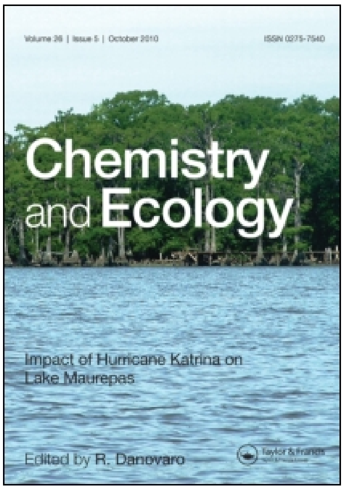

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Fin whales summering in the Pelagos Sanctuary (Mediterranean Sea): Overview of studies on habitat use and diving behaviour

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This paper presents a review and summary of data on fin whales (*Balaenoptera physalus*) in the recently established Pelagos Sanctuary for the Conservation of Mediterranean Marine Mammals. The data presented were collected by the Tethys Research Institute during summers of 1990–1999 during a long-term study on the habitat use and preferences of fin whales in this area, described as their major feeding ground in the Mediterranean. Data on the presence, distribution, habitat use, and diving behaviour are reviewed. The data presented here emphasize the crucial role that the pelagic portion of the western Ligurian Sea plays in the ecology of Mediterranean fin whales and provide impetus for the expeditious implementation of conservation and management measures in the area.

Keywords: Fin whale; *Balaenoptera physalus*; Habitat use; Diving behaviour; Mediterranean Sea; MPA

1. Introduction

The fin whale is the largest mysticete species regularly occurring in the Mediterranean Sea [1]; the species is known to concentrate in specific feeding grounds [2], with the Corso-Provençal-Ligurian basin representing the major feeding ground in the Mediterranean Basin [3]. This species has been examined in several research projects, mainly in the central and western portions and in particular in the Ligurian Sea and Gulf of Lions, using line transect surveys, telemetry, photo-identification, biopsy sampling, and other techniques to study behaviour and habitat use [3]. Genetic analysis of skin samples has provided evidence that Mediterranean fin whales belong to a resident population, characterized by limited gene flow with the North Atlantic conspecifics and residing year-round in the Mediterranean Sea [4, 5]. A comprehensive review of the fin whale in the Mediterranean Sea has recently

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been published [3]. Considerable threats exist for fin whales and other cetacean species living in the region, including, among others: by-catch in driftnet fishing activities, presence of substantial concentrations of toxic xenobiotics in the trophic chain, high levels of maritime traffic, including fast ferries, ships transporting hazardous chemicals, and offshore speedboat competitions [6].

The aim of this paper is to present a review of the various studies by the Tethys Research Institute in the Ligurian Sea during the summer months on the habitat use and preferences of the fin whale and its diving behaviour. Discussion of the data presented and reviewed in this paper focuses on providing concrete recommendations for the conservation of the species and highlighting future research activities needed for the proper management of the Pelagos Marine Protected Area, with particular emphasis devoted to proposing mitigation measures to reduce the risk represented by ship strikes. In addition, the process that led to the establishment of this important MPA—the first to encompass both national and international waters—is presented.

1.1 *Process leading to the establishment of the Pelagos Sanctuary*

Steps taken that led to the establishment of the Sanctuary are summarized in table 1. The first step for the creation of the Sanctuary was the Pelagos Project, submitted in 1990 by the Tethys Research Institute to the 'European Association Rotary for the Environment', which envisaged the creation of a Biosphere Reserve in the Corso-Ligurian Basin, and of an international authority, based in the Principality of Monaco, responsible for the sustainable management of the basin's natural resources. In March 1991, the 'Project Pelagos' was presented to the public in Monaco by the Tethys Research Institute and the European Association Rotary for the Environment. Prince Rainier III was present and strongly supported the idea to create a Sanctuary in the proposed area.

