Trends in summer abundance and distribution of fin whales in the Western Mediterranean Sea Region: New insights from a long-term monitoring program (#45467)

First submission

Guidance from your Editor

Please submit by **21 May 2020** for the benefit of the authors (and your $200 publishing discount) .

Structure and Criteria
Please read the 'Structure and Criteria' page for general guidance.

Author notes
Have you read the author notes on the guidance page?

Raw data check
Review the raw data.

Image check
Check that figures and images have not been inappropriately manipulated.

Privacy reminder: If uploading an annotated PDF, remove identifiable information to remain anonymous.

Files
Download and review all files from the materials page.

5 Figure file(s)
4 Table file(s)
2 Raw data file(s)

Structure your review

The review form is divided into 5 sections. Please consider these when composing your review:

1. **BASIC REPORTING**
2. **EXPERIMENTAL DESIGN**
3. **VALIDITY OF THE FINDINGS**
4. General comments
5. Confidential notes to the editor

You can also annotate this PDF and upload it as part of your review

When ready submit online.

Editorial Criteria

Use these criteria points to structure your review. The full detailed editorial criteria is on your guidance page.

BASIC REPORTING

- Clear, unambiguous, professional English language used throughout.
- Intro & background to show context. Literature well referenced & relevant.
- Structure conforms to PeerJ standards, discipline norm, or improved for clarity.
- Figures are relevant, high quality, well labelled & described.
- Raw data supplied (see PeerJ policy).

EXPERIMENTAL DESIGN

- Original primary research within Scope of the journal.
- Research question well defined, relevant & meaningful. It is stated how the research fills an identified knowledge gap.
- Rigorous investigation performed to a high technical & ethical standard.
- Methods described with sufficient detail & information to replicate.

VALIDITY OF THE FINDINGS

- Impact and novelty not assessed. Negative/inconclusive results accepted. *Meaningful* replication encouraged where rationale & benefit to literature is clearly stated.
- All underlying data have been provided; they are robust, statistically sound, & controlled.
- Speculation is welcome, but should be identified as such.
- Conclusions are well stated, linked to original research question & limited to supporting results.

Standout reviewing tips

The best reviewers use these techniques

Tip	***Example***
Support criticisms with evidence from the text or from other sources	*Smith et al (J of Methodology, 2005, V3, pp 123) have shown that the analysis you use in Lines 241-250 is not the most appropriate for this situation. Please explain why you used this method.*
Give specific suggestions on how to improve the manuscript	*Your introduction needs more detail. I suggest that you improve the description at lines 57- 86 to provide more justification for your study (specifically, you should expand upon the knowledge gap being filled).*
Comment on language and grammar issues	*The English language should be improved to ensure that an international audience can clearly understand your text. Some examples where the language could be improved include lines 23, 77, 121, 128 – the current phrasing makes comprehension difficult.*
Organize by importance of the issues, and number your points	*1. Your most important issue* *2. The next most important item* *3. …* *4. The least important points*
Please provide constructive criticism, and avoid personal opinions	*I thank you for providing the raw data, however your supplemental files need more descriptive metadata identifiers to be useful to future readers. Although your results are compelling, the data analysis should be improved in the following ways: AA, BB, CC*
Comment on strengths (as well as weaknesses) of the manuscript	*I commend the authors for their extensive data set, compiled over many years of detailed fieldwork. In addition, the manuscript is clearly written in professional, unambiguous language. If there is a weakness, it is in the statistical analysis (as I have noted above) which should be improved upon before Acceptance.*

Trends in summer abundance and distribution of fin whales in the Western Mediterranean Sea Region: New insights from a long-term monitoring program

Paola Tepsich Corresp., [1] , **Ilaria Schettino** [2] , **Fabrizio Atzori** [3] , **Marta Azzolin** [4, 5] , **Ilaria Campana** [6, 7] , **Lara Carosso** [7] , **Simone Cominelli** [8] , **Roberto Crosti** [9] , **Léa David** [10] , **Nathalie Di-Méglio** [10] , **Francesca Frau** [3] , **Martina Gregorietti** [11] , **Veronica Mazzucato** [7] , **Clara Monaco** [12, 13] , **Aurélie Moulins** [1] , **Miriam Paraboschi** [7] , **Giuliana Pellegrino** [7, 12] , **Massimiliano Rosso** [1] , **Marine Roul** [10] , **Sébastien Saintingan** [5] , **Antonella Arcangeli** [9]

[1] CIMA Research Foundation, Savona, Italy
[2] Department of Biology, University of Padua, Padova, Italy
[3] Capo Carbonara Marine Protected Area, Villasimius, Italy
[4] Life and System Biology Department, University of Turin, Torino, Italy
[5] Gaia Research Institute Onlus, Torino, Italy
[6] Department of Ecological and Biological Sciences, Ichthyogenic Experimental Marine Center (CISMAR), Tuscia University, Tarquinia, Italy
[7] Accademia del Leviatano, Maccarese, Italy
[8] NorthernEDGE Lab, Memorial University of Newfoundland, Newfoundland, Canada
[9] ISPRA, Rome, Italy
[10] EcoOcéan Institut, Montpellier, Francia
[11] Department of Earth and Marine Science, University of Palermo, Palermo, Italy
[12] Marecamp Association, Aci Castello, Italy
[13] Department of Agriculture, Food and Environment (Di3A), University of Catania, Catania, Italy

Corresponding Author: Paola Tepsich
Email address: paola.tepsich@cimafoundation.org

Background: The Mediterranean subpopulation of fin whale *Balaenoptera physalus* (Linnaeus, 1758) has recently been listed as Vulnerable by the IUCN Red List of threatened species. The species is also listed as species in need of strict protection under the Habitat Directive and is one of the indicators for the assessment of Good Environmental Status under the MSFD. Reference values on population abundance and trends are needed in order to set the threshold values and to assess the conservation status of the population. **Methods**: Yearly summer monitoring using ferries as platform of opportunity was performed since 2008 within the framework of the FLT Med Network. Data were collected along several fixed transects crossing the Western Mediterranean basin and the Adriatic and Ionian region. Species abundance, expressed by density recorded along the sampled transects, was inspected for assessing interannual variability together with group size. Generalized Additive Models were used to describe abundance trends over a 11 years' period (2008-2018). A spatial multi-scale approach was used to highlight intra-basin differences in species abundance and distribution during the years. **Results**: Summer abundance of fin whales in the western Mediterranean area showed a strong interannual variability, characterized by the alternance of rich and poor years. Small and large groups of fin whales were sighted only during rich years, confirming the favorable feeding condition influencing species presence. Trends highlighted by the GAM can be summarized as positive from 2008 to 2013, and slightly negative from 2014 to 2018. The sub-areas analysis showed a similar pattern, but with a more stable trend during the second period in the Pelagos Sanctuary sub-area, and a negative one in the other two sub-areas. The interannual analysis allowed to highlight reference years (i.e. 2010 and 2018) that can be used as a baseline for the assessment of trends. Our findings further confirm the need for an integrated approach foreseeing both, large scale surveys and yearly monitoring at different spatial scales to correct and interpret the basin wide abundance estimates, and to correlate spatial and temporal trends with the ecological and anthropogenic drivers.

Trends in summer abundance and distribution of fin whales in the Western Mediterranean Sea Region: new insights from a long-term monitoring program

Paola Tepsich [1], Ilaria Schettino [2], Fabrizio Atzori [3], Marta Azzolin [4,5], Ilaria Campana [6,7], Lara Carosso [7], Simone Cominelli [8], Roberto Crosti [9], Léa David [10], Nathalie Di-Méglio [10], Francesca Frau [3], Martina Gregorietti [11], Veronica Mazzucato [7], Clara Monaco [12,13], Aurélie Moulins [1], Miriam Paraboschi [7], Giuliana Pellegrino [7,12], Massimiliano Rosso [1], Marine Roul [10], Sébastien Saintingan [5], Antonella Arcangeli [9].

[1] CIMA Research Foundation, 17100 Savona, SV, Italy
[2] Department of Biology, University of Padua, 35131 Padova, PD, Italy
[3] Capo Carbonara Marine Protected Area, 09049 Villasimius, CA, Italy
[4] Life and System Biology Department, University of Torino, Torino, Italy
[5] Gaia Research Institute Onlus, Torino, Italy
[6] Department of Ecological and Biological Sciences, Ichthyogenic Experimental Marine Center (CISMAR), Tuscia University, 01016 Tarquinia, VT, Italy
[7] Accademia del Leviatano, 00054 Maccarese, RM, Italy
[8] Department of Geography, Memorial University of Newfoundland, Newfoundland and Labrador, NL A1B 3X9, Canada
[9] ISPRA, 00144 Rome, Italy
[10] EcoOcéan Institut, 34090 Montpellier, France
[11] Department of Earth and Marine Science, Laboratory of Ecology, University of Palermo, 90128 Palermo, PA, Italy
[12] Marecamp Association, 95021 Aci Castello, CT, Italy
[13] Department of Agriculture, Food and Environment (Di3A), University of Catania, 95125 Catania, CT, Italy

Corresponding Author:
Paola Tepsich[1]
CIMA Research Foundation, via Magliotto 2, Savona, 17100 Italy
Email address: paola.tepsich@cimafoundation.org

Abstract

Background: the Mediterranean subpopulation of fin whale *Balaenoptera physalus* (Linnaeus, 1758) has recently been listed as Vulnerable by the IUCN Red List of threatened species. The species is also listed as species in need of strict protection under the Habitat Directive and is one of the indicators for the assessment of Good Environmental Status under the MSFD. Reference values on population abundance and trends are needed in order to set the threshold values and to assess the conservation status of the population.

Methods: yearly summer monitoring using ferries as platform of opportunity was performed since 2008 within the framework of the FLT Med Network. Data were collected along several fixed transects crossing the Western Mediterranean basin and the Adriatic and Ionian region. Species abundance, expressed by density recorded along the sampled transects, was inspected for assessing interannual variability together with group size. Generalized Additive Models were used to describe abundance trends over a 11 years' period (2008-2018). A spatial multi-scale approach was used to highlight intra-basin differences in species abundance and distribution during the years.

Results: sSummer abundance of fin whales in the western Mediterranean area showed a strong interannual variability, characterized by the alternance of rich and poor years. Small and large groups of fin whales were sighted only during rich years, confirming the favorable feeding condition influencing species presence. Trends highlighted by the GAM can be summarized as positive from 2008 to 2013, and slightly negative from 2014 to 2018. The sub-areas analysis showed a similar pattern, but with a more stable trend during the second period in the Pelagos Sanctuary sub-area, and a negative one in the other two sub-areas. The interannual analysis allowed to highlight reference years (i.e. 2010 and 2018) that can be used as a baseline for the

assessment of trends. Our findings further confirm the need for an integrated approach foreseeing both, large scale surveys and yearly monitoring at different spatial scales to correct and interpret the basin wide abundance estimates, and to correlate spatial and temporal trends with the ecological and anthropogenic drivers.

Introduction

The fin whale *Balaenoptera physalus* (Linnaeus, 1758) is the only commonly sighted mysticete species in the Mediterranean Sea (Notarbartolo di Sciara et al., 2003). Genetic analyses based on both mitochondrial and nuclear DNA indicated that fin whales in the Mediterranean Sea are characterized by genetic isolation with limited but current exchange from the North Atlantic conspecific (Bérubé et al., 1998; Palsbøll et al., 2004).

The species is encountered throughout the basin, although its distribution is patchy (Notarbartolo di Sciara et al., 2003). Movements of the species within the Mediterranean basin do not seem to follow a clear migratory pattern, while instead the species seems to use different movement strategy ranging between a more "traditional" latitudinal displacement to movement between specific sites characterized by patches of prey abundance, following a behavior defined as nomadic opportunistic (Notarbartolo di Sciara et al., 2016). A general migratory pattern with summer concentration in higher latitudes in the north-western basin (i.e. mostly in the western Ligurian Sea and Gulf of Lion) and autumn-winter dispersal in fairly all the basin and towards southern latitudes has been recently described by different studies (Geijer, Notarbartolo di Sciara & Panigada, 2016; Arcangeli, Campana & Bologna, 2017).Three main concentration areas have been individuated. The first one is the Gulf of Lions and the Ligurian-Corsican-Provençal Basin, where the highest concentration of the entire basin was recorded, especially during summer. Species concentration in the area was the main triggering factor towards the institution here of the Pelagos Sanctuary (Notarbartolo-di-Sciara et al., 2008). The consistent presence in this area is linked with high primary production (Druon et al., 2012), being this area the only blooming area of the entire Mediterranean basin (D'Ortenzio & Ribera d'Alcalà, 2009; Mayot, 2015) and consequently sustaining a large biomass of primary production (Orsi Relini et al., 1998; Littaye et al., 2004). Other two hotspots, coinciding with rich areas are also known in the basin: one in the central Tyrrhenian Sea during summer (Arcangeli et al., 2014) and one in the Ionian Sea, around the island of Lampedusa, where a winter-spring feeding ground is reported (Canese et al., 2006; Aïssi et al., 2008). Fluctuation of local hot-spots with high inter-annual variability were related to the variability in the pattern of productivity (Druon et al., 2012; Morgado et al., 2017), the interrelate influence of both environmental and anthropogenic drivers of changes (Azzellino et al., 2017), and could be linked to biological or behavioural factors (e.g. life stage, gender, group structure) that determine small group/individual flexibility in the pattern of distribution (e.g. (Brown et al., 1995; Arcangeli, Campana & Bologna, 2017)

The Mediterranean sub-population is classified as Vulnerable by the IUCN Red List of endangered species and, according to the last assessment, the population is severely fragmented, and the current population trend is decreasing (Panigada & Notarbartolo Di Sciara, 2012). The species in the basin is facing many anthropogenic threats such as marine traffic and ship strikes (Panigada et al., 2006; David, Alleaume & Guinet, 2011; Coomber et al., 2016; Peltier et al., 2019), marine litter (Fossi et al., 2014; Di-Méglio & Campana, 2017), chemical pollution (Marsili & Focardi, 1996), and noise (Sciacca et al., 2016).

Regular systematic studies of fin whale density and abundance in the Mediterranean Basin are part of the requirements of the Marine Strategy Framework Directive (MSFD, 008/56/EC) and the Habitat Directive (HD, 92/43/EEC), but long-term basin wide information is still lacking (Panigada et al., 2017). Trends of species abundance is one of the indicators required by the MFSD for the assessment of Good Environmental Status (GES). The evaluation of trend in abundance is considered a relevant indicator to set threshold values and evaluate species population (Palialexis et al., 2019) and directional trends of the abundance values are needed to express the extent to which good environmental status is being achieved (Art. 4 of the Decision 2017/848/EU).

Abundance and density estimates for the Liguro-Provencal Basin (Forcada, Notarbartolo Di Sciara & Fabbri, 1995; Forcada et al., 1996), specific for the Pelagos Sanctuary (Gannier, 2006) and for the Ligurian sea (Laran et al., 2010) from ship based surveys performed during summer, evidenced a strong decreasing trend, even if difficulties in comparing those estimates must be taken into account (Panigada et al., 2011). Latest available abundance and density estimates for this area were obtained by aerial surveys performed in 2009 and from 2010 to 2013 from Italian research groups (Panigada et al., 2011, 2017) and from 2011 and 2012 from French groups (Laran et al., 2017). Despite the similar platform used for the surveys, strong differences were found in the final estimates: for the Pelagos Sanctuary, as an example, 330 (95%CI 172 - 633) individuals were estimated from the first groups (Panigada et al., 2017) and around 1100 (95% CI: 600–2400) from the second (Laran et al., 2017).

It has to be stressed that no abundance or density estimates exist for all the other areas of the Mediterranean sea. While Panigada et al. (2017) extended survey coverage to the southern areas of the western basin, no fin whale sighting was registered in those areas. Only recently the ACCOMBAMS surveys initiative (Panigada et al., 2019) aimed to fill this knowledge gap, with a survey that covers the entire Mediterranean Basin.

The use of ferries as platforms for conducting dedicated research has been increasing in recent years. It has been demonstrated that data collection following specific protocols, and ensuring the recording of all needed data can result in the successful use of dataset for species distribution studies (Kiszka et al., 2007; Arcangeli, Marini & Crosti, 2012; Aïssi et al., 2015; Correia et al., 2015; Morgado et al., 2017; Azzolin et al., 2020).

In the Mediterranean Basin, several research institutions, scientific associations and ferry companies are collaborating in the development of the Fixed Line Transect Mediterranean Monitoring Network (FLT Med Net). This project, coordinated by ISPRA, started in 2007 and is keeping developing year by year, with the adding of new institutions and new monitored routes distributed in the central-western Mediterranean and the Adriatic and Ionian Region. A dedicated protocol is shared by all research groups, ensuring a consistent and coordinated collection of data on cetaceans, sea turtles, seabirds and human impacts, such as marine traffic and marine litter (ISPRA, 2016). Data collected were used for investigating species distribution, habitat preference as well as quantifying impact of human activities.

In this work we used data on fin whale distribution collected by the network operating in the central-western Mediterranean and Adriatic and Ionian sea (ADRION) region. The dataset encompassed 11 years, ensuring an evaluation of short-term trends (Palialexis et al., 2019). We investigated interannual variability in species density and presence in different sub-areas. Group size variability was also investigated to inspect frequentation and use of different areas. Finally, we tested the usability of the data to assess a trend, following the request of the Habitat Directive and MSFD. In order to avoid the influence of seasonal variability, and make use of the largest dataset available, the analysis was restricted to the summer months.

Materials & Methods

Data collection

For the purpose of this analysis, we used data collected during summer months (considered from late May to end of September), from 2008 to 2018. Data were collected from dedicated observers embarked on board ferries along fixed routes, covering the western Mediterranean and ADRION region. Sampled routes are shown in Figure 1 [map of monitored routes].

Surveys were conducted from the ferries' command deck by a team of at least three MMOs (Marine Mammals Observers) that scanned a sea area of approximately 130° for each side of the command deck by naked eye and using binoculars (7x50) to confirm species and group size. Trackline of effort was recorded continuously all along the survey using a dedicated Global Positioning System (GPS). Weather conditions were recorded at the beginning of the survey and every time a change occurred. Weather data included wind speed and direction, sea state (following the Beaufort scale), cloud cover, visibility and rain. Effort was considered only under optimal conditions (Beaufort less than 4, good visibility). Everytime a cetacean sighting occurred, the following data were recorded: time, longitude, latitude, radial distance, angle between sighted animal/group and ferry route, species, number of individuals (expressed as minimum, maximum and best estimation), behavior toward the ferry (indifferent, escaping or approaching) and any peculiar observed behavior.

Radial distance was measured using either a rangefinder stick (Wright & Cosentino, 2015) or a binocular with reticle rangefinder. In this latter case, distances were subsequently converted into kilometric distances applying the formula from Kinzey & Gerrodette (2003) (see Cominelli et al., 2016 for more details on conversion). Angle between cetacean sighting and ferry course was measured using a compass or a protractor, set with the 0° coinciding with the stern of the ferry.

Data preparation

All data was imported into the software QGIS and mapped using the EPSG3035 projection. GPS points of the ferry track were used to create a transect for each trip, considering a single trip from port to port. After eliminating points where weather conditions were not ideal and during which observers were not on-effort, total length of each obtained transect was then computed. Transects were then grouped into Transect-Groups according to the route and the sea area covered so that the routes covering two sea areas were divided into two separate transect groups, separating northern (or eastern) from southern (or western) area (Table 1). For each transect group then, the maximum length recorded for a single transect was used in order to set a threshold value for assessing transect representativeness: within each transect group, transects not reaching the 30% of the maximum length were discarded from the analysis. For each transect finally, total number of fin whale sightings and total number of individuals sighted was computed.

A strip-transect framework analysis was applied to the dataset. To this end, each transect was transformed into a strip-transect. Considering the high detectability of the species and the removal of the possible bias caused by bad weather conditions, the main factor affecting width of transects is considered to be observers heights on the sea level. Differences in heights of the command deck among different ferries, radial distance and angle of each sighting were used in order to compute the effective strip widths of each transect. Ferries were categorized into 3 types, where Type I ferries included ferries with height of command deck between 12 and 15 m, Type II ferries with 20-22 m command deck heights and Type III ferries with heights between 25 and 28 m. Distance sampling analysis has been performed using the package RDistance (version2.1.3) in R (version 3.6.1). The objective of the analysis was to compute the Effective Strip Width (ESW) separately for each different type of ferry used. All sightings collected during the sampling period have been used for the assessment of the ESWs. Radial distances and angles between sightings and ferry heading were used to compute perpendicular distances. For each type of ferry three different detection functions have been tested, with zero or one adjustment: Half normal, Uniform and Hazard rate, In order to choose the optimal detection function, the 6 obtained AIC have been compared and the best model has been chosen according to lowest AIC value.

Density of fin whales (D) was then computed as

$$D_t = \frac{n_t}{2ESW_{type}l_t}$$

Where

t = transect

n_t = number of animals observed along the transect

ESW_{type}= ESW as computed for the type of ferry used for that transect

l_t= total length of the transect

Sampling frequency varied among routes, from weekly to monthly, depending on ferry company schedule. Pearson's correlation coefficient test was used in order to assess correlation among transects of the same transect group performed within the same day or consecutive days, or within the same week (considered as a minimum of 7 days separating two consecutive trips). Transects were considered as correlated when Pearson's r value was > 0.5. For routes where transects were found to be correlated, one among the two consecutive transects was randomly kept. The correlation process has been done stepwise, first starting on the same day scale, then performing the analysis on the kept dataset (without transects discarded in the previous step) for consecutive days and finally on the weekly scale. The same threshold for the correlation was applied to all steps.

Geographic scale

For the study we set two different geographic scales. The overall dataset was used to describe distribution and trend of the species at global scale, encompassing the western Mediterranean area and the ADRION region. We then highlighted 4 sub-areas: the Pelagos Sanctuary (PS), which includes the transect groups TI, TB, NC, NB, SC, SB, N_LB, S_LB, LGA, E_CVBA; the Western Pelagos (WP), including the transect groups TAL and W_CVBA; the South-Eastern Pelagos (SEP), defined by the transects CTCV, PATU, N_TUCV, S_TUCV, CAPA and the ADRION region (AD), with the transect groups N_AP and S_AP (Figure 2).

Fin whale groups

As school size can be an indicator of whale feeding success or food availability (Littaye et al., 2004), frequency distribution of size of groups was inspected at both scales (global and sub-area scale). For this analysis, group size is defined by the total number of individuals sighted at the same time after the first detection (used for the distance sampling parameters) in the area covered by the observer. Group sizes have been classified into 4 categories: “single” (for sighting with only 1 individual), “pair” (2 individuals), “small group” (3 to 5 individuals) and “large group” (more than 5 individuals).

χ^2 test were used to compare frequency distribution of group sizes among years, at both scales, as well as differences in the four sub-areas.

Summer abundance and distribution

Average density for the entire basin and for the four sub-areas were used as index to highlight patterns in the summer abundance and distribution of the species for the overall considered period. Kruskal–Wallis tests with post-hoc Dunn's tests were performed to find statistical differences among different years and among different sub-areas.

Generalized Additive Models (GAM) (Hastie & Tibshirani, 1986) were used to inspect the role of the year in describing the trends of the species presence, at all considered geographical scales. While linear regression methods are usually applied for inspecting trends in distribution, GAMs were preferred to linear models for their ability to deal with highly non-linear and non-monotonic relationships (Guisan, Edwards & Hastie, 2002), thus expected to describe the complex trends in presence distribution (Cominelli et al., 2016; Morgado et al., 2017).

GAMs were fitted applying a presence/absence approach, with a quasibinomial distribution and using Density (D) as a weight. The only explanatory variable was the year, the scale parameter was set to −1.0 and gamma to 1.4 to deal better with overdispersion in the data (Wood). Final GAM formula is

$$y = s(year, k = n)$$

Knots represent the maximum number of splines of the smooth function. Consequently, the number of knots is usually restricted in order to avoid overfitting to the data. We used knots restriction in order to assess a possible trend, overcoming the high interannual variability in the data, while avoiding to over fit the model to the data, resulting in as many splines as sampling years. Different GAMs have then been compared, varying the number of knots. Starting from the highest possible value (overfitted model, with as many knots splines as years of sampling), n was then reduced down to the minimum possible (n =2). The final n was chosen as the n value before the maximum difference in deviance explained across two consecutive models, considered as the value before reaching the over-fitted models range.

Results

ESW

During the summer months between 2008 and 2018, 228257.5 km along 1190 transects have been monitored in the Mediterranean Sea. After considering the 30% of the maximum length threshold values, 1146 transects were kept for the analyses (Table 1).

No fin whale sightings were recorded in the AD sub area, so no further analysis was possible.

1705 sightings have been collected during the entire period and among these 1687 could be used for computing ESWs. On the basis of AIC, for all the three groups of ferries a Hazard rate model with no adjustment terms was chosen as the detection function.

ESWs were respectively 1235 m for Type I ferries, 1415 m for Type II e 1143 m for Type III.

Correlation between trips

Table 2 summarizes the results of the Pearson's correlation coefficient for the different transect groups. Transects performed within the same day or consecutive days resulted correlated (Pearson's correlation index > 0.5) along the SB, NC and SC transect groups, but not in the LG and CTCV groups. However, since the test is not significant for these groups, we decided to consider transects performed on the same day as correlated, following a precautionary approach.

For the NLB and SLB transect groups, Pearson's correlation index is not calculated as not enough data were available, while for the NB, TAJ and TI there were only few cases of transects performed within the same day.

Weekly correlation was found only along the E_CVBA transect group. Following the correlation tests and not considering the N_AP and S_AP transects, 367 transects were eliminated so the final dataset consists of 779 transects.

Fin whale Group sizes

Only sightings from transects selected after checking for correlation were used to inspect group size of the species. The final dataset accounts for 1100 sightings, for a total of 1549 fin whale sighted. More than 73% of sightings were of single individuals (n=803), 21% of pairs (n=234), and the remaining 6% of groups of three or more individuals (n=67 and n=6 for "small group" and "large groups" respectively). The main outlier is represented by a sighting of 12 individuals, occurred on 05/06/2015 along the E_CVBA transect and representing a very sparse group of animals (personal communication).

χ^2 test for the entire study area indicated a significant difference in group distribution among years (χ^2= 62.915, df = 30, p-value = 0.0004027). Overall, single individuals was the main type of encounter, followed by “pair”. Small groups were detected more constantly only in 2012, 2013 and 2015 and were rare in 2009, 2010 and 2018; large groups were encountered only in 2013, 2015 and 2018.

Figure 3 represents the frequency distribution of group size by sub-areas and by years. Small and large groups of fin whales were frequently sighted only in the PS or in the WP, in 2012, 2013 and 2015, while no groups occurred in the rest of the basin.

χ^2 test found a significative difference among years in the PS (χ^2= 53.241, df = 30, p-value = 0.005[illegible]), while no differences was found in the two other sub-areas (χ^2= 16.822, df = 18, p-value = 0.5354 for the WP and χ^2= 4.9524, df = 5, p-value = 0.4217 for the SEP).

Summer abundance and distribution

Overall D in the western basin for the entire period was 0.4[illegible] (95% CI 0.36-0.49); the sub-area scale confirmed the importance of the PS, where the overall D recorded was 0.51 (95%CI 0.43 – 0.59). High D was recorded also in the WP area (0.50; 95% CI 0.29 – 0.70) while lowest value characterized the SEP (0.02; 95%CI 0.01-0.03). Differences among different sub-areas were statistically significant (KW Kruskal-Wallis chi-squared = 80.16, df = 2, p-value < 2.2e-16), confirmed by the Dunn’s post-hoc test.

Yearly D values for the overall region and for the three sub-areas are visualized in Figure 4. Kruskal-Wallis post hoc test for differences among years statistically confirmed the interannual variability (Kruskal-Wallis chi-squared = 71.874, df = 10, p-value = 1.925e-11). Dunn’s test highlighted some years as being very different from the others (Table 3) . In particular 2012, 2013 and 2015, showed highest values of the considered period, with 2013 being the most anomalous year, differing from 6 other years. Looking at the poorest years, 2008 and 2014 emerge, though in 2008 this result is most probably affected by the lack of data. 2010 and 2018

are not different from any other considered years, thus better representing the considered 'normal' presence of the species.
Concerning the sub-area analysis, no differences were found among years in the WP area (Kruskal-Wallis chi-squared = 12.4118, df = 6, p-value = 0.05) and in the SEP area (Kruskal-Wallis chi-squared = 8.6285, df = 6, p-value = 0.1956), while interannual differences were confirmed for the PS (Kruskal-Wallis chi-squared = 61.21, df = 10, p-value = 2.137e-09)
In PS, the most anomalous years appeared to be 2008, 2013 and 2015. While for 2008 we shall always consider the difference in sampling effort, in 2013 and 2015 we find the same anomalous peaks shown for the entire basin in this sub area though 2012 look more normal, being different only from 2008 and 2009 (Table 4).

Estimated trends in species abundance at all considered spatial scales are shown in Figure 5. For the entire basin, the final GAM model allowed for a maximum of 7 knots before reaching the overfitting of the data; 3 knots were enough for the WP and SEP areas, while the PEL area allowed a maximum of 9 knots. The resulting smooth splines showed an even lower number of knots, which allow for the visualization of trends. For the Western Mediterranean basin, 3 knots of the spline summarize the trend into 3 separated periods: a positively increasing trend from 2008 up to year 2013, with the predicted density values increasing over 60% in this period, then a slightly decreasing trend up to 2016 and finally a relatively stable period during the last two considered years. A similar pattern is found in the Pelagos Sanctuary area, where also the number of knots in the end is 3: after the first period with the increasing trend ending with a peak in 2012-2013, a relatively stable period is found, with a new increasing trend in the end. The Western Pelagos area showed an almost linear negative trend, while for the South Eastern Pelagos area the final smooth function shows 2 knots, indicating a slightly positive trend for the last 3 years of the considered period. Gaps in the dataset for these two sub areas though must be taken into account in the analysis of these trends.

Discussion

Fin whale summer abundance and distribution in the Western Mediterranean basin is characterized by a strong interannual variability. The analysis of density indexes, performed thanks to a synoptic data collection over the western Mediterranean basin, evidenced the alternance of normal years (as 2010 and 2018), rich years (2012, 2013 and 2015) and very poor years (2014 specifically, as for 2008 a lack of research effort in the basin needs to be evidenced). Looking at intra-basin presence and distribution, the species can be considered absent from the Adriatic sea, where no sighting occurred during the summer time over the considered period. While the species was previously sighted in the Adriatic Region, these sightings must be considered as occasional for the species (Notarbartolo di Sciara et al., 2003; Lipej, Dulčić & Kryštufek, 2004).

The Pelagos Sanctuary for marine mammals, established in 2002 in the northern area of the Western Mediterranean basin (Notarbartolo-di-Sciara et al., 2008), confirms to be a very important area for this species, hosting highest density values during summertime. The interannual variability is also present in this sub-area, as already found in previous works (Panigada et al., 2005; Cominelli et al., 2016; Morgado et al., 2017). The analysis of this biggest dataset strengthens the importance of taking into account this variability in planning monitoring on a yearly basis. The Western Pelagos sub-area emerged as an important area for the species (Arcangeli, Campana & Bologna, 2017). Density values were comparable and even higher than the ones recorded in the Pelagos Sanctuary sub-area. Values recorded here also showed the highest variability. Acoustic studies and stable isotope analysis (Castellote, Clark & Lammers, 2012a,b; Giménez et al., 2013), indicate the presence in the Mediterranean basin, and particularly in the area South of Spain, of another subpopulation of fin whales, the NENA subpopulation (North East North Atlantic fin whales), seasonally travelling here from the North Atlantic Ocean. The Balearic Basin can be considered as the easternmost range limit of the NENA males (Castellote, Clark & Lammers, 2012a,b). The highest variability recorded in the Western Pelagos sub-area can then be due to the mixing of the NENA and the MED subpopulation, occurring when the NENA fin whales travel eastern than their usual distribution. It is also interesting to highlight how in this area, in our correlation analysis, density values were found to be correlated even among surveys performed a week apart. This correlation can be interpreted as due to the constant high number of individuals recorded here, and either by a more ‘resident’ behavior of the species in this sub-area. It also needs to be underlined that the Western Pelagos together with the Pelagos Sanctuary sub-areas are recognised as an Important Marine Mammal Area for the Mediterranean sea (Agardy et al., 2019).

Similar consideration for the correlation analysis can be done for the Pelagos Sanctuary sub-area, where density values were found to be correlated at a daily scale but not at a weekly scale. This can be interpreted by the species not being stable in the area, probably following a more patchy distribution of preys all around the basin. While a clear interpretation on whale movements is not possible through our dataset, still it gives an indication on the irregular distribution of animals and the limits of surveys conducted on a short period of time, which may lead to an under-estimation of results. Repeated surveys might better catch the real distribution of the species. The species is not absent from the SouthEastern Pelagos sub-area, where rare but still yearly regular sightings were recorded. Specifically, localized hot-spots are known to occur in this basin during peculiar time of the year (Canese et al., 2006; Pace et al., 2019) while, in general, the area can be seen as a traveling area among different sub-areas. The FLT Med Network is the first and only recurring monitoring of this sub-area. Panigada et al. (2017), while extending aerial surveys in this area to provide abundance estimates, did not collect any sightings here.

Looking at interannual variability at sub-area scale, some years emerge as particularly anomalous both in the Pelagos Sanctuary and in the Western Pelagos sub-area, though, in the latter, the small dataset does not allow for the statistical tests. Still, it should be underlined that in 2012, 2013 and 2015 density values were higher than average in both sub-areas. These results partially confirm the pattern highlighted by Morgado et al. (2017), though a strong difference in the two analyses for the year 2013 is found. In our analysis, 2013 emerges as the second richest year of the entire dataset, while was classified as a poor year in the previous analysis. This difference is due to the lack of data from the Tyrrhenian area, covered in this work by the transects LGA and E_CVBA, which were not considered in the previous study. The intermittent blooming area of the Bonifacio Gyre (D'Ortenzio & Ribera d'Alcalà, 2009) can represent an alternative feeding ground for the species that can concentrate also here, rather than in the usual areas in the Western portion of the basin (Arcangeli et al., 2014). This result stresses the importance of a complete coverage of the basin when looking for trends of species.

While the species is most commonly sighted as single individuals or pairs (Notarbartolo di Sciara et al., 2003; Arcangeli, Marini & Crosti, 2012, and results from this work), particularly favorable ecosystem conditions, leading to the presence of food patches, can lead to the presence of groups

(Littaye et al., 2004; Aïssi et al., 2008). In our analysis, richest years, indicated by the highest density values, are also characterized by the presence of small groups and large groups in the Pelagos Sanctuary and Western Pelagos sub-areas. No groups were sighted on the contrary during poor years.

The lack of groups in the South Eastern Pelagos sub-area seems to confirm the importance of this region mostly as a travelling area rather than a feeding ground.

One of the main aims of the Marine Strategy Framework Directive is to assess trends in population abundance. It is widely recognized that long dataset are needed for reliable trend estimation, and 10 years have been identified as a suitable interval for the short-term trend assessment (Palialexis et al., 2019). While the strong interannual variability makes it difficult to highlight a linear trend, GAMs allowed for the identification of more complex trends at the basin as well as at sub-areas scales, highlighting the presence of strong peaks as well as poor years in density values of the species. Such complex trends are likely linked to the variability of ecosystem productivity in the Mediterranean Sea (Druon et al., 2012; Morgado et al., 2017), as well as to the interrelated effect of prey availability and the impact of human pressures (Azzellino et al., 2017). It is interesting to note that this high variability was detected even if we used the dataset collected during the summer season only, which is supposed to be the season when whales concentrate mostly in the north-western Mediterranean Sea, so in the core area of the present study. The differences about rich or poor years found by our study could explain the differences in abundance estimates for the Pelagos Sanctuary obtained by Panigada et al. (2017) and Laran et al. (2017). Indeed, for the second assessment, surveys were performed in a peaking year (2012), while the aerial surveys dataset from 2009 and 2010 were used by Panigada et al. (2017). Considering that, on the basis of our findings, also the results of the ASI of 2018 could be "corrected" or at least the interpretation could be smoothed. These findings further sustain the need for a large scale continuous monitoring in order to be able to detect the interannual component of the variability as well as for correlating the abundance and distribution of animals with the environmental and anthropogenic drivers.

Conclusions

The FLT Med Network, operating since 2008 in the Western Mediterranean Basin and in the Adriatic and Ionian region, is the only recurring monitoring occurring in the basin. The use of ferries as a platform of opportunity and a strong scientific protocol shared among all institutions, allow for a consistent data collection. Repeatability of surveys as well as the possibility of surveying areas usually difficult to reach, allowed for the collection of a unique dataset during the all year. Moreover, the rapid development of the network with new routes along the recently established SPAMI Spanish corredor (Barcelona-Tangeri route) and in the Gibraltar Strait (two routes) demonstrated the feasibility of further expand the surveyed area, allowing to include already known important areas such as the Lampedusa and Malta areas, or areas where information are extremely lacking as in the eastern Mediterranean basin.

The importance of datasets collected by the FLT Med Network has already been recognized within the MSFD and specifically for the floating marine litter monitoring in high sea areas and more recently for the sea turtles' assessment. The yearly monitoring and the GAM approach for the definition of trends, allow for the interpretation of these results as required by the MSFD and HD. Looking at the complex trends, we can distinguish within our sampling periods the two reference periods indicated by the MFSD, namely 2007-2012 as the first reporting period and 2013-2018 as the second reporting period. Keeping the spatial scale addressed by the MFSD, equal to the Western Mediterranean Basin, it is possible to confirm an increasing trend followed by a negative trend, with a -40% percentage variation from 2012 to 2018. On the other hand, the interannual analysis allowed to highlight reference years that can be used as a baseline for the definition of the trend of the following years. This is another approach that has been suggested for the evaluation of trends of population abundance, given the lack of abundance estimates in past years and the difficulties in conducting large scale surveys. We highlight 2010 and 2018 as reference years for the evaluation of the following years, being those years the less different from the others. Looking at these two reference year, the variation is -7 % , indicating a limited negative trend for this area.

Our results also highlighted the importance of considering different spatial scales when looking at species presence and distribution, together with the need to specifically address peculiar areas known to be important for the species.

An integrated approach foreseeing both, large basin wide scale surveys and yearly monitoring would allow a better interpretation of results. Indeed, the large basin wide scale surveys conducted every 6 or 10 years would allow for more accurate abundance estimates over the whole range of the species, while the results from yearly monitoring with ferries could help correct and interpret the large scale surveys, adding the information on interannual variability, and helping in addressing abundance estimates into rich or poor years. Our work not only confirmed some previous findings about species presence in the area but also enlarged current knowledge of species presence in other areas previously poorly investigated.

Acknowledgements

We wish to thank all the ferry companies who are thoughtfully collaborating with us in the FLT Med Network, and specifically the Corsica Sardinia Ferries, Grimaldi Lines, Minoan and Tirrenia. We are particularly thankful to Cristina Pizzuti (CSF), Rosa Cappuccio (Grimaldi) and all the staff of the ferries for the constant and kind support on all logistic aspects. This work would not be possible without all the students, volunteers and researchers who professionally and passionately collect data onboard.

References

Agardy T, Cody M, Hastings S, Hoyt E, Nelson A, Tetley M, Notarbartolo di Sciara G. 2019. Looking beyond the horizon: An early warning system to keep marine mammal information relevant for conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 29:71–83. DOI: 10.1002/aqc.3072.

Aïssi M, Arcangeli A, Crosti R, Daly Yahia MN, Loussaief B, Moulins A, Pellegrino G, Rosso M, Tringali LM, Tepsich P. 2015. Cetacean occurrence and spatial distribution in the central Mediterranean Sea using ferries as platform of observation. *Russian Journal of Marine Biology* 41:343–350. DOI: 10.1134/S1063074015050028.

Aïssi M, Celona A, Comparetto G, Mangano R, Würtz M, Moulins A. 2008. Large-scale seasonal distribution of fin whales (Balaenoptera physalus) in the Central Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom* 88:1253–1261.

Arcangeli A, Campana I, Bologna MA. 2017. Influence of seasonality on cetacean diversity, abundance, distribution and habitat use in the western Mediterranean Sea: Implications for conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* 27:995–1010. DOI: 10.1002/aqc.2758.

Arcangeli A, Marini L, Crosti R. 2012. Changes in cetacean presence, relative abundance and distribution over 20 years along a trans-regional fixed line transect in the Central Tyrrhenian Sea. *Marine Ecology* 34:112–121.

Arcangeli A, Orasi A, Carcassi SP, Crosti R. 2014. Exploring thermal and trophic preference of Balaenoptera physalusin the central Tyrrhenian Sea: a new summer feeding ground? *Marine Biology* 161:427–436.

Azzellino A, Airoldi S, Lanfredi C, Podestà M, Zanardelli M. 2017. Cetacean response to environmental and anthropogenic drivers of change: Results of a 25-year distribution study in the northwestern Mediterranean Sea. *Deep Sea Research Part II: Topical Studies in Oceanography* 146:104–117. DOI: 10.1016/J.DSR2.2017.02.004.

Azzolin M, Arcangeli A, Cipriano G, Crosti R, Maglietta R, Pietroluongo G, Saintingan S, Zampollo A, Fanizza C, Carlucci R. 2020. Spatial distribution modelling of striped dolphin (Stenella coeruleoalba) at different geographical scales within the EU Adriatic and Ionian Sea Region, central-eastern Mediterranean Sea . *Aquatic Conservation: Marine and Freshwater Ecosystems*:1–14. DOI: 10.1002/aqc.3314.

Bérubé M, Aguilar A, Dendanto D, Larsen F, Notarbartolo di Sciara G, Sears R, Sigurjonsson J, Urban R. J, Palsboll PJ. 1998. Population genetic structure of North Atlantic, Mediterranean Sea and Sea of Cortez fin whale, Balaenopera physalus (Linnaeus 1758): analysis of mitocondrial and nuclear loci. *Molecular Ecology* 7:585–599.

Brown MR, Corkeron PJ, Hale PT, Schultz KW, Bryden MM, Brown MR, Corkeron PJ, Hale PT, Schultz KW, Bryden MM. 1995. Evidence for a Sex-Segregated Migration in the Humpback Whale (Megaptera novaeangliae) Stable URL : http://www.jstor.org/stable/50160 Linked references are available on JSTOR for this article : Evidence for a sex-segregated migration in the humpback wha. 259:229–234.

Canese S, Cardinali A, Fortuna CM, Giusti M, Lauriano G, Salvati E, Greco S. 2006. The first identified winter feeding ground of fin whales (Balaenoptera physalus) in the Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom* 86:903–907.

Castellote M, Clark CW, Lammers MO. 2012a. Fin whale (Balaenoptera physalus) population identity in the western Mediterranean Sea. *Marine Mammal Science* 28:325–344.

Castellote M, Clark CW, Lammers MO. 2012b. Acoustic and behavioural changes by fin whales (Balaenoptera physalus) in response to shipping and airgun noise. *Biological Conservation* 147:115–122.

Cominelli S, Moulins AAA, Rosso M, Tepsich P. 2016. Fin whale seasonal trends in the Pelagos Sanctuary, Mediterranean Sea. *Journal of Wildlife Management* 80:490–499. DOI: 10.1002/jwmg.1027.

Coomber FG, D'Inc?? M, Rosso M, Tepsich P, Notarbartolo di Sciara G, Moulins A. 2016. Description of the vessel traffic within the north Pelagos Sanctuary: Inputs for Marine Spatial Planning and management implications within an existing international Marine Protected Area. *Marine Policy* 69:102–113. DOI: 10.1016/J.MARPOL.2016.04.013.

Correia AM, Tepsich P, Rosso M, Caldeira RMA, Sousa-Pinto I. 2015. Cetacean occurrence and spatial distribution: Habitat modelling for offshore waters in the Portuguese EEZ (NE Atlantic). *Journal of Marine Systems* 143:73–85. DOI: 10.1016/j.jmarsys.2014.10.016.

D'Ortenzio F, Ribera d'Alcalà M. 2009. On the trophic regimes of the Mediterranean Sea: a satellite analysis. *Biogeosciences* 6:139–148.

David L, Alleaume S, Guinet C. 2011. Evaluation of the potential of collision between fin whales and maritime traffic in the north-western Mediterranean Sea in summer, and mitigation solutions. *Journal of Marine Animals and Their Ecology* 4:17–28.

Di-Méglio N, Campana I. 2017. Floating macro-litter along the Mediterranean French coast: Composition, density, distribution and overlap with cetacean range. *Marine Pollution Bulletin* 118:155–166. DOI: 10.1016/j.marpolbul.2017.02.026.

Druon J-N, Panigada S, David L, Gannier A, Mayol P, Arcangeli A, Cañadas A, Laran S, Di Méglio N, Gauffier P. 2012. Potential feeding habitat of fin whales in the western Mediterranean Sea: an environmental niche model. *Marine Ecology Progress Series* 464:289–306.

Forcada J, Aguilar A, Hammond P, Pastor X, Aguilar R. 1996. Distribution and abundance of fin whales (Balaenoptera physalus) in the western Mediterranean sea during summer. *Journal of Zoology* 238:23–34.

Forcada J, Notarbartolo Di Sciara G, Fabbri F. 1995. Abundance of fin whales and striped

dolphins summering in the Corso-Ligurian Basin. *Mammalia* 59:127–140.
Fossi MC, Coppola D, Baini M, Giannetti M, Guerranti C, Marsili L, Panti C, de Sabata E, Ciò S. 2014. Large filter feeding marine organisms as indicators of microplastic in the pelagic environment: the case studies of the Mediterranean basking shark (Cetorhinus maximus) and fin whale (Balaenoptera physalus). *Marine Environmental Research* 100:17–24.
Gannier A. 2006. Le peuplement estival de cétacés dans le Sanctuaire Marin Pelagos (Méditerranée nord-occidentale): distribution et abondance. *Mammalia* 70:17–27.
Geijer CKA, Notarbartolo di Sciara G, Panigada S. 2016. Mysticete migration revisited: are Mediterranean fin whales an anomaly? *Mammal Review* 46:284–296. DOI: 10.1111/mam.12069.
Giménez J, Gómez-Campos E, Borrell A, Cardona L, Aguilar A. 2013. Isotopic evidence of limited exchange between Mediterranean and eastern North Atlanticfin whales. *Rapid Communications in Mass Spectometry* 27:1801–1806.
Guisan A, Edwards TC, Hastie T. 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. *Ecological Modelling* 157:89–100.
Hastie T, Tibshirani R. 1986. Generalized Additive Models. *Statistical Science* 1:297–318.
ISPRA. 2016. *Agreement "Fixed Line Transect monitoring using ferries as platform of observation for marine mega and macro fauna and main threats". Technical annex I - monitoring protocol for cetaceans and sea turtles. pp.19.*
Kinzey D, Gerrodette T. 2003. Distance measurements using binoculars from ships at sea: accuracy, precision and effects of refraction. *Journal of Cetacean Research and Management* 5:159–171.
Kiszka J, Macleod K, Van Canneyt O, Walker D, Ridoux V. 2007. Distribution, encounter rates, and habitat characteristics of toothed cetaceans in the Bay of Biscay and adjacent waters from platform-of-opportunity data. *ICES Journal of Marine Science* 64:1033–1043.
Laran S, Joiris C, Gannier A, Kenney RD. 2010. Seasonal estimates of densities and predation rates of cetaceans in the Ligurian Sea, northwestern Mediterranean Sea: An initial examination. *Journal of Cetacean Research and Management* 11:31–40.
Laran S, Pettex E, David L, Dorémus G, Falchetto H, Monestiez P, Van Canneyt O. 2017. Seasonal distribution and abundance of cetaceans within French waters- Part I: The North-Western Mediterranean, including the Pelagos sanctuary. *Deep Sea Research Part II:*

Topical Studies in Oceanography 141:20–30. DOI: 10.1016/J.DSR2.2016.12.011.

Lipej L, Dulčić J, Kryštufek B. 2004. On the occurrence of the fin whale (Balaenoptera physalus) in the Northern Adriatic. *Journal of the Marine Biological Association of the United Kingdom* 84:861–862.

Littaye A, Gannier A, Laran S, Wilson JPF. 2004. The relationship between summer aggregation of fin whales and satellite-derived environmental conditions in the northwestern Mediterranean Sea. *Remote Sensing of Environment* 90:44–52.

Marsili L, Focardi S. 1996. Organochlorine levels in subcutaneous blubber biopsies of fin whale (Balaenoptera physalus) and striped dolphin (Stenella coeruleoalba) from the Mediterranean Sea. *Environmental Pollution* 91:1–9.

Mayot N. 2015. Interannual variability of the Mediterranean trophic regimes. :14941–14980. DOI: 10.5194/bgd-12-14941-2015.

Morgado C, Martins A, Rosso M, Moulins A, Tepsich P. 2017. Fin Whale Presence and Distribution in the Pelagos Sanctuary: Temporal and Spatial Variability Along 2 Fixed-Line Transects Monitored in 2009-2013. *International Journal of Marine and Environmental Sciences* 1:1–14.

Notarbartolo-di-Sciara G, Agardy T, Hyrenbach D, Scovazzi T, Van Klaveren P. 2008. The Pelagos Sanctuary for Mediterranean marine mammals. *Aquatic Conservation: Marine and Freshwater Ecosystems* 18:367–391. DOI: 10.1002/aqc.855.

Notarbartolo di Sciara G, Castellote M, Druon J-N, Panigada S. 2016. Fin Whales, Balaenoptera physalus: At Home in a Changing Mediterranean Sea? *Advances in Marine Biology* 75:75–101. DOI: 10.1016/BS.AMB.2016.08.002.

Notarbartolo di Sciara G, Zanardelli M, Jahoda M, Panigada S, Airoldi S. 2003. The fin whale Balaenoptera physalus (L 1758) in the Mediterranean Sea. *Mammal Review* 33:105–150.

Orsi Relini L, Relini G, Palandri G, Relini M, Garibaldi F, Cima C, Torchia G, Costa C. 1998. Notes on ecology of the mediterranean krill, a mirror of the behaviour of mediterranean fin whales. In: Evans PGH, Parsons ECM eds. *European Research on Cetacean*. Monaco, 119.

Pace DS, Pellegrino G, Cafaro V, Paraboschi M, Silvestri M, Pavan G, Alessi J, Angeletti D, Ardizzone G, Arcangeli A. 2019. An integrated approach for cetacean knowledge and conservation in the central Mediterranean Sea using research and social media data sources. :1302–1323. DOI: 10.1002/aqc.3117.

Palialexis A, Connor D, Damalas D, Gonzalvo J, Micu D, Mitchel I, Korpinen S, Rees AF, Somma F. 2019. *Indicators for status assessment of species, relevant to MSFD Biodiversity Descriptor*. DOI: 10.2760/282667.

Palsbøll PJ, Bérubé M, Aguilar A, Notarbartolo-Di-Sciara G, Nielsen R. 2004. Discerning between recurrent gene flow and recent divergence under a finite-site mutation model applied to North Atlantic and Mediterranean Sea fin whale (Balaenoptera physalus) populations. *Evolution* 58:670–675.

Panigada S, Araujo H, Belmont J, Cañadas A, David L, Di-Méglio N, Dorémios G, Gonzalvo J, Holcer D, Laran S, Lauriano G, Le Ravallec C, Paiu RM, Perri M, Pierantonio N, Popov D, Ridoux V, