediterranean common dolphin population in the IUCN Red List of Threatened Animals.

Following a recommendation of the ACCOBAMS Scientific Committee during its first meeting (Tunis, 2002), the ACCOBAMS Secretariat commissioned a small group of scientists expert in the field, including the author of this thesis, to develop a “Mediterranean Common Dolphin Conservation Plan” during 2004 (Bearzi *et al*. 2004). This Plan, reviewed by the Scientific Committee of ACCOBAMS acknowledges that: ”1) the formulation and recommendation of management measures is made difficult by the present lack of understanding of the cause(s) for common dolphin decline in the region; 2) nevertheless, it can be assumed that most of the factors that are responsible for the decline of common dolphins in the Mediterranean derive from human activities in this marine region that are unsustainable and/or illegal (e.g., overfishing, use of driftnets, pollution); 3) the fate of Mediterranean common dolphins depends on range States having the political will to take responsible and precautionary action to mitigate the known anthropogenic threats; 4) the principal management measures that will benefit common dolphins are already embedded in existing legislation and treaties; 5) if all such measures, invoked by existing international, regional and national legal instruments for the management of the Mediterranean, were to be fully implemented and enforced, the decline of common dolphins would likely cease.”

This Conservation Plan which basically concludes that “honouring existing obligations with regard to the management of fisheries, pollution and other forms of habitat degradation represents the single most important action to stop the decline of Mediterranean common dolphins and facilitate their recovery” focuses on three lines of action:

Firstly, in relation to the existing obligations of member states, the Plan strongly advocates that such obligations be respected and implemented without any further delay.

Secondly the Plan includes a series of management, legislation, research, capacity building, awareness & education actions that “specifically address the problem of common dolphin conservation in the Mediterranean, with special attention to areas that report common dolphins in sizeable numbers and appear to contain important habitat for the species.”

Thirdly, the Plan establishes an initial selection of eight Areas of Conservation Importance (ACIs) where management actions should be undertaken immediately focusing on research to fill in the present knowledge gaps that prevent the identification of effective conservation strategies. The selection of the ACI corresponding to the area of the Alborán Sea and Gulf of Vera was based on the work contained in this thesis, mainly the high relative density of common dolphins in this area, due both to large density of groups and to very large group sizes (Chapters 5 and 6, and confirmed later by the studies shown in Chapters 8 and 9). These results highlighted the special relevance of this area in the context of Mediterranean common dolphin conservation efforts.

The Plan, with an initial implementation phase of five years, establishes a priority for management actions in ACIs. It proposes a more simplified and efficient initial alternative strategy than the establishment of MPAs, based on: “1) the currently incomplete state of knowledge about common dolphin distribution and long-term movements, 2) the inherently dynamic nature and likely large spatial extent of the habitat used by these animals year-round, and 3) the cumbersome institutional and governance issues affecting the design, enforcement and implementation of “traditional” MPAs, which are likely to be improved in the future.”

In addition to the actions for promoting a management approach which is intended to pave the way for the future establishment of networks of MPAs or large MPAs to protect Mediterranean common dolphins, designed on the basis of appropriate information on their ecology, distribution, long-range movements and spatial needs, the Plan also focuses on the need for capacity building and education. The outreach actions of the Plan, respond to the common interest expressed by the contracting parties of ACCOBAMS which consider "diffusing research and monitoring abilities throughout the region a timely challenge and one of the highest priorities as far as cetacean conservation is concerned" (ACCOBAMS, 2002).

11.3.3 Conservation Plan for bottlenose dolphins

The overall aim of the LIFE-Nature project “Conservation of cetaceans and turtles in Murcia and Andalucía” (LIFE02NAT/E/8610) is to contribute to Spain’s commitments to the European Union’s Habitat Directive (C.D. 92/43/EEC) with respect to the conservation of the three marine pelagic species of the Directive’s Annex II, the bottlenose dolphin, the harbour porpoise *(Phocoena phocoena)* and the loggerhead turtle *(Caretta caretta)* in the regions of Andalucía and Murcia.

To achieve this aim, the project has been developed at three levels:

- Developing diverse cetacean and sea turtle population study techniques in order to establish the most cost efficient tools for the long term **MONITORING** of trends in the conservation status of these species and their habitats
- Developing **CONSERVATION** Plans for the target species as well as **MANAGEMENT** Plans for the SAC's proposed in the region
- To create a link between monitoring, conservation and management with the different stakeholders to **INVOLVE** them in the management process, to ensure that biodiversity conservation targets and economic development are compatible.

Furthermore, under Spanish legislation a Conservation Plan for species catalogued as "vulnerable" in the National Catlogue of Threatened Species (such as the bottlenose dolphin) that applies to the whole region needs to be developed.

For this reason, the development of a Conservation Plan for bottlenose dolphins in Andalucía and Murcia, described in Chapter 10, is part of the work of this thesis. But the process described for this Conservation Plan is not only valid for this particular species in this particular area. It can be applicable to any species in any area. For example, the same process and structure is being applied to the Conservation Plan for loggerhead turtles within the same LIFE-Nature project. It is also being taken as the model of how conservation efforts should be directed, and how a conservation plan should be developed, within the framework of a project for the conservation of bottlenose dolphins in European waters of the NE Atlantic that is being prepared under the coordination of the University of Cork (Ireland). Furthermore, this Conservation Plan will be used by the Spanish Ministry of Environment as the model for the development of a National Strategy for the conservation of this species in all Spanish waters.

The wide applicability of the process and structure of the Conservation Plan for bottlenose dolphins described in Chapter 10 makes it not only one of the most important contributions of this work to conservation efforts for this species, but also a valuable contribution to conservation efforts in general for marine mammals and other marine species such as sea turtles, in any geographical area.

11.3.4. Establishment of a baseline for long-term monitoring

The importance of obtaining baseline information and carrying out a Monitoring Plan has been highlighted in Chapter 1. The studies carried out in the context of this thesis, which have gradually grown into a management process in the form of the LIFE-Nature project, have allowed for the establishment of much baseline data for future management. In doing so, these studies have also highlighted the importance of taking into account the natural fluctuations in dolphin populations in the extensive and dynamic marine environment in the establishment of baseline data and the analysis of trends.

In summary, this thesis has provided baseline information on: a) preferred habitats and relative density for 7 species of odontocentes in the northern Alborán Sea and Gulf of Vera (Chapters 5 and 6); b) abundance estimate for bottlenose dolphins in the northern part of the Alborán Sea, and in particular in the sub-area off Southern Almería (Chapter 7); c) estimated abundance and habitat preference variations of bottlenose dolphins off Southern Almería (proposed SAC) over 12 years (Chapter 7); d) abundance estimate of common dolphins in the northern Alborán Sea and Gulf of Vera, including estimates for the sub-areas of Western Alborán, Southern Almería and Gulf of Vera (Chapter 8); and e) habitat preference of common dolphins according to different behavioural states and other intrinsic factors in the northern Alborán Sea and Gulf of Vera, including preferred habitats for feeding and for groups with calves (Chapter 9).

As highlighted in Chapter 7, the abundance estimates represent the average number of dolphins in the study areas during the defined periods, not the size of a population using the areas. The study area is not a closed one, with movement of individuals into and out of the adjacent areas. But in terms of monitoring conservation status within a defined area such as an SAC, we are interested in whether the average number of animals using the area changes over time. Therefore, if the same methods are used across years, the estimates obtained are valuable in monitoring changes in abundance in the study area.

When dealing with the area of Alborán, four or five years of survey is too short a period to detect any trend in abundance and long-term monitoring is required. But in the rest of the area (Southern Almería and Gulf of Vera), 12 to 13 years of study are already useful in terms of monitoring trends during this period, and show that the methods used in this work are useful for this objective.

In the case of bottlenose dolphins, the long time series of data allowed the documentation of an increase and subsequent decrease in abundance that is likely a result of natural fluctuations (Chapter 7).

The results highlight the importance of long-term studies to understand variation in abundance in a given area, and the need for an adequate long-term monitoring programme. In the case of common dolphins, the long time series of data has shown a decline in abundance in the Gulf of Vera, while the density appears stable in the northern Alborán Sea during this time.

Ideally, the monitoring programme should be developed not only to allow the detection of changes in abundance in the long-term, but also the differentiation between natural fluctuations and real trends in the abundance of the population. The observed fluctuations in abundance of bottlenose dolphins off Southern Almería stress the need for the monitoring programme to cover not only the proposed SAC but also a wider area outside it to improve our understanding of fluctuations or trends in numbers and shifts in distribution. This wider information may have important implications for the management of the protected areas (Wilson *et al.* 2004). In the same way, the decline of common dolphins in the Gulf of Vera shows the importance of extending the monitoring to wider areas to be able to understand the changes (which in this case do not seem to be due to a natural fluctuation but rather to the impact of a newly developed human activity): where have the dolphins gone when the area stops being suitable? This event also shows how essential is the monitoring of the human activities in order to be able to identify possible links between a change in the conservation status of the population and changes in human activities.

11.3.4.1. Monitoring in Andalucía and Murcia

Monitoring of the populations in Andalucía and Murcia will continue using the same methods (so results are comparable), although improved whenever possible and adding information from other sources such as photo-identification and mark-recapture. The core area for future monitoring will be Southern Almería, both for logistical reasons and because it is the area with highest diversity of species, highest density of bottlenose dolphins and one of the areas with highest density of common dolphins. However, periodic monitoring will be carried out also in the Gulf of Vera (focussing mainly on trends in common dolphin abundance) and in the Western Alborán Sea.

11.3.4.2. Monitoring in the Island of Alborán

During this work several survey transects were made to the Island of Alborán, showing that this area is of high interest for the bottlenose dolphins and other species (Chapter 6). It has been determined, therefore, that long-term monitoring (including obtaining some baseline informaiton on abundance and detailed habitat preference) should be done in this area. In the efforts to develop cost-effective ways of monitoring, the opportunity offered by the General Secretariat of Maritime Fisheries to use the lighthouse and infrastructures of the island and the Fisheries patrol boat to carry out the monitoring of the bottlenose population, is a very important constribution within the framework of the European Commission policy in marine biodiversity conservation.

During 2005 a bottlenose dolphin monitoring programme for the waters of the Island of Alborán was approved by the General Secretariat of Maritime Fisheries. This project is in a preparatory phase and will start in 2006. The general objective of this project is to obtain scientific data for the monitoring of the bottlenose dolphin population in waters of the Fisheries Reserve of the Island of Alborán and contribute to its management plan. Two phases are considered:

1) To obtain baseline information on the bottlenose dolphin population in waters of the Island of Alborán, including: a) identity of the population; b) abundance estimate; and c) distribution and habitat use.

2) Long-term monitoring of the bottlenose dolphin population in waters of the Island of Alborán, including: a) abundance estimates and trends; b) distribution and habitat use, especially in relation with the trawling areas and ships; and c) population dynamics.

To reach these objectives, sightings will be made from land (from the ad hoc platform built on the island's lighthouse), and line transects will de made from the patrol boat "Isla de Nubes".

11.3.5. Public awareness

Dolphins can be a powerful tool for education, and as such have been used during this work. Images and sounds, subproducts of this study, have been extensively used in public conferences, public awarness articles and educational materials. However, the *leit motiv* of these educational products has been to move away from the romantic view of the emblematic species to demonstrate the importance of the marine ecosystem as a whole including man. It has also been highlighted in all educational products that big changes can be made with individual actions.

In addition, through the LIFE-Nature Project we have stressed to the stakeholders and the general public the importance of basing the conservation measures on scientific data. This issue becomes a challenge when competing with organisations that use the same charismatic animals in precisely the opposite way.

The two main ways of public awareness were: through direct contact during the field work, and through the press. Direct contacts were done at many levels, from the authorities (Guardia Civil del Mar, Customs, Fisheries inspectors, port authorities, etc.) to fishermen and tourists. The aesthetic aspect of the research ship was a very useful tool in this sense, because it attracted the attention of tourists, sailors and stakeholders in general. In this way, the simple presence of *Toftevaag* in some ports has produced, over the years, a change of attitude at local level towards cetaceans, the marine environment and its conservation. It was this experience, to a large extent, that inspired the philosophy of the educational part of the LIFE-Nature Project.

With regard to the press, there has been a very wide coverage in written press (newspapers and magazines), radio and television (including several documentaries), reaching a large sector of the population.

11.4. FUTURE WORK

The work developed in this thesis using data collected over 14 years of research in the study area does not stop here. There is still much work to do towards the conservation of cetaceans and their habitats in the Alborán Sea and the Mediterranean as a whole. There are three parallel lines along which work will continue during the next years.

11.2.3.1. Research

As discussed above, to obtain baseline information on abundance and distribution is of fundamental importance for effective conservation. This information has already been obtained for the study area for common and bottlenose dolphins. However, given the high mobility and wide distribution range of cetaceans, it is necessary to obtain this information for the whole Mediterranean Sea to have a more complete overview of the population(s) that inhabit it. For this reason, a multispecies basin-wide survey (with several vessels simultaneously) is been planned at present to obtain baseline information on abundance and distribution of the cetacean species inhabiting the Mediterranean Sea. The organisation of this survey has been commissioned by ACCOBAMS to the author of this thesis, and work is already in progress (Cañadas *et al*. 2004).

In parallel, more research will be done in the study area of this thesis to obtain new information. In particular, abundance estimates will be made for bottlenose dolphins in the Gulf of Vera and for other species in the whole study area. The influence of ‘intrinsic’ factors in the habitat preference of bottlenose dolphins will also be investigated, as well as the social structure and other parameters for several species through photo-identification.

The applicability of the methods used in this work, especially the novel spatial analysis, will be further investigated to improve them and to solve the difficulties encountered as much as possible.

11.2.3.2. Monitoring

Monitoring of the populations will continue in the study area. The same methods (improved when possible) will be used, to generate long time series that will help in analysing trends in abundance and habitat use of the different species.

11.2.3.3. Management and conservation

The Conservation Plan for the bottlenose dolphin will be finished and submitted to the European Commission and the Spanish competent authorities in July 2006. Since then, the continued work in the study area will contribute to it through the monitoring of the population(s) and human activities and by providing new baseline information. There will also be collaboration and involvement in the implementation of several management, capacity building and public awareness actions of the Plan. Similar contribution will be provided to the ACCOBAMS Conservation Plan for common dolphins.

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CAPÍTULO 11

DISCUSIÓN GENERAL: HACIA LA CONSERVACIÓN DE LOS DELFINES EN EL MAR DE ALBORÁN

El estado de conservación del medio marino en el Mediterráneo es preocupante (EAA 1999), y se refleja hasta cierto punto en el estado de conservación de los cetáceos que habitan en esta cuenca (por ejemplo, altos niveles de contaminantes en la grasa, altas tasas de captura accidental en artes de pesca en algunas zonas, declive de la(s) población(es) de delfín común, fragmentación de la(s) población(es) de delfín mular, etc.). Por lo tanto, hay un interés creciente por la conservación de los cetáceos y su medio ambiente en el Mediterráneo. Se necesita una ciencia rigurosa que provea de un soporte básico para acciones de conservación que tengan alguna garantía de éxito. Cualquier Plan de Conservación o acción de gestión debe estar basado en un conocimiento científico básico de la especie, su ecología y su hábitat.

Por lo tanto, el objetivo general de esta tesis fue el de contribuir a la conservación de los cetáceos en general, y de los delfines mulares y comunes en particular, en el Mar de Alborán. Para esto se siguieron dos vías paralelas: a) la investigación acerca de aspectos de la ecología de las especies en la zona, y b) la propuesta de medidas de conservación y gestión basadas en esta información científica.

11.1 APLICABILIDAD DE LOS MÉTODOS UTILIZADOS EN ESTE ESTUDIO

El estudio realizado en el Capítulo 6 ilustra la utilidad de los modelos de preferencia de hábitats como herramienta para ayudar a identificar potenciales AMPs. En resumen, los análisis incorporan datos sobre el medio ambiente para generar una predicción espacial de densidad relativa basada en la preferencia de hábitats, definidos éstos como combinaciones de variables ambientales. Las áreas identificadas para las AMPs candidatas proporcionan así la mejor descripción disponible sobre distribución, según las características del hábitat que demuestran ser importantes. Esto representa una gran mejora sobre el uso de simples medidas de ocurrencia animal tales como simples mapas de distribución o tasas de encuentro. Otra característica de este método es que se pueden identificar áreas con hábitat aparentemente adecuado pero pocos avistamientos debido a poco esfuerzo de búsqueda, lo cual resulta útil para desarrollar futuros programas de investigación o monitorización.

Una ventaja de este método es que los modelos pueden ser actualizados para incorporar nuevos avistamientos y datos ambientales para clarificar preferencias (y mecanismos asociados) y explorar así si se producen cambios aparentes en la preferencia de hábitats. Realizar una nueva valoración de las relaciones entre la abundancia relativa y los variables ambientales es una manera útil de monitorizar la efectividad del AMP en conseguir la protección deseada. También proporciona una manera de realizar estudios más detallados para explorar los mecanismos que determinan la distribución de los cetáceos y por lo tanto proporcionar una mejor predicción de los efectos de factores antropogénicos en su estado de conservación.

El trabajo hecho en el capítulo 9 sugiere que cuanto más podamos introducir en los modelos los factores intrínsecos que es probable que influencien la densidad y el uso del hábitat, mejor podremos conseguir una visión más clara sobre los patrones de distribución de los animales, ayudando de gran manera al entendimiento de la ecología de la especie.

En los Capítulos 7 y 8, el análisis espacial usado en el Capítulo 6 fue combinado con datos de transecto lineal, produciendo estimas de abundancia. Este método, llamado ‘estima de abundancia basada en modelo’ es una técnica alternativa a la estándar (‘estima de abundancia basada en diseño’), adecuada para estimar abundancia en los estudios que no se han diseñado para tener igual probabilidad de cobertura. Éste es un método relativamente nuevo que todavía no se ha aplicado extensamente, y algunas preguntas siguen estando aún sin resolver ya que todavía está en una fase relativamente temprana de su desarrollo. Sin embargo, ha demostrado ser un buen método para describir la distribución de los cetáceos, y estimar su abundancia, en base a los datos recogidos en este estudio.

Este método se debe utilizar cuidadosamente ya que también tiene algunas desventajas o requisitos, por ejemplo: a) aunque es innecesario un diseño sistemático, se requiere una cobertura razonable a lo largo de toda la gama de valores de las variables explicativas usadas; b) el número relativamente grande de observaciones que se necesitan para permitir la modelización, significa que el método puede no funcionar muy bien en áreas de baja densidad sin una cantidad grande de esfuerzo, y puede no ser siempre posible hacer las estratificaciones deseadas (por ejemplo por años, estaciones, estados de comportamiento, etc.); c)potencialmente un gran numero de variables podrían estar involucradas, algunas conocidas o sospechadas y cuantificables pero otras desconocidas o muy difíciles de cuantificar y por lo tanto que no es posible utilizar, lo cual disminuye el poder de los modelos y hace su interpretación más difícil; d) existe el riesgo de ‘overfitting’ de los datos o de crear un 'efecto-borde' produciendo densidades y mapas de superficie poco realistas; y e) los modelos para especies con baja densidad son difíciles de aplicar y solo un bajo porcentaje de la devianza queda explicado. Una dificultad añadida encontrada a lo largo de esta tesis fue el carácter novedoso de los métodos aplicados, especialmente en especies marinas como los cetáceos.