Two years later, on 22 March 1993, the Ministers of the Environment of France and Italy, and the Minister of State of the Monaco Principality, signed a joint declaration in Brussels for the institution of a Mediterranean Sanctuary for marine mammals. In the Sanctuary, all direct takes and intentional harassment of marine mammals were to be forbidden, potentially invasive research activities and whale-watching would be regulated, large-scale pelagic driftnet fishing

Table 1. Steps leading to the establishment of the Pelagos Sanctuary.

1980s	Widespread concern in Italy and France for the impact of pelagic driftnets and other human activities on cetacean populations in the area
1990	The Tethys Research Institute formulates 'Project Pelagos' for a Reserve of the Biosphere in the Ligurian-Corsican-Provençal Basin to protect cetaceans, sponsored by the European Association Rotary for the Environment (AERA)
1991	AERA and Tethys present 'Project Pelagos' in Monaco, in the presence of Prince Rainier III, who embraces the idea
1992	The governments of Italy and France join Monaco in an international effort to establish a marine mammal sanctuary in the area
1993	France, Italy, and Monaco sign a Declaration, in Brussels, for the establishment of a marine mammal sanctuary in the area
1999	France, Italy, and Monaco sign the Agreement, in Rome, on the creation of an international sanctuary for marine mammals in the Mediterranean
2001	The Parties to the Barcelona Convention inscribe the Sanctuary in the List of Specially Protected Areas of Mediterranean Importance (SPAMIs)
2002	The Agreement on the Sanctuary comes into force

banned, offshore speedboat competitions limited and eventually forbidden, and special effort devoted to control and curb pollution harmful to cetaceans.

In the following years, several initiatives were taken to implement the above objectives, including:

- Recommendation 19.92 (Establishment of a marine Sanctuary for large and small cetaceans in the Ligurian Sea, Western Mediterranean) adopted by the IUCN General Assembly, January 1994;
- the mentioning of the Sanctuary in the IUCN Action Plan for the Conservation of Cetaceans;
- a clear reference to the necessity of creating specially protected areas in the high seas, provided for in the Protocol concerning Specially Protected Area and the Biological Diversity in the Mediterranean of the Barcelona Convention, and in the Agreement for the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS), promoted by the Bonn Convention.

On 29 September 1998, the Italian Government officially agreed on a proposal involving the establishment of an international protected area for cetaceans in the Mediterranean Sea—approx. 100 000 km^2 wide—between the continental coast of Italy, Monaco and France, Corsica, and northern Sardinia (figure 1). The Agreement was finally signed in Rome on 25 November 1999 and deposited with the Principality of Monaco. In November 2001, the Parties to the Barcelona Convention inscribed the Sanctuary in the List of Specially Protected Areas of Mediterranean Importance (SPAMI). With the inscription of the Sanctuary in the List

