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4 authors:

Simone Cominelli
Memorial University of Newfoundland

Aurelie Moulins
CIMA Research Foundation

Massimiliano Rosso
CIMA Research Foundation

Paola Tepsich
CIMA Research Foundation

Research Article

Fin Whale Seasonal Trends in the Pelagos Sanctuary, Mediterranean Sea

SIMONE COMINELLI,[1] *Department of Biosciences, Parma University, Strada dell'Università, 12, 43100 Parma PR, Italy*
AURELIE MOULINS, *CIMA Research Foundation, via Magliotto 2, 17100 Savona, Italy*
MASSIMILIANO ROSSO, *CIMA Research Foundation, via Magliotto 2, 17100 Savona, Italy*
PAOLA TEPSICH, *CIMA Research Foundation, via Magliotto 2, 17100 Savona, Italy; and Department of Informatics Bioengineering Robotics and System Engineering (DIBRIS), University of Genoa, Genoa, Italy*

ABSTRACT Since 2009, a cetacean presence and distribution long-term monitoring study has been ongoing in the Pelagos Sanctuary, a pelagic marine protected area located in the northwestern Mediterranean Sea. One of the objectives of this study is to assess trends in cetacean presence and distribution to achieve good environmental status (GES) of pelagic marine waters. We assessed the density variability of the fin whale (*Balaenoptera physalus*) in the Pelagos Sanctuary. We used data collected during summer months (Jun–Sep) from 2009 to 2013, along 2 fixed transects crossing the Pelagos Sanctuary, using ferries as platforms of opportunity. We compared 2 un-corrected indexes: the linear encounter rate and density index, computed applying distance sampling methodology to select the most precise method. We also evaluated the effect of environmental covariates (e.g., platform height, Beaufort sea state, wind speed and direction, cloud cover and rain, longitude, latitude) on abundance and density estimation. Finally, we defined an unbiased index and used it to analyze the temporal and spatial variability of fin whale density in the Pelagos Sanctuary. Fin whale density along the 2 transects varied on a yearly basis, with a peak in 2012 and 2013. Variability also occurred on a monthly basis, with a peak during the first half of the season. A longitudinal and a depth gradient were also evident, confirming differences in species displacement in the area. These results are consistent with previous studies, and update current knowledge of species presence in the area. The protocol tested in this work can be easily applied to the other cetacean species inhabiting the Pelagos Sanctuary providing a novel and cost-effective method to assess long-term trends in cetacean distribution and detect incipient changes in species density. © 2015 The Authors. *Journal of Wildlife Management* published by The Wildlife Society.

KEY WORDS fin whale, Ligurian Sea, monitoring, Pelagos Sanctuary, platforms of opportunity, seasonal trends.

Monitoring wild animal populations plays a key role in the ecology and conservation of species. In particular, assessing changes in local populations is important to understand the temporal dynamics of animal populations (Thomas 1991), evaluate management effectiveness for harvested (Formentin and Powers 2005) or endangered species (Stokes et al. 2010), document compliance with regulatory requirements (Gibbs et al. 1999), and detect incipient change (Hamer and McDonnell 2008). Major issues in wildlife monitoring include the selection of the most suitable survey method (Barrìo et al. 2010) and the assessment of the effect of potential bias on species detection probability, including weather conditions (Bas et al. 2008), observers' experience (Williams et al. 2006), or animal behavior (Bailey et al. 2004). Such issues are particularly relevant when considering remote areas (Mallory et al. 2003) or cryptic and rare species (Smallwood and Fitzhugh 1995, Marino 2003) but also for long-term monitoring of populations to detect population changes (Pollock et al. 2002).

Currently, monitoring plans undertaken within the European Union (EU) are mainly focusing on species and habitat identified by the Habitat Directive (Directive 92/43/EEC). The Habitat Directive, however, is restricted to benthic habitats and encompasses only few pelagic species. The recent adoption in 2008 of the Marine Strategy Framework Directive (MSFD Directive 2008/56/EC) allowed European countries to fill the existing gaps due to the lack of monitoring programs in the pelagic realm. The objective of the MSFD is to achieve good environmental status (GES) of the EU's marine waters by 2020, and to protect the resource base upon which many marine-related economic and social activities depend. Each member state must provide a detailed assessment of the state of their respective environment, state a definition of GES at a

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[1]*E-mail: simocephalus@gmail.com*

regional level, and establish clear environmental targets and monitoring programs. The MSFD includes a requirement to adopt specific and standardized methods for monitoring and assessment to ensure consistency and to compare the achievements of GES throughout European marine environments (van Lanker 2010). Consequently, key indicator species have been chosen as targets for dedicated assessment and monitoring programs. Cetaceans are considered flagship species of marine conservation (Wang et al. 2006); they play a critical role in marine ecosystems (Bowen 1997) and are sentinels of ocean health (Wells et al. 2004, Bossart 2011). Thus, they have been identified as target species for the assessment of GES in countries including Italy (Tunesi et al. 2013), France, and Spain (Santos and Pierce 2015).

According to the International Union for Conservation of Nature (IUCN) Red list, the fin whale (*Balaenoptera physalus*) is classified as an endangered species, and its decline has been estimated to be of at least 50% of the global population over the last 3 generations (Reeves et al. 2003). Fin whales are the only mysticete regularly found in the Mediterranean Sea, with higher occurrence in the pelagic areas (Canese et al. 2006). The Mediterranean subpopulation is listed as data deficient (Reeves and Notarbartolo di Sciara 2006), and is characterized by genetic isolation from the North Atlantic population (Bérubé et al. 1998, Palsbøll et al. 2004). The northwestern summer population (in the Pelagos Sanctuary) has recently been estimated to be of 148 individuals, suggesting a decline in fin whale numbers over the last 2 decades when these results are compared with previous estimations (Panigada et al. 2011).