Pero tiene algunas ventajas importantes, tales como: a) usando las características del ambiente para predecir abundancia se puede aumentar la precisión; b) la abundancia se puede estimar para cualquier sub-área dentro del área de estudio; y c) este método no requiere un esquema de muestreo seleccionado al azar o sistemático, y es por lo tanto conveniente para los datos recogidos por plataformas de oportunidad o en estudios dedicados que no sigan un diseño sistemático. Este último punto es muy importante porque muchos de los datos sobre distribución y densidad de cetáceos en Europa, y particularmente en el Mediterráneo, se están recogiendo con muestreos sin diseño sistemático similares al utilizado en este trabajo. Este método constituye, por lo tanto, un modo muy prometedor de analizar éstas grandes colecciones de datos.

11.2. ECOLOGÍA DE LOS DELFINES EN EL MAR DE ALBORÁN

11.2.1. Visión general

Como se indica en el capítulo de introducción (Capítulo 1), antes de comenzar este estudio en 1992, se había realizado muy poca investigación sobre cetáceos en la zona. Los conocimientos sobre la diversidad de especies en la zona, su densidad relativa, sus preferencias de hábitat y, en general, sobre cualquier aspecto de su ecología, eran prácticamente inexistentes y en todo caso extrapolados de otras áreas geográficas. Este estudio, por lo tanto, ha contribuido durante sus 15 años de duración hasta la fecha, a aumentar considerablemente los conocimientos sobre varias especies de cetáceos en el Mediterráneo, y en particular en el mar de Alborán y Golfo de Vera.

Desde el principio, este estudio mostró ser ésta una zona de gran interés para los cetáceos tanto por su diversidad, con 9 especies regulares identificadas (rorcual común, cachalote, orca, calderón negro, calderón gris, zifio de Cuvier, delfín listado, delfín común y delfín mular), mas otras 3 más esporádicas (marsopa, zifio calderón, falsa orca), como por su relativamente elevada densidad. Por ejemplo, el calderón negro presenta las mayores tasas de encuentro de todo el Mediterráneo en esta zona (Cañadas and Sagarminaga 2000); el delfín mular presenta unos tamaños de grupo muy superiores a los registrados en el resto del Mediterráneo, y su densidad es comparable o relativamente superior a la de otras zonas mediterráneas, con frecuentes incursiones de grandes grupos inmigrantes (Cañadas and Hammond in press; Capítulo 7); las mayores densidades de delfín común en toda la cuenca Mediterránea donde se han realizado estudios se dan en el Mar de Alborán (Bearzi *et al.* 2003; Capítulo 8). Todo esto se debe fundamentalmente a las especiales características oceanográficas de esta región, como zona de transición entre el Atlántico y el Mediterráneo, con una hidrología altamente dinámica y una importante productividad (Capítulo 2).

La primera fase de este trabajo, que se centró en el estudio de la distribución de siete especies de odontocetos en las aguas del sur de Almería, indicó que la fisiografía local puede desempeñar un papel significativo en su distribución (Capítulo 5). Se identificaron dos grupos de especies según su distribución con respecto a profundidad. Delfines listados, calderones grises, calderones negros, ballenas picudas y cachalotes, muestran preferencia por aguas profundas. El delfín común y el mular fueron encontrados con más frecuencia en aguas menos profundas.

La característica común a todas las especies en el grupo de aguas profundas más obvia es sus hábitos de alimentación. Las cinco especies incluidas en este grupo se han descrito con frecuencia como teutofágicas, aunque ciertas especies como el delfín listado tienen una gama más amplia de presas. Asimismo, y en contraste con el grupo de aguas profundas, los delfines común y mular (grupo de aguas menos profundas), a pesar de su consideración como especies muy oportunistas con una amplia gama de presas, han demostrado tener preferencia por peces sobre calamares en muchos estudios de dieta. Por lo tanto, la clasificación de odontocetos en el mar de Alborán según su preferencia de profundidades parece coincidir con una clasificación general según hábitos de alimentación. En el Capítulo 5 se hace además un análisis algo más detallado de estos hábitos de alimentación y sus gradientes de distribución respecto a profundidad, incrementándose esta coincidencia entre ambos parámetros.

En esa primera fase se hizo pues una primera descripción de algunas preferencias de hábitat de las siete especies de odontocetos estudiadas, poniendo de relieve la diferenciación entre los delfines mular y común con las otras especies más oceánicas.

En una segunda fase se profundizó en el análisis de las preferencias de hábitat de las diferentes especies de odontocetos utilizando la herramienta del análisis espacial (Capítulo 6). En este caso el área de estudio se extendió también a toda la zona del norte del Mar de Alborán y el Golfo de Vera. Los resultados de estos nuevos análisis básicamente coinciden con los de la primera fase, pero dotándoles de mayor robustez.

Todas las especies pudieron ser observadas en todas las estaciones, por lo que su presencia en la zona de estudio no la podemos considerar estacional sino permanente, independientemente de que se den fluctuaciones estacionales de densidad o variaciones en el uso del hábitat.

Habiéndose extendido la zona de estudio a todo el norte del mar de Alborán y el Golfo de Vera, los delfines mulares y comunes siguen mostrando la mayor presencia en las aguas de la plataforma continental y la caída de la plataforma en toda la región. Las otras cinco especies, sin embrago, se distribuyen fundamentalmente por las aguas profundas, evitando la plataforma continental. Gracias a este trabajo, se han podido identificar los patrones de distribución generales de estas especies en toda la zona, de lo cual no existía ninguna información previa. A modo de resumen se podrían resaltar los siguientes puntos:

El delfín listado es la especie más abundante de todas (como sucede en la mayor parte del Mediterráneo) (Notarbartolo di Sciara 1993; Ganier 1995; Forcada and Hammond 1998; Gaspari 2004), y presenta los mayores tamaños medios de grupo hacia el oeste (Málaga y Granada). Sus mayores densidades se dan en las aguas profundas del mar de Alborán, seguido por el Estrecho de Gibraltar y finalmente por el Golfo de Vera. Parece tener preferencia por aguas más cálidas que el delfín común, lo cual coincide con observaciones realizadas en otras zonas geográficas como el Atlántico NE (Forcada *et al*. 1990) y por aguas profundas con poca presencia en la plataforma continental, como se ha descrito también para otras zonas del Mediterráneo (Notarbartolo di Sciara 1993; Gannier 1995; Gaspari 2004; Gómez de Segura en prep.). En el Estrecho de Gibraltar, al área preferente del delfín listado es algo más estrecha y más cerca del centro del canal que para el delfín común.

Las mayores densidades relativas de calderón negro se dan en el Estrecho de Gibraltar y las aguas profundas de Granada y Almería hasta el sudeste de Cabo de Gata, aunque también se encuentran con mucha frecuencia en las aguas profundas del Golfo de Vera, siempre más allá de la isóbata de los 500 m. En un estudio comparativo paralelo sobre el calderón negro en el Mediterráneo (no incluido en esta tesis), se mostró que esta región cuenta con las mayores tasas de encuentro de esta especie respecto a todas las áreas prospectadas de la cuenca mediterránea (Cañadas and Sagarminaga 2000). Hay muy pocos estudios sobre el calderón negro de aleta larga, la que nos ocupa, y los que hay se refieren sobretodo a su alimentación (Gannon *et al*. 1997) o a temas acústicos y de comportamiento (Baraff 1998; Rendell and Gordon 1999; Baird *et al*. 2002; Ottensmeyer and Whitehead 2003). La distribución y preferencias de hábitat de esta especie sólo ha sido investigada con cierta asiduidad, que sepamos, en las aguas de las Islas Faroe (Atlántico NE) – debido a la caza de esta especie en esa zona- (Bloch *et al*. 1989; Buckland *et al*. 1993) y en aguas de Nueva Escocia y costa NE de Estados Unidos (Payne and Heinemann 1993; Ottensmeyer, comm. pers.). En el Mediterráneo sólo hay menciones ocasionales a la presencia de esta especie o con breves descripciones de su distribución general (por ejemplo, Di Natale 1982; Notarbartolo di Sciara *et al*.1993; Gannier 1995). Este trabajo aporta, por lo tanto información sobre una especie muy poco estudiada a nivel de preferencias de hábitat.

El calderón gris, sin embargo, se encuentra sólo en la mitad oriental del mar de Alborán y en el Golfo de Vera, incrementándose su densidad y sus tamaños de grupo de oeste a este. Su distribución es muy similar a la del calderón negro (excepto por su ausencia en aguas del Estrecho de Gibraltar), aunque algo más restringida y con tendencia a aguas más profundas, especialmente más allá de los 800 m de profundidad. Las preferencias de hábitat de esta especie en la zona de estudio coinciden con las descritas en algunos de los pocos estudios realizados en este campo sobre esta especie en otras zonas geográficas como el Golfo de México (Baumgartner 1997) o el Mar de Liguria en el Mediterráneo (Gaspari 2004), pero sin embargo discrepan de otras en las que calderones grises son observados con frecuencia sobre la plataforma continental (Leatherwood *et al*. 1980; Gill *et al*. 1997). La total ausencia de avistamientos en la zona occidental del mar de Alborán y en el Estrecho de Gibraltar, podría sugerir que la población de esta especie en el Mediterráneo se encuentra aislada de la del Atlántico norte, con un flujo mínimo (en todo caso no detectado) o inexistente a través del Estrecho.

Los zifios o ballenas picudas tienen en la zona de estudio la distribución más restringida, fundamentalmente reducida a las aguas profundas (de alrededor de 1000 m) al sur de Almería, con algunos pocos avistamientos en el Golfo de Vera. Como en el caso del calderón gris, no se han registrado avistamientos de estas especies en el extremo occidental del Mar de Alborán ni en el Estrecho de Gibraltar, lo que podría indicar que la población(es) Mediterránea/s pudiera estar relativamente aislada de la del Atlántico, aunque no descartamos que si se de algún paso a través del Estrecho pero que, debido a la pequeñísima conspicuidad de estos animales hayan pasado siempre desapercibidos. La identificación de la zona con mayor densidad de esta especie al sur de Almería impulsó la propuesta de protección de esta área, llamada desde entonces ‘Área Oceánica del sur de Almería’, especialmente en cuanto a emisiones acústicas potencialmente perjudiciales para esta familia de cetáceos (ver más abajo).

Los cachalotes no se observan con demasiada frecuencia en la zona de estudio, excepto en el Estrecho de Gibraltar, y su distribución es muy similar a la de los calderones grises y los zifios, en aguas profundas sobretodo del sur de Almería.

En los dos apartados siguientes se hace una síntesis más detallada sobre los conocimientos adquiridos a lo largo de este trabajo sobre el delfín mular y el delfín común.

11.2.2. Síntesis para el delfín mular

El delfín mular se encontró en toda el área del estudio y en todas las estaciones. Sus densidades más altas se dan en la sección central del Estrecho de Gibraltar, el sur de Almería (especialmente la zona del Seco de los Olivos) y la isla de Alborán. La densidad relativa declina hacia el norte de Cabo de Gata, pero aumenta otra vez hacia Murcia.

Los delfines mulares parecen tener preferencia por áreas de profundidades entre 200 y 600m y de pendiente escarpada (especialmente alrededor del "Seco de los Olivos"). Esto coincide con los hábitos de alimentación descritos más comunes de esta especie en el Mediterráneo occidental (principalmente presas demersales; Gannier 1995, Blanco *et al*. 2001, Cañadas *et al*. 2002).

La estima de abundancia para el período de 2000 a 2003 en el área de Alborán es de 584 delfines (95%CI = 278 – 744), concentrados principalmente en el sur de Almería, las áreas costeras de Granada y el sur de Punta Calaburras en Málaga. En el área de Almería, la abundancia estimada durante el primer período estudiado (1992 a 1997) fue de 111 delfines (95%CI = 54 - 234). En el segundo período (1998 a 2000), después de la llegada de los animales "inmigrantes", la abundancia estimada aumentó en un factor de cuatro. En 2001-2003, la abundancia estimada disminuyó a la mitad (Capítulo 7). A pesar de las diferencias en abundancia estimada a lo largo de los años, el área central de mayor densidad fue la misma en los tres períodos: alrededor del "Seco de los Olivos". Esta es una zona de importantes upwellings inducidos por la topografía, que ha sido destacado por tener las concentraciones más altas del ictioplancton de la mitad norte del mar de Alborán (Rubín *et al*. 1992). Como se destaca en el Capítulo 7, estas estimas de abundancia están potencialmente subestimadas, pero al ser muy probable que la g(0) esté cerca de uno, la diferencia es probablemente mínima.

Este estudio provee la primera estima de abundancia de delfín mular para el Mediterráneo sud-occidental (y uno de los primeros de toda la cuenca Mediterránea), y constituye el primera análisis de su preferencia del hábitat en esta cuenca, identificando los 'puntos calientes' de su distribución en el área de estudio. Es también la primera vez que se realiza un análisis robusto de tendencias de la densidad a lo largo de más de 10 años en una porción del mar Mediterráneo. Todo esto tiene implicaciones importantes para la conservación (véase abajo).

11.2.3. Síntesis para el delfín común

El delfín común también se encontró en toda la zona de estudio y en todas las estaciones. Muestra preferencia por áreas con aguas más frescas que el promedio de toda la zona. El área con la predicción más alta de ocurrencia incluye las bahías de Málaga y de Estepona, especialmente en Punta Calaburras, coincidiendo con la rama norte del giro anticiclónico occidental del mar de Alborán (Gascard and Richez, 1985; Parrilla and Kinder, 1987). Sin embargo, al sur de Almería el tamaño medio de grupo es mucho más grande que en las otras áreas. Al combinar los resultados de ambos modelos (grupos y tamaños de grupo), estas dos áreas resultan tener la densidad relativa más alta, especialmente en las profundidades entre los 100 y los 400m.

Los resultados también destacaron la importancia del Estrecho de Gibraltar, especialmente sus áreas más costeras, incluyendo la bahía de Algeciras. Las densidades relativas son bajas en el Golfo de Vera. Sin embargo, dentro de esta área son más altas en el sur (específicamente al sureste de Cabo de Gata), donde se forma a menudo el productivo frente termohalino "Almería-Orán" (Tintoré *et al*., 1988). Al norte de aquí, las áreas con densidad relativa más altas están en aguas más profundas que en el mar de Alborán.

La abundancia total para toda el área de estudio desde Gibraltar hasta el Golfo de Vera entre 2000 y 2004 fue estimada en 19,428 animales (95%CI = 15,277 - 22,804). Existe una variación estacional en densidad en la zona sur de Almería, con una densidad media más alta en verano que en el invierno (Capítulo 8). Hay también diferencias geográficas cuando se considera el conjunto del área de estudio (entre 2000 y 2004) durante el verano, con una densidad mucho más alta en el oeste que en el este, y densidad intermedia al sur de Almería en la zona centro (Capítulo 8).

En las áreas del mar de Alborán las estimas de densidad se mantienen bastante estables a lo largo de los años, desde 1992 en Almería meridional y desde 2000 en Alborán occidental, sin tendencias detectadas. Esto puede sugerir que en el mar de Alborán (o, más exactamente, en la zona norte del mar de Alborán) la población de delfines comunes hasta ahora va bien, por lo menos durante el período de tiempo que abarca este estudio. Por otra parte, es de preocupar la caída drástica en densidad de delfines comunes en el Golfo de Vera después de 1996 a alrededor de un tercio de la estimada entre 1992 y 1995 (Capítulo 8).

El patrón general es siempre el mismo en todos los modelos, independientemente del área o los años modelizados (a excepción de 1999): densidad más alta de animales hacia el extremo occidental del mar de Alborán con un segundo pico al sur de Almería, y densidades más altas alrededor de la caída de la plataforma (100-400m), con un segundo pico más ligero en aguas profundas (800-1200m), mostrando así una distribución bimodal.

Hay un cambio estacional en la distribución y densidad durante los meses de invierno (octubre a mayo). Este cambio se refleja en una densidad más baja para los meses del invierno debido a que los grupos son más pequeños, y hay mayor densidad de grupos hacia aguas más profundas. El mismo cambio de patrón ocurrió durante el verano de 1999, cuando se detectó una fuerte caída en temperatura superficial del mar durante algunos días. En los Capítulos 8 y 9 se discuten las posibles razones para estos cambios, relacionadas posiblemente con cambios en la disponibilidad de presas en estos meses.

Siempre con densidades más altas hacia el oeste, los grupos con crías tienden a preferir aguas más costeras y los grupos sin crías aguas más profundas. En ambos casos, sin embargo, se observa un segundo pico de densidad más pequeño en aguas profundas y costeras respectivamente. Los grupos simples (monoespecíficos) siguieron el patrón general de densidades más altas alrededor de la caída de la plataforma al sur de Almería y sobretodo hacia el extremo occidental del área (Alborán occidental), mientras que las densidades más altas de animales en grupos mixtos (mezclados con delfín listado) se dan en las aguas profundas del sur de Almería y en la sección occidental del área de estudio. En la sección más occidental, sin embargo, la densidad más alta se da también alrededor del borde de la plataforma. Las densidades más altas de animales alimentándose (en horas diurnas) se dan en las aguas más costeras. La densidad de los animales clasificados como ‘remoloneando’ sigue el patrón general indicado más arriba, con las densidades más altas hacia el oeste y alrededor del borde de la plataforma, con un segundo pico más pequeño en aguas profundas, al igual que los animales que se encuentran desplazándose. Hay un fuerte contraste entre los patrones de densidad de grupos y de tamaños de grupo en grupos socializando, produciendo un fuerte patrón bimodal, con más grupos más pequeños en aguas profundas, y menos grupos pero más grande en aguas menos profundas. Este bimodalidad en los grupos socializando desaparece al estratificarlos en grupos simples y mixtos, aunque las diferencias no son demasiado fuertes: densidad más alta de animales socializando en grupos simples a lo largo de las aguas menos profundas del borde de la plataforma, y densidad más alta de animales socializando en grupos mixtos en aguas más profundas, pero sobretodo al oeste.

En general, se puede concluir que las áreas del borde de la plataforma, y especialmente de Málaga y del sur de Almería, parecen ser el hábitat preferido para esta especie en la mayoría de las situaciones, pero principalmente al alimentarse y cuando hay crías en los grupos. Esto es probablemente así debido a ser el hábitat principal para lo que parece ser las especies principales de su dieta en el área del estudio.

Este trabajo constituye la primera estima de abundancia de delfines comunes en el mar Mediterráneo y, además, el primer análisis en profundidad en Europa sobre preferencia de hábitat, en función no sólo de factores extrínsecos sino también intrínsecos. Por lo tanto, se ha recogido gran cantidad de información nueva que constituye una importante línea de base para los esfuerzos de conservación de esta especie.

11.3. HACIA LA CONSERVACIÓN DE LOS DELFINES EN EL MAR DE ALBORÁN

Los trabajos realizados en este estudio han contribuido significativamente a la conservación de los cetáceos en el mar de Alborán, y el Mediterráneo en general. Se han propuesto varias Áreas Marinas Protegidas en base a la información presentada aquí. En concreto cuatro LIC (uno ya aprobado en Murcia y otros 3 propuestos en Andalucía) y una ZEPIM. Se han sentado también las bases para la elaboración del Plan de Conservación del delfín mular en Andalucía y Murcia, y se ha colaborado activamente en la elaboración del Plan de Conservación del delfín común en el Mediterráneo de ACCOBAMS. Se han llevado a cabo también ya una serie de medidas de gestión, y se ha trabajado, tanto de forma activa como por pasiva, en la sensibilización pública, siendo éste un factor fundamental a la hora de poner en práctica acciones de conservación.

11.3.1. Propuestas de Área Marinas Protegidas

En base a los resultados obtenidos a lo largo de los catorce años que dura este estudio, con la información recopilada y una vez realizada la identificación de las áreas de interés para la conservación de los cetáceos, junto con el estudio del entorno socioeconómico y de las presiones humanas que actúan sobre las poblaciones estudiadas en dichas áreas, se ha podido llegar a unas propuestas de designación de áreas marinas protegidas (AMPs), cada cual bajo la categoría de protección más afin a sus características o necesidades: LIC (para el caso de areas importantes para el delfín mular o la marsopa), ZEPIM (en el caso de que hubiera áreas importantes y representativas para toda la zona biogeográfica Mediterránea), u otras nuevas dadas sus especiales características.

Dado que uno de los objetivos del "Proyecto de identificación de las áreas de especial interés para la conservación de los cetáceos en el Mediterráneo español" fue el de cumplir con la finalidad que propugnan tanto el Convenio de Berna, la Directiva Hábitats de la Unión Europea, el Convenio de Barcelona, el Protocolo sobre las zonas especialmente protegidas y la diversidad biológica en el Mediterráneo y el Acuerdo sobre la Conservación de los Cetáceos del mar Negro, el mar Mediterráneo y la Zona Atlántica Contigua (ACCOBAMS), a la hora de seleccionar las áreas se tuvo en cuenta los requerimientos de dichos marcos de conservación (Capítulo 6).

Este estudio, por lo tanto, ha hecho una contribución importante a la puesta en práctica de la Directiva Hábitat por parte del gobierno español, proporcionando una base científica para la definición de LIC con el objeto de promover la conservación del delfín mular en el sur de España. También proporciona valiosa información para contribuir a los objetivos de conservación y a los planes de gestión para estas áreas.

Este trabajo también ha destacado las áreas que son importantes para grupos de especies de cetáceos. La creación de AMPs que cubran los 'hot spots' identificados para los cetáceos, apoyado por el desarrollo y la puesta en práctica de una estrategia eficaz de gestión, debería contribuir a la conservación de estas especies en la región con más eficacia que la gestión de especies aisladas. Además, los resultados de este trabajo han llamado la atención de varias administraciones del gobierno y organizaciones internacionales de conservación sobre la importancia del mar de Alborán para la conservación de cetáceos y de la biodiversidad en general, no solamente para España pero también para el mar Mediterráneo en su totalidad. El plan de conservación de ACCOBAMS para el delfín común mediterráneo incluye el mar de Alborán como una de las áreas claves para la conservación de esta especie y se están diseñando acciones de gestión para este propósito (Bearzi *et al.* 2004). Este trabajo también ha contribuido a los esfuerzos comunes de varios institutos de investigación y de otras organizaciones (Instituto Español de Oceanografía, Universidad de Málaga, Sociedad Española de Cetáceos, UICN y WWF) para promover la creación de un AMP en el mar de Alborán para la conservación no solamente de las especies de cetáceos, sino de toda la biodiversidad y los procesos ecológicos de esta área.

Es esencial que una ciencia robusta proporcione la base para la designación del área y la monitorización de los logros. Este trabajo proporciona no solamente un análisis científico robusto para la designación de AMPs sino también una herramienta para la medida objetiva de su éxito mediante la monitorización para determinar el uso futuro del hábitat tanto en el interior como en el exterior las áreas seleccionadas.

El siguiente paso será la elaboración de unos planes de gestión para estas áreas marinas protegidas, para lo cual se han puesto en marcha dos procesos paralelos. Por un lado se inició un proceso de establecimiento de los objetivos de conservación, un análisis de la situación y de las potenciales amenazas y una priorización de acciones correctoras. Por otro lado se realizaron una serie de giras costeras con el fin de identificar a las personas y colectivos que debieran ser actores en cada una de las acciones del plan de gestión con el fin de implicarles en un proceso cuyo fin es la elaboración de un plan de gestión basado en datos científicos y consensuado por todas las partes. Este proceso que en un principio se había previsto lento, con el fin de evitar pasos en falso, ha ido en el caso de algunas acciones mucho más rápido al detectarse sinergias y posiciones comunes, permitiendo avances significativos en aspectos concretos de la conservación de cetáceos. Estos planes de gestión se elaborarán en detalle durante el primer semestre de 2006.

Una consideración importante para la conservación de los cetáceos en el mar de Alborán es que algunas acciones de gestión podrían y deben ser puestas en ejecución haya o no AMPs específicas designadas. Algunos ejemplos de esto se dan en el Capítulo 6.

11.3.1.1. Propuestas de LIC

Actualmente ha sido ya aceptado por el gobierno español en 2000 un LIC para delfín mular en la región de Murcia (ES6200048 Medio Marino) como resultado de una propuesta de la SEC (Sociedad Española de Cetáceos), de acuerdo con los datos recogidos durante este estudio de 1992 a 1998 (Figura 11.1).

En el Capítulo 6 se hace una breve descripción de las 3 nuevas propuestas de LIC que se han realizado en el marco del 'Proyecto Mediterráneo': Estrecho de Gibraltar, Sur de Almería e Isla de Alborán (Cañadas *et al*. 2005) (Figura 11.1), y un resumen de algunas medidas de gestión propuestas para paliar las amenazas detectadas en cada una de ellas.

No se recoge la presencia de delfín mular ni marsopa en ninguno de los LIC propuestos en la actualidad por la Comunidad Autónoma Andaluza. Es por tanto no sólo obviamente insuficiente la situación actual sino necesaria la declaración de LIC que cubran al menos un mínimo de área de distribución de estas especies del Anexo II de la Directiva Hábitats, cuya presencia en esta zona, dados los conocimientos actuales, es de gran importancia y amplia distribución. El LIC de Murcia, ya aprobado por la Región de Murcia, (ES6200048 Medio Marino) si cubre, sin embargo, el rango de distribución del delfín mular en la zona del sur de Murcia.

Las nuevas tres áreas propuestas son aquellas con mayor densidad de delfín mular, representando según los estudios realizados los hábitats de mayor interés para la conservación de esta especie. La designación de estas áreas como áreas marinas protegidas, y en especial una adecuada gestión de las mismas, son necesarias para poder mantener un estado de conservación favorable para esta especie. Aunque los LIC son solo directamente relevantes para el delfín mular y la marsopa, muchas de las amenazas reales y potenciales para ellas también son compartidas por otras especies de cetáceos. Indirectamente, por lo tanto, los planes de gestión desarrollados para los LIC pueden beneficiar también a otros cetáceos que ocupan las mismas áreas.

Es importante resaltar, como ya se dice en el Capítulo 1 (Introducción), que es absolutamente fundamental el desarrollar unos planes de gestión adecuados y eficaces para cada una de las áreas marinas protegidas propuestas. Estos planes pueden tener un proceso y una estructura muy similares al Plan de Conservación que se expone en el apartado siguiente, pero enfocado a las características concretas del área donde se propone el LIC.

Por lo tanto, gracias a los datos obtenidos a lo largo de este trabajo, se propuso un LIC, ya aprobado, en Murcia, y se han propuesto otros tres en Andalucía (Figura 11.1). Los tres LIC propuestos están siendo evaluados en estos momentos por la Junta de Andalucía y por el Ministerio de Medio Ambiente, quienes han de decidir aun quien posee las competencias adecuadas para tomar la decisión y llevar a cabo su gestión.

11.3.1.2. Propuesta de ZEPIM

Para el Mediterráneo, el instrumento ZEPIM representa una medida complementaria a la Directiva Hábitats potencialmente importante para la conservación y la gestión adecuadas de poblaciones de cetáceos y de sus hábitats.

Habiéndose detectado mediante el análisis socioeconómico superficial (Capítulo 4) una serie de amenazas potencialmente importantes que requerirían la adopción de medidas de gestión a escala mayor de la que podría quedar cubierta por una adecuada red de Lugares de Interés Comunitario (LIC), se presentó la propuesta de creación de una Zona de Especial Protección del Mediterráneo ZEPIM a las autoridades competentes. La zona propuesta como ZEPIM abarca la mitad norte del Estrecho de Gibraltar (pero incluyendo las aguas de la Comunidad Autónoma de Ceuta) y del mar de Alborán (incluyendo la Isla de Alborán), y las aguas del Golfo de Vera incluyendo la zona sur de la región de Murcia (Figura 11.1). El ZEPIM propuesto incluye áreas costeras y oceánicas (incluyendo los LIC propuestos). De acuerdo con los análisis realizados, contiene hábitats preferidos para varias especies de cetáceos y se ajusta a los criterios específicos de ZEPIM importantes para cetáceos, así como a los criterios generales (Capítulo 6).

Los resultados de los diversos análisis realizados mostraron claramente la particular relevancia de la cuenca de Alborán y el Estrecho de Gibraltar en el marco de la conservación de los cetáceos, ya no solo en España sino para la zona biogeográfica mediterránea. La importancia de la región para la migración y alimentación de estas especies la convierten en un eslabón esencial para cualquier posible recuperación de las poblaciones actualmente más vulnerables y fragmentadas en las aguas mediterráneas.

Por ejemplo, la ZEPIM propuesta tiene la tasa de encuentro más alta del Mediterráneo para los calderones negros (Cañadas and Sagarminaga, 2000) y uniría los núcleos de población de esta especie en el Estrecho de Gibraltar y en el área de Almería-Golfo de Vera. El mar de Alborán es actualmente el hábitat remanente más importante para el delfín común en el Mediterráneo (Bearzi *et al*. 2003). Las áreas predichas de importancia para el delfín común (Capítulo 6) no cubiertas por los LIC propuestos incluyen las aguas costeras de Málaga y de Granada. En las aguas profundas del sur de Almería, hay una alta diversidad de cetáceos y los análisis demostraron claramente su importancia para las especies oceánicas (Capítulos 5 y 6), las cuáles son principalmente teutófagas (ballenas picudas, calderón gris, calderón negro, cachalote y delfín listado) así como para delfines mulares y comunes. Esta ZEPIM puede también desempeñar un papel importante conectando los LIC propuestos para el delfín mular así como con el LIC existente en Murcia. Finalmente, parece ser una zona de paso importante en las migraciones del rorcual común entre el Mediterráneo y el Atlántico (Guinet *et al*. in press).

La importante productividad y biodiversidad de la cuenca de Alborán, es sin lugar a dudas la explicación principal de la gran diversidad de especies de cetáceos así como del actual estado de conservación de estas poblaciones. Esta situación realmente no es más que el reflejo normal de una región marítima cuya relevancia va mucho más allá de la conservación exclusiva de especies emblemáticas como cetáceos y tortugas. Desde su función como “motor hidrológico” del Mediterráneo occidental, pasando por sus características geográficas hasta la riqueza y diversidad de sus redes tróficas nos muestran claramente la importancia de Alborán para la conservación del Mar Mediterráneo a escala global.

Los requerimientos espaciales de especies marinas pelágicas como las objeto de este estudio son de gran escala y muestran claramente la importancia de un diseño de áreas marinas que sea adecuada. Esto lleva también a salirse de un enfoque demasiado cernido sobre determinadas especies prioritarias olvidando que no constituyen más que un eslabón de unas cadenas tróficas complejas.

Una gestión integrada aplicada a toda al área entera sería probablemente más significativa para la conservación de las especies de cetáceos que el desarrollo de los planes específicos de gestión para AMPs relativamente pequeñas como son los LIC. Incluso si los planes de gestión se desarrollan y se implementan con éxito en AMPs pequeñas, sin una cierta conectividad entre ellas, sus objetivos de conservación no podrían ser conseguidos en su totalidad.

11.3.1.3. Propuesta de Área Oceánica

Se realizó una propuesta de protección, al Ministerio de Medio Ambiente, para la denominada ‘Área Oceánica’ en el marco del ‘Proyecto Mediterráneo’ (Figura 11.1). Hay que considerar el carácter innovador de ésta propuesta, al tratarse de un área marina oceánica, alejada de la costa. En general, las áreas oceánicas de importancia para los cetáceos han recibido poca atención en términos de conservación, aunque existen algunos precedentes en el Atlántico Noroeste (el Stellwagen Bank, frente a las costas de Massachussets, y el Cañón del Gully, en Nueva Escocia) y el Santuario de Cetáceos ‘Pelagos’ del mar de Liguria en el Mediterráneo (www.cetaceansanctuary.com). La problemática de designar para su protección determinadas zonas externas a las aguas territoriales y el hecho de ser áreas exclusivamente oceánicas, sumado al escaso conocimiento que ha habido sobre las mismas ha impedido hasta ahora que se hayan declarado zonas protegidas con estas características. Sin embargo la Estrategia nacional de biodiversidad y desarrollo sostenible ya dispone la importancia de crear categorías de protección estrictamente marinas y se vislumbra la importancia de las áreas marinas que no tienen porque estar indefectiblemente ligadas a costa ya que esto dependerá del objeto de protección que se requiera. Es pues éste un problema que se ha de resolver y que no ha de impedir el proponer una zona marina a proteger con estas características si la importancia del sitio así lo demanda.

Como se demuestra en el Capítulo 6, se encuentra en la zona de aguas profundas al sur de la bahía de Almería una gran diversidad de especies y los modelos muestran claramente su especial relevancia para la conservación de algunas de éstas que se concentran en los entornos de la isóbata de los mil metros. Así, es ésta una zona de gran interés para las ballenas picudas, para el calderón gris, el calderón negro, el cachalote y el delfín listado, además de contar con la presencia también de delfín mular (que escapa a las propuestas de LIC) y delfín común.

Cabe resaltar sobretodo la importancia de estas aguas para algunos miembros de la familia de los Ziphiidae. Aunque estas especies no estén incluida en los anexos de la Directiva Hábitats o en el Catálogo Nacional de Especies Amenazadas, principalmente por falta de datos científicos, resulta importante resaltar la relevancia de esta zona con el fin de proponer medidas de gestión con respecto a la utilización de sonares y explosiones submarinas tanto de uso militar como científico. Esto es especialmente importante para las ballenas picudas, las cuáles son vulnerables a ciertas actividades militares (Frantzis1998; Jepson *et al.* 2003). Estas especies tienen la distribución más restringida en el área de estudio, y en general su distribución se reduce principalmente al área oceánica del sur de Almería. Se estima que el principio de precaución debería prevalecer en estos momentos con el fin de evitar fenómenos de mortandad masiva de estas especies, por lo que se inició la creación de una vía de comunicación con el Ministerio de Defensa con el fin de poner a disposición de la Armada española, la OTAN y la Dirección General de Marina Mercante los datos científicos necesarios para evitar o reducir el impacto de actividades que puedan generar fuentes de contaminación acústica potencialmente peligrosas.

Esta área, por otro lado, constituye un nexo de unión entre los LIC propuestos del sur de Almería y la Isla de Alborán (ver Capítulo 6), constituyendo así también un corredor para los desplazamientos de delfines mulares entre ambas áreas.

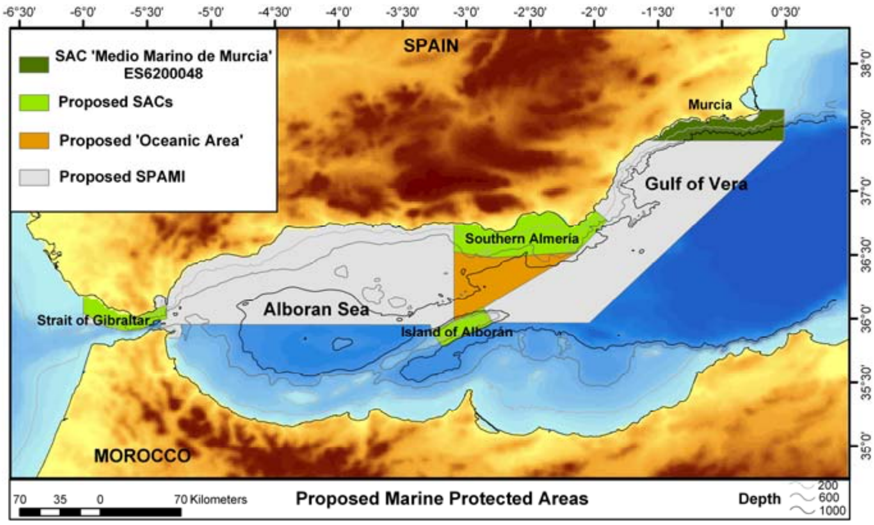

Figura 11.1. Áreas Marinas propuestas a lo largo de este trabajo.

11.3.2. Plan de Conservación para el delfín común

La revisión del estado del delfín común en el Mediterráneo ha sido uno de las prioridades de ACCOBAMS desde su primera reunión de las partes en 2002. Los datos recogidos en el mar de Alborán y el Golfo de Vera a través del trabajo de esta tesis fue parte de un primer paso en esta dirección con su contribución a la publicación de un artículo que se centra en la ecología, estado y conservación de los delfines comunes mediterráneos (Bearzi *et al.*, 2003). Este artículo proporcionó el fondo científico para la inclusión de la población mediterránea de delfín común en la Lista Roja de animales amenazados de la UICN.

Siguiendo una recomendación del comité científico de ACCOBAMS durante su la primera reunión (Túnez, 2002), el Secretariado de ACCOBAMS comisionó a un pequeño grupo de científicos expertos en la materia, incluyendo el autor de esta tesis, para desarrollar un "Plan de Conservación del delfín común del Mediterráneo" (Bearzi *et al*. 2004). Este plan, revisado por el comité científico de ACCOBAMS reconoce que: ”1) la formulación y la recomendación de las medidas de gestión resulta difícil debido a la actual falta de comprensión sobre la(s) causa(s) del declive del delfín común en la región; 2) sin embargo, se puede asumir que la mayoría de los factores son responsables de dicho declive derivan de actividades humanas en esta región marina que son insostenibles e ilegales (por ejemplo, sobrepesca, uso de redes de deriva, contaminación, etc.); 3) el destino de los delfines comunes del Mediterráneo depende de lo voluntad política de los Estados miembros para tomar acciones responsables y preventivas para atenuar las amenazas antropogénicas conocidas; 4) las principales medidas de gestión que beneficiarán a los delfines comunes se encuentran ya recogidas en la legislación y tratados existentes; 5) si todas esas medidas, invocadas por instrumentos jurídicos internacional, regionales y nacionales existentes para la gestión del Mediterráneo, se implementasen en su totalidad y se hiciesen cumplir, el declive de delfín común probablemente cesaría.”

Este Plan de Conservación concluye básicamente que "honrar las obligaciones existentes con respecto a la gestión de las pesquerías, la contaminación y otras formas de degradación del hábitat representa la acción más importante para detener el declive del delfín común del Mediterráneo y facilitar su recuperación", y se centra en tres líneas de acción:

En primer lugar, en lo referente a las obligaciones existentes de los Estados miembros, el plan aboga fuertemente por que tales obligaciones sean respetadas y puestas en ejecución sin más retraso.

En segundo lugar, el plan incluye una serie de acciones de legislación, gestión, investigación, creación de capacidad y sensibilización y educación que específicamente tratan el problema de la conservación del delfín común en el Mediterráneo, con atención especial a las áreas con densidades considerables y que parecen contener hábitats importantes para la especie.

En tercer lugar, el plan establece una selección inicial de ocho Áreas de Importancia para la Conservación (ACIs) donde las acciones de gestión se deben emprender inmediatamente, centrándose en la investigación para completar los vacíos de conocimiento actuales que dificultan la identificación de las estrategias eficaces de conservación. La selección del AIC correspondiente al área del mar de Alborán y al Golfo de Vera fue basada en el trabajo contenido en esta tesis, debido tanto a la alta densidad de grupos como a los grandes tamaños de grupo (Capítulos 5 y 6), confirmado luego por los estudios descritos en los capítulos 8 y 9. Estos resultados destacaron la especial relevancia de esta zona en el contexto de los esfuerzos de conservación del delfín común Mediterráneo.

El Plan, con una fase inicial de puesta en práctica de cinco años, establece una prioridad para las acciones de gestión en las ACIs. Propone una estrategia inicial alternativa simplificada y más eficiente que el establecimiento de AMPs basándose en: "1) el estado de conocimiento actualmente incompleto sobre la distribución del delfín común y sus movimientos a largo plazo, 2) la naturaleza intrínsecamente dinámica y probable gran extensión espacial del hábitat usado por estos animales a lo largo de todo el año, y 3) la lentitud y complicación institucional y gubernamental en los asuntos que afectan al diseño, aplicación y puesta en práctica de AMPs "tradicionales", que se espera sean mejoradas en el futuro.”

Además de las acciones para promover un enfoque de la gestión que facilite el futuro establecimiento de redes de AMPs o de grandes AMPs para proteger a los delfines comunes mediterráneos, diseñadas en base a información apropiada sobre su ecología, distribución, movimientos y necesidades espaciales, el plan también se centra en la necesidad de la creación de capacidad y de la educación. Estas acciones responden al interés común expresado por las partes contratantes de ACCOBAMS que consideran el “difundir las capacidades de investigación y de monitorización en toda la región un desafío oportuno y una de las prioridades más altas en relación a la conservación de los cetáceos” (ACCOBAMS, 2002).

11.3.3. Plan de Conservación para el delfín mular

El objetivo general del Proyecto LIFE-Naturaleza “Conservación de cetáceos y tortugas en Murcia y Andalucía” (LIFE02NAT/E/8610) es el contribuir a los compromisos de España con la Directiva Hábitats de la Unión Europea (C.D. 92/43/EEC) en relación a la conservación de tres especies pelágicas marinas del Anexo II de la Directiva, el delfín mular, la marsopa común (*Phocoena phocoena*) y la tortuga boba (*Caretta caretta*) en las regiones de Andalucía y Murcia.

Para alcanzar este objetivo, el proyecto se desarrolló a tres niveles:

- Desarrollar varias técnicas de estudio de poblaciones de cetáceos y tortugas marinas para establecer las herramientas más efectivas para la **MONITORIZACIÓN** a largo plazo de las tendencias en el estado de conservación de estas especies y sus hábitats
- Desarrollar Planes de **CONSERVACIÓN** para las especies objetivo así como Planes de **GESTIÓN** para los LIC propuestos en la región
- Crear un vínculo entre la monitorización, conservación y gestión con los diferentes usuarios para **IMPLICARLES** en el procesote gestión, para asegurar que los objetivos de conservación de la biodiversidad y el desarrollo económico sean compatibles.

Por otra parte, bajo la regulación española se requiere la elaboración de un Plan de Conservación para las especies catalogadas como ‘vulnerables’ en el Catálogo Nacional de Especies Amenazadas (como el delfín mular), que se aplica a toda la región.

Por esta razón, el desarrollo de un Plan de Conservación para el delfín mular en Andalucía y Murcia, descrito en el Capítulo 10, es parte del trabajo de esta tesis. Pero el proceso descrito para este Plan de Conservación no es válido sólo para esta especie en particular ni esta región en particular. Puede ser aplicable a cualquier especie en cualquier región. Por ejemplo, el mismo proceso y estructura están siendo aplicados al Plan de Conservación de la tortuga boba en el mismo proyecto LIFE-Naturaleza. También está siendo tomado como modelo de cómo deberían ser dirigidos los esfuerzos de conservación, y de cómo se debería desarrollar un plan de conservación, en el marco de un proyecto para la conservación del delfín mular en las aguas europeas del Atlántico nor-oriental que está siendo preparado bajo la coordinación de la Universidad de Cork (Irlanda). Por otra parte, este Plan de Conservación será usado por el Ministerio de Medio Ambiente como modelo para el desarrollo de la Estrategia Nacional para la conservación de esta especie en todas las aguas españolas.

11.3.4. Establecimiento de líneas de base para la monitorización a largo plazo

En el Capítulo 1 (Introducción) se destacó la importancia de la obtención de información de base y de realizar un plan de monitorización. Los estudios realizados en el contexto de esta tesis, que se han ido convirtiendo gradualmente en un proceso de conservación en la forma del proyecto LIFE-Naturaleza, ha permitido el establecimiento de mucha información de base para la gestión futura. Estos estudios también han destacado la importancia de adaptar el establecimiento de la información de base y del análisis de las tendencias, a las fluctuaciones naturales de las poblaciones de delfín en el ambiente marino, tan extraordinariamente extenso y dinámico.

En resumen, este trabajo ha proporcionado información de base sobre: a) hábitats preferidos y densidad relativa para 7 especies de odontocentos en el norte del mar de Alborán y el Golfo de Vera (Capítulos 5 y 6); b) estima de abundancia para el delfín mular en la parte norte del mar de Alborán, y en particular en la sub-área del sur de Almería (Capítulo 7); c) variaciones en la abundancia estimada y en la preferencia de hábitat del delfín mular en la zona sur de Almería (LIC propuesto) a lo largo de 12 años (Capítulo 7); d) estima de abundancia de delfín común en el norte del Mar de Alborán y Golfo de Vera, incluyendo estimas para las sub-áreas de Alborán occidental, sur de Almería y Golfo de Vera (Capítulo 8); y e) preferencia de hábitat del delfín común según diversos estados del comportamiento y otros factores intrínsicos en el norte del Mar de Alborán y Golfo de Vera, incluyendo los hábitat preferidos para alimentación y para grupos con crías (Capítulo 9).

Como se destaca en el Capítulo 7, las estimas de abundancia representan el número medio de delfines en las áreas de estudio durante los períodos definidos, no el tamaño de la población que usa las áreas. El área del estudio no es cerrada, sino que hay movimiento de individuos dentro y fuera de las áreas adyacentes. Pero en términos de la monitorización del estado de conservación dentro de un área definida como un LIC, estamos interesados en si el número medio de animales que usan el área cambia a lo largo del tiempo. Por lo tanto, si se utilizan los mismos métodos a lo largo de los años, las estimas obtenidas tienen son valiosas para la monitorización de cambios en abundancia dentro del área de estudio.

Al tratar con el área de Alborán, cuatro o cinco años de estudio es un período demasiado corto para detectar cualquier tendencia en abundancia y se requiere una monitorización a más largo plazo. Pero en el resto del área (sur de Almería y Golfo de Vera), 12 a 13 años de estudios están resultando ya útiles en términos de la monitorización de las tendencias durante este período, y demuestra que los métodos usados en este trabajo son útiles para este objetivo.

En el caso del delfín mular, la larga serie de datos permitió la documentación de un aumento y disminución subsiguiente en la abundancia que es probablemente el resultado de fluctuaciones naturales (Capítulo 7). Los resultados destacan la importancia de estudios a largo plazo para entender las variaciones en abundancia en un área dada, y la necesidad de un adecuado programa de monitorización a largo plazo. En el caso del delfín común, la larga serie de datos ha permitido mostrar un declive en abundancia en el Golfo de Vera, mientras que la densidad aparece estable en la zona norte del mar de Alborán a lo largo de este período de tiempo.

Idealmente, el programa de monitorización se debe desarrollar de forma que permita no solamente la detección de cambios en la abundancia a largo plazo, sino también la diferenciación entre fluctuaciones naturales y tendencias reales en la abundancia de la población. Las fluctuaciones observadas en la abundancia de delfín mular del sur de Almería recalcan la necesidad de que el programa de monitorización cubra no solamente el LIC propuesto sino también un área más amplia fuera de él para mejorar nuestra comprensión sobre las fluctuaciones o tendencias en abundancia y cambios en la distribución. Esta información puede tener implicaciones importantes para la gestión de las áreas protegidas (Wilson *et al.* 2004). De la misma manera, el declive de delfín común en el Golfo de Vera demuestra la importancia de ampliar la monitorización a áreas más amplias para poder entender los cambios (que en este caso no parecen ser debidos a una fluctuación natural sino al impacto de una actividad humana desarrollada recientemente): ¿a dónde han ido los delfines cuando el área ya no resulta adecuada? Este acontecimiento también demuestra lo esencial que es la monitorización de las actividades humanas para ser capaces de identificar posibles vínculos entre cambios en el estado de conservación de la población y cambios en las actividades humanas.

11.3.4.1. Monitorización en Andalucía y Murcia

La monitorización de las poblaciones en Andalucía y Murcia continuará utilizando la misma metodología empleada hasta el momento (con el fin de que los datos sean comparables), aunque con mejoras sustanciales e información añadida por otros medios como la foto-identificación (que ya se está llevando a cabo de forma paralela a esta tesis con los datos recogidos por este estudio) y análisis de marcaje-recaptura. El área central para la monitorización futura será la zona del sur de Almería, tanto por razones logísticas como por ser el área con la mayor diversidad de especies, densidad más alta de delfín mular y una de las más altas para delfín común. Sin embargo, se realizará una monitorización periódica también en el Golfo de Vera (enfocada especialmente sobre las tendencias en la abundancia de delfín común) y en sector oriental del mar de Alborán.

11.3.4.2. Monitorización en la Isla de Alborán

Durante este trabajo se hicieron varias incursiones a la Isla de Alborán, y se pudo constatar que ésta representa una zona de gran interés para el delfín mular además de para otras especies (Capítulo 6), y se determinó la necesidad de realizar una monitorización a largo plazo en esta zona. En el esfuerzo por desarrollar técnicas de monitorización económicamente efectivas, la oportunidad prestada por la Secretaria General de Pesca Marítima de utilizar las instalaciones del Faro de la Isla de Alborán y las singladuras de la patrullera “Isla de Nubes” para el desarrollo de un programa de monitorización de delfín mular constituye una contribución de gran importancia en el marco de la política comunitaria de conservación de la biodiversidad marina.

Durante 2005 se presentó a la Secretaria General de Pesca Marítima un proyecto de monitorización del delfín mular en aguas de la Isla de Alborán, que fue aprobado. Este proyecto se encuentra en estos momentos en fase de organización del trabajo de campo y comenzará a lo largo de2006.

El objetivo global de este programa es la obtención de datos científicos para la gestión y monitorización de la población de delfín mular en aguas de la Reserva de Pesca de la isla de Alborán. Se consideran dos fases:

1) Obtención de líneas de base sobre la población de delfín mular en aguas de la isla de Alborán: a) identidad de la población, b) estima de abundancia y c) distribución y uso de hábitat.

2) Monitorización a largo plazo de la población de delfín mular en aguas de la isla de Alborán: a) estima de abundancia y tendencias, b) distribución y uso de hábitat, en particular en relación con las zonas y barcos de pesca de arrastre, y c) datos de dinámica de poblaciones.

Para conseguir los objetivos, se realizarán avistamientos desde tierra (desde la plataforma construida *ad hoc* en el faro de la isla), y transecto lineal con la patrullera “Isla de Nubes”.

11.3.5. Sensibilización pública

Los delfines pueden ser una herramienta asombrosa para la educación, y como tal se han utilizado a lo largo de los años que dura este trabajo. Imágenes y sonidos, subproducto de este estudio, se han utilizado extensamente para las conferencias públicas, artículos y otros materiales educativos. Sin embargo, hay que resaltar que el *leit motiv* de estos productos educativos ha sido moverse lejos desde la vista romántica de la especie emblemática para demostrar la importancia del ecosistema marino en su totalidad incluyendo al hombre. En este sentido se ha hecho hincapié con frecuencia en que mientras que los delfines vendrán o irán de esta región dependiendo de su estado de conservación y de su capacidad de carga, otros valores naturales o culturales como por ejemplo las praderas de *Posidonia*, las pesquerías artesanales, etc. es probable que desaparezcan para siempre si no tomamos acción rápidamente.

Otro aspecto usado en todos los productos educativos ha sido resaltar que es con acciones individuales que los cambios grandes pueden ser realizados. Por atraparte, con el Proyecto LIFE-Naturaleza hemos intentado demostrar a los usuarios del mar y al público nuestra opinión de la importancia de basar nuestras medidas de conservación en datos científicos. Esto objetivo resulta ser realmente un desafío cuando se compite con organizaciones que usan los mismos animales carismáticos precisamente del modo opuesto.

Las dos formas principales de sensibilización pública que se ha llevado a cabo son: el contacto directo durante las campañas y la prensa.

El contacto directo se realizaba a muchos niveles, desde las autoridades (Guardia Civil del Mar, Aduanas, Inspección Pesquera, autoridades portuarias, etc.) hasta pescadores y turistas. El aspecto estético del barco de investigación resultó ser una herramienta muy útil en este sentido, pues atraía la atención de los paseantes por los puertos, los navegantes, y en general los usuarios del mar que se encontrasen en las cercanías. El *Toftevaag* como pesquero de época ha permitido en muchas ocasiones romper el hielo con el sector pesquero, haciendo posible un acercamiento y un entendimiento que se ha traducido en diversas formas de colaboración. De esta forma, la simple presencia del *Toftevaag* en algunos puertos ha supuesto a nivel local cambios de actitud con respecto a los cetáceos, el medio marino y su conservación. Es de hecho en gran parte esta experiencia la que inspiró la filosofía de la rama educativa del proyecto LIFE, “Todos por la Mar”.

En cuanto a la prensa, la cobertura ha sido muy amplia, tanto en prensa escrita (periódicos y revistas) como audiovisual (radio y televisión), llegando a un sector muy amplio de la población, mostrando la relevancia de los trabajos y el interés del público en los mismos.

11.4. TRABAJO FUTURO

Todo el trabajo desarrollado en esta tesis, resultado de 14 años de investigaciones en la zona de estudio, no finaliza aquí. Aun queda mucho camino por recorrer hacia la conservación de los cetáceos y su medio ambiente en el mar de Alborán y el Mediterráneo en general. Podríamos hablar de 3 líneas paralelas en las que se va a continuar trabajando en los próximos años:

11.2.3.1. Investigación

Como ya se ha comentado, obtener la información de base sobre temas como abundancia y distribución es de fundamental importancia para una conservación efectiva. En este sentido, y aunque ya se ha obtenido esta información para la zona de estudio, dadas las características de alta movilidad de los cetáceos y sus amplios rangos de distribución, es necesario obtener esta información para toda la cuenca Mediterránea con el fin de tener una visión completa de las poblaciones que la habitan, y no sólo de una porción de ellas. Por esta razón, se está planificando ya un censo de cetáceos a gran escala cubriendo todo el mar Mediterráneo de una sola vez (con varios barcos simultáneamente). La organización de este censo ha sido encargado por ACCOBAMS a la autora de esta tesis, y se está trabajando ya en este sentido (Cañadas *et al*. 2004). Con este censo se pretende obtener datos sobre abundancia y uso del hábitat de las especies que habitan el Mediterráneo.

Paralelamente, se seguirán realizando investigaciones en la zona de estudio de esta tesis para obtener nuevas informaciones. En concreto se realizarán estimas de abundancia del delfín mular en el Golfo de Vera (prevista para 2006) y de las otras especies en toda la zona de estudio. También se investigará la influencia de los factores ’intrínsecos’ en la distribución del delfín mular, y se estudiará la estructura social de las distintas especies mediante foto-identificación. Un aspecto importante es que se seguirá investigando en la aplicabilidad de los métodos usados en este trabajo, especialmente el análisis espacial que tan novedoso es en este campo, para mejorarlos y solventar las dificultades encontradas.

11.2.3.2. Monitorización

Como se explica en el apartado 11.2.2.5, se continuará con la monitorización de las poblaciones en la zona de estudio, con las mismas metodologías empleadas hasta ahora (y mejoradas en la medida de lo posible) para mantener una serie temporal larga que contribuya a analizar las tendencias en el estado de conservación de las distintas especies.

11.2.3.3. Gestión y conservación

El Plan de Conservación del delfín mular estará finalizado, y entregado a la Comunidad Europea y las autoridades competentes españolas en Julio de 2006. A partir de entonces, se contribuirá al mismo mediante la monitorización de las poblaciones y de las actividades humanas y mediante la aportación de nuevas informaciones de base. Igualmente se colaborará en la implementación de las acciones de gestión, de creación de capacidad y de sensibilización de dicho Plan que se encuentren a nuestro alcance. Lo mismo se puede decir en relación al Plan de Conservación del delfín común del Mediterráneo de ACCOBAMS, y con los Planes de Gestión de las áreas marinas protegidas propuestas, que serán finalizados también a lo largo de 2006.

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