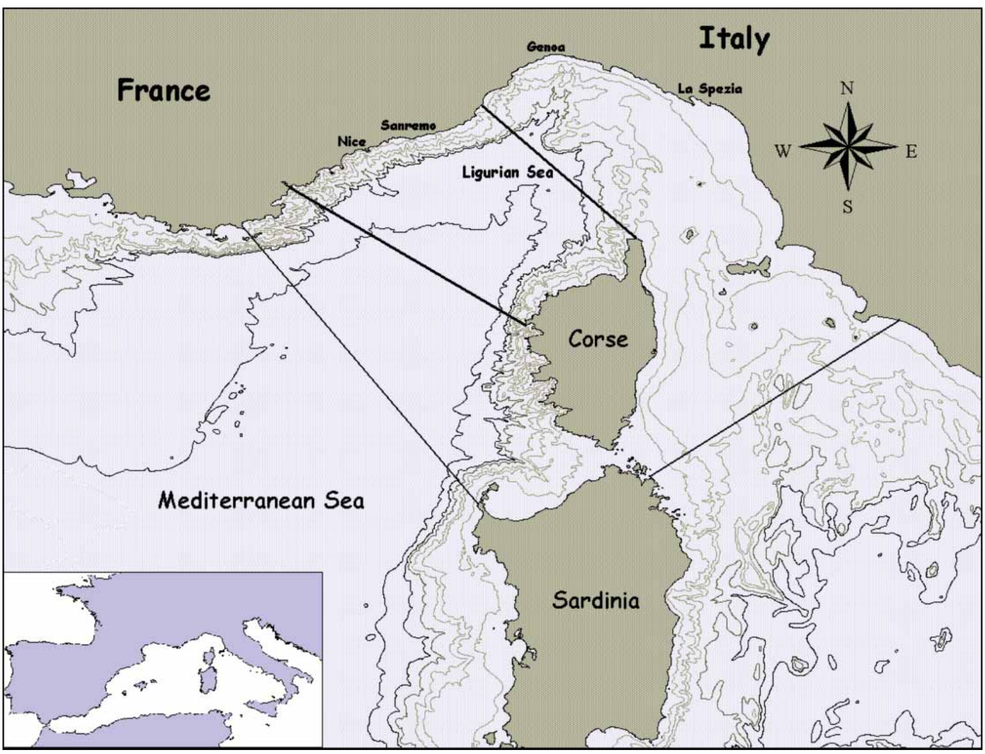

Figure 1. Borders of the Pelagos Sanctuary and the sub-area covered by this research.

of the SPAMIs, 21 Mediterranean States that are Party to the SPA Protocol of the Barcelona Convention became bound by the provisions of the Sanctuary Agreement, practically extending a conservation regime to the Mediterranean high seas. After having been ratified by Monaco in 2000, by France in 2001, during 2002 the Sanctuary Agreement was ratified by the Italian Government and, on 21 February 2002, it officially came into force.

2. Materials and methods

2.1 *Study area*

The region of interest in the greater Ligurian-Provençal basin is delimited to the west by Saint Raphael (43° 25′ N, 006° 50′ E) on the French coast, to the east by Cape Mele (43° 55′ N, 008° 10′ E) on the Italian coast, and to the south by Cape Corso (43° 00′ N, 009° 25′ E) and Girolata (42° 20′ N, 008° 35′ E) on the Island of Corsica (figure 1). This area has a surface of approximately 24 000 km^2 and a mean depth of 2300 m, and is characterized by a well-defined cyclonic circulation active all year round, which enhances strong upwelling currents and maintains surface temperatures distinctly lower than other Mediterranean areas [7]. Due to these oceanographic features, linked to strong atmospheric forcing (i.e. the Mistral wind regime), which causes vertical mixing and nutrient enrichment of surface waters, the Corso-Ligurian basin represents an area of high productivity which supports a substantial biomass of krill, *Meganyctiphanes norvegica*, and therefore hosts a richer cetacean fauna compared with bordering regions characterized by lower primary production [8, 9]. In addition, this area contains a habitat suitable for the breeding and feeding needs of the entire complement of cetacean species regularly found in the Mediterranean Sea.

Results from previous surveys have emphasized that cetaceans in this region are significantly more abundant in comparison with all other seas surrounding Italy and the rest of the western Mediterranean basin [10]. The fin whale population in the western Mediterranean Sea has been estimated at 3500 individuals during the summer, based on line-transect sampling methods [11], with approximately 900 of these whales being concentrated in the Corso-Ligurian Basin [12].

2.2 *Methods*

The data reviewed in this paper were collected from 1990 to 1999 in the Ligurian Sea from dedicated research cruises organized during the summer months by the Tethys Research Institute. The aims of this long-term study were to gain insights on the cetacean populations regularly living in the area, with particular emphasis dedicated to the fin whale. Different research platforms were used for this research, all of them being auxiliary sailing vessels with lengths ranging from 15 to 20 m, with a mean cruising speed of 9–11 km/h. Once spotted, usually by naked eye, the whale or whales were usually approached at a close distance to determine the aggregation size and the presence or absence of juveniles, and to take pictures for photo-identification purposes [13, 14]. Other research techniques were applied during a fin whale sighting, including the collection of biopsy samples for genetic [4, 5] and toxicological analyses [15, 16], the study of behavioural reactions to approaching vessels [17, 18], and the use of telemetry devices (velocity–time–depth recorders) to describe the whales' diving behaviour [19, 20].

3. Results and discussion

3.1 *Habitat use*

During the study period, 870 d were spent at sea, surveying a total of 73 046 km, with 540 sightings of fin whales. In general, whales aggregated in small groups, ranging from one to seven individuals, with a mean group size of 1.74 and a standard error of 0.05.

Barale and colleagues [21] conducted a comparison of *in situ* measurements with historical and concurrent remote sensing data, to describe fin whale abundance and spatial distribution in relation to the surface patterns of temperature and chlorophyll-like pigments.

The satellite data showed that the Ligurian-Provençal basin, where fin whales are most abundant, presents very low surface temperatures in winter [22], followed by a cycle of higher temperatures in summer. This situation is usually associated with low pigments in winter, followed by a pronounced spring bloom [22], a summer minimum of the concentrations, and a very limited secondary bloom in the fall. The authors analysed maps of satellite-derived sea surface temperature and chlorophyll-like pigment concentration to determine the environmental characteristics and variability of the study region. Superimposing fin whale sightings on the concurrent satellite images, a correlation emerged between high sighting frequencies and the local lowest temperatures and highest pigments. In addition, Panigada and colleagues [23] investigated the relationship between fin whale presence and physiographic parameters such as water depth, slope, and distance from the nearest coast, as well as inter-annual patterns in mean aggregation size and encounter rate. To provide fin whale relative abundance indices, and to apply simple habitat selection models, the authors divided the study area into a grid of cells with a surface area of 62.5 km^2. Physiographic variables including mean, range, and standard deviation of depth and slope, and distance from the nearest coastline were calculated for each cell using GIS tools. A Generalized Linear Model (GLM) was used to model the distribution of fin whales in relation to these variables. The GLM revealed that water depth was the most significant variable in describing fin whale distribution, with more than 90% of the sightings occurring in waters deeper than 2000 m. Mean yearly fin whale encounter rates showed no significant differences in the first 5 yr but decreased steadily between 1995 and 1999.

3.2 *Diving behaviour*

Panigada and colleagues presented insights [19, 20] on the diving behaviour of Mediterranean fin whales in the western Ligurian Sea. The aim of the research was to describe the diving habits of fin whales while in their major feeding ground in the Mediterranean Sea, and to relate it to the diel vertical migration of their prey in association with the deep scattering layer. Fifteen fin whales were tagged between 1998 and 2002, totalling over 35 h of dive data. The sensors remained on the body of the whales for different periods of time, varying from a few minutes to more than 8 h. The whales were tagged with two different instruments: a VHF radio transmitter and a velocity–time–depth-recorder. These instruments were remotely attached to the animals by means of a suction cup. Panigada and colleagues [20] reported the results of three successful taggings, lasting a minimum of 6 h each, and with depths of at least 468 m. Two whales started to perform deep dives (>400 m) after 5 p.m., in coincidence with the presumed upward migration of the deep scattering layer (DSL), while until 5 p.m. they remained close to the surface performing shallower dives. Another whale was tagged at 11.50 a.m. and until 6 p.m. performed a series of deep dives. One of the deployed tags remained on the whale until 10 p.m. and showed a steady decrease in diving depth, coinciding with the upward vertical migration of the DSL. Most of the deep dives performed by the three whales involved a series of ascending and descending vertical excursions in proximity to the bottom of each dive, with amplitudes up to 50 m. These spikes have been described for fin and blue whales in the Pacific Ocean and in the Sea of Cortez, and have been interpreted as feeding lunges [24].

4. Conclusion and future recommendations

In the Sanctuary, the fin whale is exposed to several anthropogenic threats, including direct human disturbance due to noise, chemical pollution, and collisions with vessels. Collisions represent a primary source of concern, due to the large number of ferries and commercial ships crossing the waters of the Sanctuary daily [25, 26]. Data on presence, distribution and habitat use and preferences of fin whales in the area will provide valuable information for a management strategy, suggesting mitigation measures to reduce the risk of collision. The identification of possible critical habitats for the fin whale in the area will also represent an important tool and will lead towards a conservation plan for this species.

The analysis performed by Barale and colleagues [21] suggested that the environmental characteristics of the north-western Mediterranean—vertical mixing and consequent primary and secondary productivity—are the key to describing habitat preferences of the fin whales. The relationship between biological and physical parameters proved to be a valuable tool to shed light into the habitat preferences of Mediterranean fin whales in their principal feeding grounds.

The results reviewed in this paper showed that depth was the principal physiographic parameter describing the occurrence of fin whales in the study area, in agreement with other studies carried out in the Mediterranean Sea and in the North Atlantic Ocean [3, 27, 28]. This is in agreement with the presence, in the centre of the Sanctuary, of a large dome of cold water, characterized by high levels of nutrients levels and upwelling currents [29], favouring high levels of prey.

Generalized Linear Models proved to be useful tools to investigate the distribution of fin whales in relation to specific variables. It is recommended that in the future, particular emphasis should be devoted to habitat prediction models, to provide correct estimates of cetacean distribution in relation to the examined variables [30, 31]. We suggest that the relationship between biological and remotely sensed physical parameters (i.e. SST, ocean colour, wind speed, salinity, and wave height) will be investigated further, contributing to the description of specific locations which could be treated as critical habitats for cetacean species present in the Sanctuary area. In addition, it may eventually be possible to forecast areas of high fin whale densities from remote sensing data and the use of habitat selection models [32].

More data are required over a wider area and throughout the seasons to determine the relative abundance and habitat preferences of a wide range of cetacean species in the Pelagos Sanctuary. Moreover, similar research should be conducted in other areas of the Mediterranean Sea, including the Levantine Basin, which, at present, remains poorly monitored and rarely studied with respect to cetaceans. Understanding how Mediterranean cetaceans utilize their habitat will support the management of the Pelagos Sanctuary and will provide the policy makers with useful tools for the establishment of protection zones and for correct plans and schedules for vessels and naval traffic. In addition, the presented data can help identify areas of low fin whale density that, if considered by ship companies in the definition of their routes, may reduce the probability of collisions.

We suggest dedicating more effort to the study of the diving behaviour of this species in the Ligurian Sea, an area quite 'unique' in terms of krill distribution throughout the water column—with depths of more than 800–1000 m during the day [33, 34]—and fin whale foraging behaviour [19, 20]. Collecting more parameters relating to diving behaviour such as diving angle, stroke and glide frequency [35], and orientation (pitch, roll, heading of the animal) [36], and the concurrent use of playback experiments, will describe fin whales' reaction to acoustic alerting devices possibly used to warn whales of approaching boats [37], as a possible mitigation measure to reduce ship strikes.

We also propose the collection of diving data covering the whole 24 h period; this would allow a more complete description of the foraging behaviour and in particular may confirm the association of fin whales with the deep scattering layer. Moreover, this will investigate whether fin whales also follow the downward vertical migration, performed by the krill early in the morning.

We also recommend investigating the winter diving behaviour, to assess whether the Mediterranean fin whales have extended their feeding activities in the winter, as proposed by Notarbartolo di Sciara and colleagues [10]. This would, most likely, produce different results from the summer results, since prey abundance peaks in February at shallower depths (200 m), with diel vertical migrations of approximately 100 m [34], as described in the Sicily Channel shelf near Lampedusa [38], where fin whales engage in surface feeding activities.

It is noteworthy to mention that at present, as a consequence of the different threats affecting Mediterranean cetaceans, two management and conservation Agreements are now active in the Basin: the Pelagos Sanctuary for Cetaceans, which has recently come into force following the ratification process by the three signatory Parties, and the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and contiguous Atlantic area (ACCOBAMS) which came into force on 1 June 2001. Both these Agreements require further information to achieve certain objectives and to provide a proper science-based management regime.

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