Collecting data on cetacean distribution is difficult because they inhabit one of the most inaccessible environments, they are wide-ranging, and most species normally spend short periods of time at the surface showing only small portions of the body (Redfern et al. 2006). Furthermore, the implementation of effective and long-term monitoring plans is limited by the high costs of dedicated surveys at sea. Platforms of opportunity (e.g., whale watching vessels (Hauser et al. 2006, Koslovsky et al. 2008), commercial ships, including cargo and passenger ships (Williams 2003, Kiszka et al. 2007, Correia et al. 2015), and oceanographic vessels (Friedlaender et al. 2006, Barlow and Forney 2007)) represent a good and cost-effective alternative, allowing for collection of data over extended periods, with sustainable expenses (Williams 2003, Evans and Hammond 2004). One of the main requirements of an effective monitoring plan is its representativeness, its reproducibility, and repeatability over time, to allow direct comparison of data (Boitani and Fuller 2000). Considering the nature of their commercial activity, whale watching vessels do not fully respond to monitoring needs because the temporal and spatial coverage of survey effort is usually biased, being concentrated in areas where cetaceans are present. Moreover, such vessels tend to return to the same position every day and focus on easily sighted species (Koslovsky et al. 2008). Finally, whale watching vessel operability is restricted to national waters. Conversely, oceanographic and commercial ships follow fixed routes that are usually repeated methodically, thus allowing a systematic and unbiased sampling design. Additionally, these ships also operate in high-seas areas allowing researchers to survey areas that are not typically included in sampling designs. However, vessel speed, observer's position, and operating meteorological conditions cannot be adapted to meet cetacean research needs and must then be taken into account with a dedicated post-processing of data. We used data collected from 2009 to 2013 from passenger ferries crossing the northern Ligurian Sea used as platforms of opportunity for monitoring cetacean presence in the central part of the Pelagos Sanctuary. Our objective was to explore the potential use of 2 different measures of relative abundance, the linear encounter rate and the density index, to assess summer fin whale distribution along the 2 surveyed routes. We tested the effect of temporal and meteorological covariates (i.e., year, month, latitude, longitude, Beaufort sea state, wind state, wind direction, cloud cover) and the effect of sampling methods to cope with possible bias in the observed distribution. Data collected from surveys used in this study were part of the Fixed Line Transect Network for monitoring cetaceans in the Mediterranean Sea (Arcangeli et al. 2013).

STUDY AREA

The Ligurian Sea is located in the northwestern area of the Mediterranean Sea and is one of the coldest areas of the Mediterranean Sea. Water average temperatures in the Ligurian Sea, at a depth of 10 m, are 12.7–13.0° C during the winter and 21.0–22.5° C in summer (Brasseur et al. 1995, Barth et al. 2005). The Pelagos Sanctuary is a pelagic marine-protected area dedicated to the conservation of marine mammals, extending over 87,500 km^2 in the Ligurian Sea (Notarbartolo di Sciara et al. 2008). It was established on 21 February 2002 after being ratified by Monaco (2000), France (2001), and Italy (2002). It is located between southeastern France, Monaco, northwestern Italy, and Sardinia, encompassing Corsica and the Tuscan Archipelago (Fig. 1). The Sanctuary contains deep-water and shelf-slope habitats suitable for the breeding and foraging needs of the 8 cetacean species found in the western Mediterranean Sea: fin whale, striped dolphin (*Stenella coeruleoalba*), sperm whale (*Physeter macrocephalus*), bottlenose dolphin (*Tursiops truncatus*), Cuvier's beaked whale (*Ziphius cavirostris*), long-finned pilot whale (*Globicephala melas*), common dolphin (*Delphinus delphis*), and Risso's dolphin (*Grampus griseus*). Nonetheless, the area currently has one of the higher (if not the highest) levels of ship traffic in the whole Mediterranean basin, and is the recipient of pollutants coming from the greatly developed coasts of Italy and France (Notarbartolo di Sciara et al. 2008). Ship strikes are the main threat to fin whales and predictive models show that the collision potential is higher in the northwestern area of the sanctuary than in the adjacent areas outside of the Marine Protected Area boundaries (David et al. 2011). Furthermore, ship traffic is not the only threat to cetaceans in the area: striped dolphin populations within the Marine Protected Area show greater toxicological stress when compared to other Mediterranean populations; indicating that the Pelagos

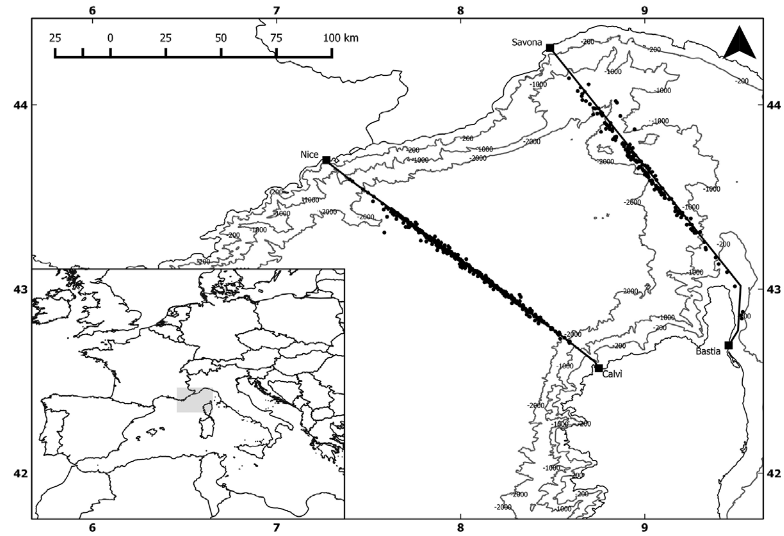

Figure 1. Boundaries of the Pelagos Sanctuary, Mediterranean Sea, and the survey routes: Savona–Bastia and Nice–Calvì with their respective fin whale sightings, 2009–2013. The 200, 1,000, and 2,000 bathymetric lines are displayed.

Sanctuary is a highly contaminated area, with hazardous levels of pollutants for cetacean and other marine species (Fossi et al. 2013).

The 2 most abundant cetacean species in the Pelagos Sanctuary are the fin whale and the striped dolphin, accounting for 20% and 60%, respectively, of all historical summer-time cetacean sightings (Notarbartolo di Sciara 1994). However, year-round fin whale distribution in the Mediterranean basin and its connection with the North Atlantic is still being investigated (Giménez et al. 2013, 2014, Castellote et al. 2014). The fin whale population in the North Atlantic is fragmented into 8 subpopulations (i.e., stocks) and little exchange occurs among stocks. The Gibaltar Strait is commonly considered the border separating the Mediterranean stock from the northeastern North Atlantic subpopulation, but this subdivision is still unclear, and some individuals from the northeastern North Atlantic stock are suspected to feed in the northwestern Mediterranean Sea (Giménez et al. 2013). These findings suggest an overlap of the 2 populations in the area, rather than the existence of definite boundaries (Castellote et al. 2014).

METHODS

Survey Protocol

We collected data on the presence of cetaceans during summer (Jun–Sep) from 2009 to 2013 with a team of Marine Mammal Observers (MMO) aboard ferries operated by the Corsica Ferries company along 2 routes: Savona–Bastia (SB) and Nice–Calvì (NC). We used 44 observers (9 in 2009, 10 in 2010, 10 in 2011, 7 in 2012, 8 in 2013) to collect data. Observers were in teams of 4 members, with $\geq$1 expert observer (i.e., prior experience) on board each ferry. We trained observers during May of each year, conducting assisted surveys to maximize uniformity of data collection. A training survey followed the same rules of a regular survey and involved all new observers and 2 expert observers with the task of directing and assisting the volunteers. We excluded data collected in May from the analysis. Searching effort ended in conditions of poor visibility (i.e., fog, heavy rain) or prohibitive sea state conditions. The 2 ferry routes cross the northern Ligurian Sea longitudinally, and consequently, are in the center of the Pelagos Sanctuary (Fig. 1). The 2 surveyed routes lie on several different habitats. The NC route lies mainly on the bathyal plain (with a depth of 2,000–2,500 m in the middle of the Ligurian Sea). It also crosses a small portion of the continental shelf and slope off of the coast of France and Corse, where several submarine canyons exist. The SB route is characterized by complex topography as it crosses the Genoa Canyon Basin and a seamount area, both recognized as cetacean presence hot spots within the Pelagos Sanctuary (Moulins et al. 2008). This route crosses over a wide area of the shelf off of eastern Corsica where bathyal plains are absent. The compiled survey data collected along the 2 routes provide a representative sampling of cetacean habitat in the Pelagos Sanctuary. We considered each route to be a fixed transect, consisting of 2 legs (outbound and return), sampled on a weekly basis. For the purpose of this study, each leg was considered as an independent survey. Cetacean data were collected by a team comprised of 4 MMOs with different roles: 2 observed the sea from the ferry command deck, scanning an area covering approximately 130° for each respective side of the ferry with binoculars (7×50 mm), and 1 recorded data. Shifts of positions, from one side of the ferry to the other and from the observing position to the data recording position occurred every 30 minutes to avoid fatigue. Data collection started 30 minutes after departure and ended 30 minutes before arrival, approximately. Ferry departure times varied throughout the season from 0700 to 0800, and arrival times (for a round trip) varied from 2030 to 2130. Data collection concluded at sundown because of diminished visibility. Data collected during each survey included name of ferry, date and time, vessel track recorded by a portable global positioning system (GPS), sea state (Beaufort scale), wind speed and direction, cloud cover, rain, and visibility. We recorded meteorological conditions at the beginning of each survey and with any change in conditions. Each time we sighted a cetacean, we recorded the time and GPS position of the ferry at the moment the sighting occurred, sighting distance and angle in respect to vessel heading, species, group size, behavior, and naval traffic in the area. We measured sighting distances using the reticule scale of 7×50 mm binoculars and subsequently converted it into kilometric distances applying the formula from Kinzey and Gerrodette (2003):

$$D_a = h_e \times \sin(\theta + \alpha) - \sqrt{R_E^2 - (h_e \times \cos(\theta + \alpha))^2},$$

where θ is the angle below the horizon to the sighting, in radians, α is the angle above the horizon to the horizontaltangent $= \text{a} \tan\left(\frac{\sqrt{2R_E h + h^2}}{R_E}\right)$ in radians, h is the eye height above sea level in km, R_E is the radius of earth (6,371 km), and $h_e = R_E + h$.

The fleet is composed of several ferries with different characteristics. We used a linear model to test the effect of ferry characteristics including cruise speed and deck height on the recorded sighting distances. The linear model formula was $Distance \sim H + v$, where H is the observation point's height expressed in m a.s.l. (above sea level) and v is the speed of the ferry expressed in knots (nautical miles traveled/hr). We investigated the influence of observation height and speed on sighting distances using stepwise selection and found that platform height ($R^2 = 0.017$, $P = 0.08$) was the main, if not the only, structural factor influencing sighting distances. Therefore, we selected this parameter to categorize ferries into 2 different classes. Type I ferries had a command deck 12–15 m above sea level, whereas Type II ferries were larger, with the command deck 20–22 m above sea level (Table S1, available online at www.wildlifejournals.org). To compare data collected from different platforms types, we standardized all surveys to Type I ferries. We estimated a truncation distance using the software Distance (Thomas et al. 2010) for each survey platform. The truncation distance is defined as the maximum perpendicular distance at which it is possible to sight animals. We then removed all sightings beyond the estimated truncation distance for Type I ferries.

Data Analysis

We performed data analysis in 3 subsequent steps. First, we assessed fin whale presence in the study area through the application of 2 different indexes: linear encounter rate (LER) and density index (D). We calculated the LER equation as the number of animals sighted along a transect divided by the length of the transect times 100. To compute D, we transformed the linear transect into a strip transect, and computed the width applying distance sampling methods (Buckland et al. 2001):

$$D = \frac{n_t}{A_t} \times 100,$$

where n is the number of animals sighted along a transect (t) and A is the effective surveyed area of transect t, defined as follows:

$$A = 2 \times \mu \times L_t,$$

where μ is the effective strip half-width and L_t is the length of the transect (Buckland et al. 2001). Both indexes are multiplied by 100 to change the measurement unit to the number of animals sighted every 100 km for LER and the number of animals sighted every 100 km^2 for D. We computed the 2 indexes (LER and D) for each survey separately, considering each survey as an independent sampling unit. We stratified the dataset by year and month to detect, respectively, inter-annual variability of fin whale presence during the study period and intra-annual variability of species presence during the summer. Second, we inspected the influence of weather conditions on both indexes. Sea state, cloud cover, wind speed, and wind direction could influence species detectability of the observers. To test the effect of these meteorological variables on the estimations obtained by the 2 indexes, we stratified each transect according to meteorological condition. Therefore, a sampling unit was set to a continuous period of effort under the same meteorological conditions. We divided each transect into sampling units (segments) using the GPS positions upon which we recorded meteorological conditions and selected the condition of the initial point of the sampling unit to characterize the segment. We computed a new value for LER for each segment, defining the meteorological linear encounter rate (LER_w). We tested the significance of all of the meteorological conditions on the LER_w using generalized linear models (GLMs) with a Gaussian error distribution. We selected GLMs because of the non-normal error distribution in our dataset; our sightings data (count data) were bounded below (Crawley 2007). We also included year, month, longitude, and latitude of the meteorological points (beginning of the segment) as covariates in the models, as proxies for inter-annual and seasonal variability (year and month, respectively) and habitat differences among the 2 considered routes or along the same route (longitude and latitude, respectively). Thus, the GLM general equation for LER_W included sampled year (2009, 2010, 2011, and 2012), sampled month (Jun, Jul, Sep, and Aug), Beaufort sea state value (ranging from 0 to 6), cloud cover (ranging from 0 to 8), wind direction in degrees (from 0 to 360), longitude, and latitude.

To evaluate the significance of the environmental and meteorological variables on the density index estimations (D_w), we applied a multiple covariate distance sampling (MCDS; Buckland et al. 2004) analysis, fitting the detection function considering 3 different models: half-normal + cosine, half-normal + simple polynomial, and half-normal + Hermite polynomial. We based model selection on Akaike's Information Criterion (AIC). Finally, we used information gained by the GLMs and MCDS to obtain unbiased indexes and we compared the effectiveness of both. Because no absolute abundance estimation methods are applicable to this dataset, it was not possible to evaluate accuracy of indexes. We evaluated the effectiveness of the applied methods using index precision. To compare the precision of 2 indexes with different units (no./km for the LER_w and no./km^2 for the D_w), we used the coefficient of variation (Barrìo et al. 2010). The estimate with the minimum coefficient of variation was the best estimate over the various meteorological conditions tested using GLM and MCDS analyses, therefore, the most precise index to assess fin whale spatial and temporal distribution along the 2 routes. We performed all spatial analysis using ArcGIS10 (Environmental Systems Research Institute, Inc., Redlands, CA) and statistical analyses using R (R version 3.0.2, http://cran.r-project.org, accessed 25 Sep 2013) and Distance software.

RESULTS

Between 2009 and 2013, the monitoring program covered a surveyed linear distance of 41,928 km. On average, each survey was 135.9 km (±41.6 SD) of effort (Table 1). The distance surveyed each year ranged from 6,603 km in 2009 to 9,324 km in 2013. Monthly effort ranged from 1,073 km in September 2009 to 2,862 km in June 2013. In general, survey effort was lower during September when compared to the other 3 months of sampling because of less favorable meteorological conditions. Overall, we recorded 1,947 cetacean sightings, rejecting all unidentified cetaceans and sightings with incomplete information. The fin whale was the second most commonly sighted species, accounting for 760 sightings (39%). The most commonly sighted species was striped dolphin with 1,020 sightings (52%); the remaining 9% included sperm whale (39%), bottlenose dolphin (24%), Cuvier's beaked whale (17%), long-finned pilot whale (8%), common dolphin (7%), and Risso's dolphin (5%). Overall, we recorded 1,036 meteorological points, with an average of 3.4 ± 0.9 (SD) meteorological points per transect. We truncated fin whale sighting distances based on the maximum linear sighting distance (5,700 m; Fig. 2) for Type I platforms. As a consequence, all animals sighted farther away were removed from the dataset; we removed 98 sightings from the initial 760, reducing the sample size to 662 fin whales sightings.

Fin whale LERs displayed annual and monthly differences, but with high standard deviations. Linear encounter rate alternated between poor (2009, 2011, 2013) and rich years (2010, 2012), and among these 2 groups 2009 had the lowest estimated encounter rate (LER = 0.33; SD = 0.85) and 2012 had the highest estimated encounter rate (LER = 2.34; SD = 2.80). In 2009, the LER increased in the first half of the sampling season (Jun–Jul), decreased in August, and then increased again in September. In 2010 and 2011, the LER increased during the first 3 months,

Table 1. Summary of surveys of fin whales in the Pelagos Sanctuary, Mediterranean Sea including the distance surveyed (km), number of transects surveyed, number of sightings, and distance surveyed (km) by ferry route: Savona–Bastia (SB) and Nice–Calvì (NC).

Year	Month	km	Transects	Sightings	SB	NC
2009		6,603	53	17	4,140	2,463
	Jun	1,777	14	4	1,116	661
	Jul	2,258	19	12	1,433	825
	Aug	1,325	11	0	950	375
	Sep	1,243	9	1	641	602
2010		8,692	63	133	4,213	4,497
	Jun	2,595	17	33	1,193	1,402
	Jul	2,324	16	32	1,070	1,254
	Aug	2,490	19	51	1,245	1,245
	Sep	1,283	11	17	705	578
2011		8,705	65	88	4,805	3,900
	Jun	2,247	16	14	1,239	1,008
	Jul	2,291	18	27	1,310	981
	Aug	2,708	18	47	1,260	1,448
	Sep	1,459	13	0	996	463
2012		8,604	66	221	4,385	4,219
	Jun	2,534	17	42	1,520	1,014
	Jul	2,129	17	81	795	1,334
	Aug	2,104	16	63	1,153	951
	Sep	1,837	16	35	917	920
2013		9,324	59	203	5,078	4,246
	Jun	3,041	17	49	2,018	1,023
	Jul	2,741	18	116	1,132	1,609
	Aug	2,224	14	31	1,301	923
	Sep	1,318	10	7	627	691
Total		41,928	306	662	22,621	19,307
	Jun	12,194	81	142	7,104	5,108
	Jul	11,743	88	268	5,716	6,003
	Aug	10,851	78	192	5,915	4,942
	Sep	7,140	59	60	3,886	3,254

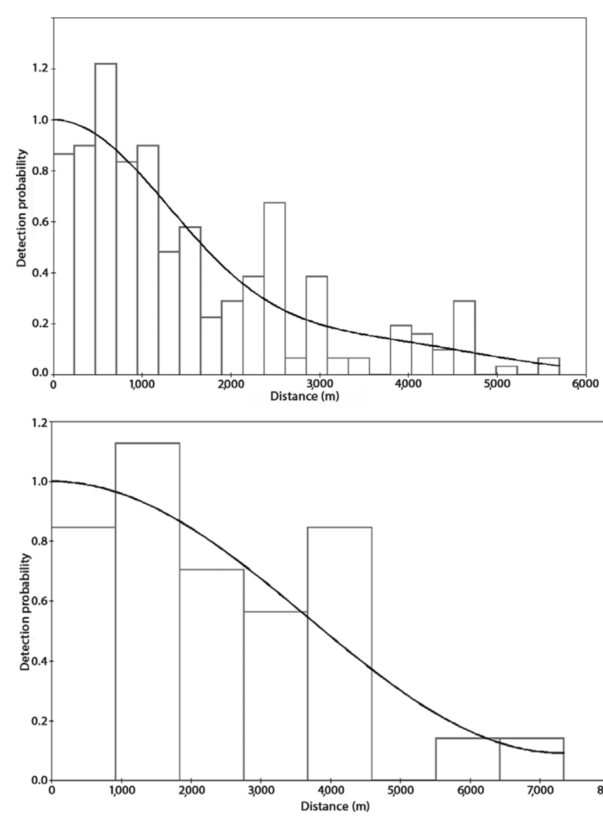

Figure 2. Detection functions for fin whale sightings from Types I and II ferries in the Pelagos Sanctuary, Mediterranean Sea, 2009–2013. Type I ferries had a maximum sighting distance of 5,700 m, whereas Type II ferries had a maximum sighting distance of 7,350 m.

then decreases in September. In 2012 and 2013, the LER increased during the first half of the season (Jun–Jul; $LER_{2012\_06} = 1.67$, $SD_{012\_06} = 2.34$; $LER_{\ 2012\_07} = 3.19$, $SD_{2012\_07} = 3.28$; $LER_{2013\_06} = 1.49$, $SD_{2013\_06} = 1.00$; $LER_{2013\_07} = 6.46$, $SD_{2013\_07} = 5.97$) and decreased during the second half (Aug–Sep; $LER_{2012\_08} = 2.65$, $SD_{012\_08} = 3.15$; $LER_{2012\_09} = 1.84$, $SD_{2012\_09} = 2.25$; $LER_{2013\_08} = 1.91$, $SD_{2013\_08} = 1.34$; $LER_{2013\_09} = 0.90$, $SD_{2013\_09} = 1.39$), although in 2012, the LER in August and September was still greater than in June. Comparable differences and patterns were obtained through the estimation of densities. The density index estimations were generally characterized by smaller standard deviations, also highlighting the above mentioned patterns ($D_{2012\_06} = 0.35$, $SD_{012\_06} = 0.12$; $D_{2012\_07} = 0.93$, $SD_{2012\_07} = 0.20$; $D_{2013\_06} = 0.22$, $SD_{2013\_06} = 0.07$; $D_{2013\_07} = 0.35$, $SD_{2013\_07} = 0.13$; $D_{2012\_08} = 0.58$, $SD_{012\_08} = 0.17$; $D_{2012\_09} = 0.36$, $SD_{2012\_09} = 0.10$; $D_{2013\_08} = 0.23$, $SD_{2013\_08} = 0.05$; $D_{2013\_09} = 0.922$, $SD_{2013\_09} = NA$). In 2009, 2011, and 2013, D estimations were lowest, whereas estimations in 2010 and 2012 were slightly greater (Fig. 3). Years 2010 and 2011 displayed similar monthly patterns with a positive peak in August ($D_{2010\_08} = 1.27$, $SD_{2010\_08} = 0.29$; $D_{2011\_08} = 0.61$, $SD_{2011\_08} = 0.18$), whereas in 2012 and 2013, the peak was in July ($D_{2012\_07} = 0.93$, $SD_{2012\_07} = 0.20$; $D_{2013\_07} = 0.35$, $SD_{2012\_70} = 0.13$). The density indexes in 2009 differed between early and late season; June ($LER_{2009\_06} = 0.35$, $SD_{2009\_06} = 1.00$; $D_{2009\_06} = 0.58$, $SD_{2009\_06} = 0.55$) and July ($LER_{2009\_07} = 0.66$, $SD_{2009\_07} = 1.09$; $D_{2009\_07} = 0.56$, $SD_{2009\_07} = 0.20$) were characterized by fin whale presence in the area, whereas August (no sightings to compute the indexes) and September ($LER = 0.07$) were characterized by absence of the species with only 1 sighting over a period of 2 months, making it impossible to calculate a value for D because of small sample size.

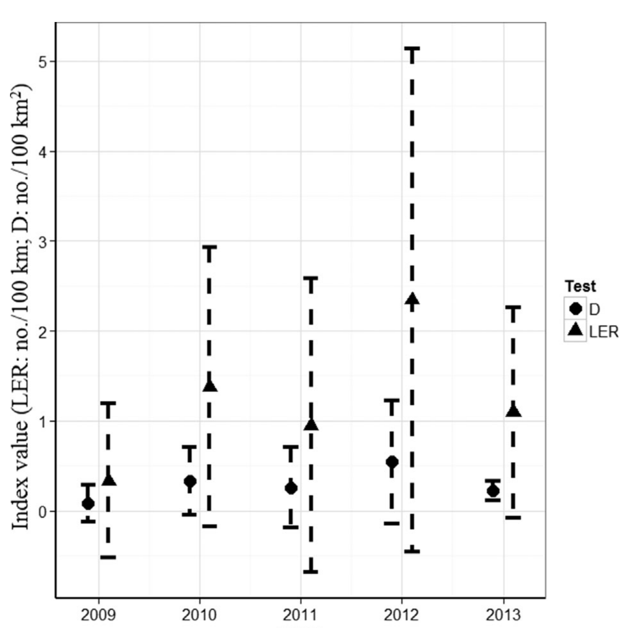

Figure 3. Linear encounter rates (LER), expressed as the number of animals sighted/100 km, and density indices (D), expressed as the number of animals sighted/100 km^2, with relative standard deviation plotted per year (2009–2013) for fin whales in the Pelagos Sanctuary, Ligurian Sea, northwestern Mediterranean Sea.

We tested correlation among the environmental and meteorological variables to be included in the GLM and in the MCDS analysis with the Spearman's test. Sea state and wind speed were highly correlated ($r = 0.7757$, $P < 0.001$). As a consequence, we removed wind speed from both analyses. The model selection procedure, using the stepAIC function in R, led to the removal of sea state, cloud cover, and wind direction (Table 2). The selected model predicting LER_W included year, month, latitude, and longitude and GLM results revealed significant differences at the basin scale (i.e., considering the 2 routes together; Table 3).

The MCDS analysis used to compute D_w values demonstrated that sea state and longitude influenced fin whale detection probabilities and consequently D_w (Table 4). The 2 models differed by <2 AIC so it was not possible to select a single model. Sea states >4 led to a reduction of the effective strip width from approximately 2,500 m to 1,500 m. Consequently, we excluded all sightings recorded under conditions of sea state above 4 from the calculations of the indexes. Both GLM and MCDS analyses indicated that meteorological variables (e.g., wind state, wind direction, cloud cover) did not affect indexes estimation, and according to GLMs results, fin whales displayed an east–west gradient with higher index values along the NC route ($LER_{wNC} = 2.17$, $SD_{wNC} = 2.31$; $D_{wNC} = 0.42$, $SD_{wNC} = 0.23$) than along the SB ($LER_{wSB} = 0.75$, $SD_{wSB} = 0.93$; $D_{wSB} = 0.12$, $SD_{wSB} = 0.09$).

To take into account the geographical effect after platform standardization and correction for weather variables, we computed the indexes at a regional scale (i.e., separately for the SB transect and the NC transect). Indexes revealed a positive correlation between LER and D at the basin scale ($r = 0.599$, $P \leq 0.05$) and at the regional scale (NC: $r = 0.912$, $P \leq 0.001$; SB: $r = 0.755$, $P \leq 0.001$). The comparison between the coefficients of variation of the 2 raw indexes (LER and D) revealed that, in every case, D ($D_{CV\_range\_2009} = 0.0–4.94$; $D_{CV\_range\_2010} = 0.10–0.86$; $D_{CV\_range\_2011} = 0.0–1.82$; $D_{CV\_range\_2012} = 0.32–2.35$; $D_{CV\_range\_2013} = 0.14–1.81$), provided more precise estimates than LER ($LER_{CV\_range\_2009} = 0.0–20.16$; $LER_{CV\_range\_2010} = 1.90–8.34$; $LER_{CV\_range\_2011} = 0.0–11.24$; $LER_{CV\_range\_2012} = 2.72–21.17$; $LER_{CV\_range\_2013} = 0.91–10.39$). The comparison between CVs of the 2 indexes by route (NC and SB) also showed that the CV of D ($D_{CV\_NC\_range\_2009} = 0–0.77$; $D_{CV\_SB\_range\_2009} = 0.0485$; $D_{CV\_NC\_range\_2010} = 0.17–0.26$; $D_{CV\_SB\_range\_2010} = 0.19–0.34$; $D_{CV\_NC\_range\_2011} = 0.0–0.03$; $D_{CV\_SB\_range\_2011} = 0.0–0.27$; $D_{CV\_NC\_range\_2012} = 0.17–0.40$; $D_{CV\_SB\_range\_2012} = 0.26–0.238$; $D_{CV\_NC\_range\_2013} = 0.16–0.35$; $D_{CV\_SB\_range\_2013} = 0.0–0.32$) was lower than the CV of LER in every month–year estimate ($LER_{CV\_NC\_range\_2009} = 0.0–3.17$; $LER_{CV\_SB\_range\_2009} = 0.0–3.91$; $LER_{CV\_NC\_range\_2010} = 1.51–2.99$; $LERCV\_SB\_range\_2010 = 1.46–2.82$;

Table 2. Model selection results based on Akaike's Information Criterion (AIC) for general linear models predicting meteorological linear encounter rates (LER_W) of fin whales in the Pelagos Sanctuary, Mediterranean Sea, 2009–2013. We also present the number of parameters (K) and model weights (w_i).

Model	AIC	ΔAIC	K	w_i
LER_w ~ year + month + longitude + latitude	−3,052.72	0	52	0.65
LER_w ~ year + month + wind direction + longitude + latitude	−3,051.46	1.26	52	0.35
LER_w ~ year + month + sea state + wind direction + longitude + latitude	−3,042.01	10.71	52	0.00
LER_w ~ year + month + sea state + cloud cover + wind direction + longitude + latitude	−3,021.27	31.45	52	0.00

$LER_{CV\_NC\_range\_2011} = 0.93–2.29$; $LER_{CV\_SB\_range\_2011} = 0.0–0.51$; $LER_{CV\_NC\_range\_2012} = 0–1.86$; $LER_{CV\_SB\_range\_2012} = 1.60–4.58$; $LER_{CV\_NC\_range\_2013} = 0.37–1.36$; $LER_{CV\_SB\_range\_2013} = 0.51–2.45$). Because of its higher precision, we selected D_w to describe fin whale spatial and temporal distribution along the 2 monitored routes.

Concerning fin whale spatial distribution, D_w indicated a greater density of fin whales along the NC than the SB route ($D_{NCw} = 0.70$, $SD = 0.43$; $D_{SBw} = 0.25$, $SD = 0.19$), confirming an uneven geographical distribution of the species in the western Pelagos Sanctuary. Concerning fin whale temporal distribution, we calculated the lowest value for D_W along the SB in July 2011 ($D_{SBw} = 0.15$; $SD = 0.02$), and the highest in July 2012 ($D_{NCw} = 2.21$; $SD = 0.26$) along the NC route. The range of D_w values computed for the SB varied between 0 and 0.7 individuals/100 km^2. September had the lowest values, with $D_w \neq 0$ only in 2010 and 2013. July is the only month in which D_w was greater than 0 for each year. Excluding these small variations between months, the presence of the species along this route can be considered constant across the sampling season and over the different years, with an average of 0.25 ± 0.19 encounters/100 km^2 surveyed. We calculated greater variability in D_w along the NC route than along the SB route. The NC index values were between 0 and 2.3, being 3 times greater than values found along the SB route. Neither the NC or SB routes displayed a constant presence of the species; for both routes, presence increased in the first half of the season (Jun and Jul) and decreased in the second half (Aug and Sep; see Fig. S2, available online at www.wildlifejournals.org).

DISCUSSION

Monitoring is "...the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective" (Elzinga et al. 2001:2). Monitoring plan efficiency depends on meeting 3 requirements: ecological relevance, statistical credibility, and cost effectiveness (Peltier et al. 2013). The monitoring program described herein was carried out within a pelagic protected area that covers zones of high cetacean biodiversity. The use of ferries allowed systematic data collection along fixed transects, moreover, thanks to the support of the ferry company, the operative expenses were low, allowing for a yearly replication of the transects. However, the use of non-dedicated platforms and the lack of dedicated sampling design resulted in bias in the dataset. In particular, platform characteristics affect animal sightability; different platforms can consistently vary in speed, height, and viewing area (Evans and Hammond 2004). Also, operating conditions (e.g., meteorological conditions) affect animal sightability. This is particularly true for cetaceans (Palka 1996, Barlow et al. 2001) and other taxa (e.g., birds; Bas et al. 2008). Consequently, when measuring changes in animal abundance by the use of sighting rates, it is essential to take into account the effect of these covariates on the estimations and implement corrections to compensate for the introduced variability. The use of different platforms is uncommon in cetacean surveys because they are typically carried out from a single vessel (Kiszka et al. 2007), and in the case of different research vessels (Gerodette and Focada 2002), observer eye height and speed are standardized. The use of a variety of platforms in this study introduced heterogeneity among

Table 3. General linear model results for variables found to predict meteorological linear encounter rates (LER_W) of fin whales in the Pelagos Sanctuary, Mediterranean Sea, 2009–2013. Coefficients (coeff.) for non-significant effects are omitted.

Variable	Coeff.	P
Year		
2009	0.640	≤0.001
2010		0.247
2011		0.423
2012	0.018	0.002
2013	0.029	≤0.001
Month		
Jun	0.640	≤0.001
Jul	0.016	≤0.001
Aug		0.171
Sep		0.264
Latitude	−0.011	0.002
Longitude	−0.013	<0.001

Table 4. Model selection results based on Akaike's Information Criterion (AIC) for multiple covariate distance sampling analysis models predicting meteorological density indices (D_w) of fin whales in the Pelagos Sanctuary, Mediterranean Sea, 2009–2013. We also present the number of parameters (K) and model weights (w_i).

Covariates	AIC	ΔAIC	K	w_i
Sea state	11,002.30	0.00	7	0.68
Sea state + longitude	11,004.33	2.03	8	0.25
Sea state + latitude	11,006.90	4.60	8	0.07
Sea state + cloud cover + longitude + latitude	11,010.42	8.12	10	0.01
Cloud cover	11,042.49	40.19	10	0.00
Cloud cover + longitude	11,043.78	41.48	11	0.00
Cloud cover + latitude	11,044.44	42.14	11	0.00
Cloud cover + longitude + latitude	11,046.07	43.77	12	0.00
Longitude + latitude	11,046.28	43.98	3	0.00

transects, making it necessary to adopt a correction factor, the truncation distance. The ferry fleet used in this study was composed of heterogeneous vessels with average speeds ranging from 16 to 27 knots and observation point heights of 12 m, 15 m, 20 m, and 22 m. We did not test the effect of speed because this parameter is strictly affiliated with the type of ferry, thus, directly proportional to the height of the observation point. Distance analysis for ferry types showed that Type II (20–22 m) platforms have a greater maximum sighting distance than Type I (12–15 m) platforms by approximately 1,000 m. This difference yielded variability in the surveyed area/transect. This bias, which is caused by the characteristics of the platform, should be taken into account when analyzing data from these kinds of surveys. Index comparisons via coefficients of variation showed that D_w was the most precise method to study fin whale spatial and temporal distribution; nevertheless, the results obtained from both models (i.e., GLM and MCDS) provided useful information to adjust and refine the analysis of this dataset. Cloud cover, wind speed, and wind direction had an insignificant influence across the estimates of both indices, but a potential effect on the other 7 cetacean species inhabiting the Pelagos Sanctuary cannot be excluded.

Fin whales have distinctive blows, which can be observed from great distances and their size is sufficient to make them easy to detect in conditions up to sea state 4. Sea states >4 affected animal sightability, with a reduction in the effective strip width of approximately 1,000 m. This result could be partially due to the small sample size of animals sighted under these extreme conditions and in part due to uneven distribution of the samples because >80% of the meteorological points were recorded under Beaufort sea states ranging from 0 to 2.

Fin whales demonstrate annual and monthly seasonality. Fin whale annual presence in the Pelagos Sanctuary is likely linked to prey (i.e., northern krill, *Meganyctiphanes norvegica*) abundance, which depends on the magnitude of the seasonal algal bloom (Cotté et al. 2011, Visser et al. 2011), whereas the monthly distribution is likely related to its timing (Littaye et al. 2004). The Mediterranean fin whale population displays seasonal migration, with the northwestern Mediterranean Sea playing the role of a summer feeding ground (Panigada et al. 2006, Bentaleb et al. 2011, Castellote et al. 2012, Druon et al. 2012). Fin whale summer distribution and its inter-annual variability are closely linked to spatial and temporal interactions with their prey species in the northwestern Mediterranean Sea. Thus, fin whales demonstrated large-scale fidelity, corresponding to the prey spatial and temporal predictable distribution, and meso-scale fidelity, with higher density in the areas where northern krill tend to concentrate (Littaye et al. 2004, Cotté et al. 2009).

Fin whale distribution was correlated to longitude. This relationship can be due to physiographical differences in the 2 surveyed routes. The transition from the western part to the eastern part of the sanctuary displayed a drop in the number of encountered animals. This geographical difference can be interpreted as an east–west gradient in species presence, with richer areas in the western part of the Pelagos Sanctuary. Splitting the dataset for the 2 routes confirms that fin whale presence is, on average, 3 times higher along the western route (NC) than along the eastern route (SB), as shown in other works (Gannier 2002, Laran and Gannier 2008), but this distribution pattern is variable among seasons. Another factor that should be considered is latitude. In the Ligurian Sea, bottom depth generally increases when traveling from north to south, but this pattern is reversed when reaching the Corsican coast, with a depth that is decreasing traveling from north to south. Latitude can be considered a proxy of depth (Forney 2000). Fin whales exhibit a preference for pelagic environments (with a depth >2,000 m; Azzellino et al. 2008).

Fin whale distribution inside the Pelagos Sanctuary varies annually and monthly depending on ecological processes and spatially, following a depth gradient. The annual seasonality displays fluctuations in fin whale presence, without an overall trend, as shown in a previous study analyzing data collected from 1990 to 1999 (Panigada et al. 2005). Additionally, our study is underlining that the presence of this species varies at a monthly scale during summer at least along the NC route. These results demonstrate how variable fin whale distribution can be in the area (with 3 different recognizable patterns over a period of 5 years) at a small temporal scale, suggesting that focusing on an annual resolution could lead to imprecise results. Furthermore, previous attempts to determine fin whale absolute abundance in the area were conducted in short periods (Gerodette and Focada 2002), or during years of low presence of the species, such as 2009 (Panigada et al. 2011), yet the results of this study suggest that a dedicated survey to estimate species abundance should be conducted for >1 year, focusing the effort on pelagic environments and taking into account the intra-annual variability in this species presence.

MANAGEMENT IMPLICATIONS

The conservation status of the Mediterranean subpopulation of fin whales is unknown, and more effort should be dedicated to design a monitoring program with a representative spatial and temporal cover. The Pelagos Sanctuary is the only pelagic Marine Protected Area established in the Mediterranean Sea and was established to protect the 8 cetacean species that inhabit the area. To prevent ship collisions in sensitive areas, and to define the effectiveness of the Marine Protected Area on fin whale conservation, it is necessary to improve the precision, and consequently, the reliability of estimated population trends. As a consequence, collected data should be standardized for platform type, geographic gradients and seasonal variability in species distribution should be considered when designing dedicated surveys, and operative conditions should be recorded. With this work, we have set the optimal framework for the analysis of data collected from monitoring programs like the one described above. Further work will be required to apply this procedure to the other cetacean species in the area. Following this standardized protocol will allow comparison of cetacean spatial and temporal distribution in the Pelagos Sanctuary and detection of incipient changes in species presence, providing reliable information for the management of the area.

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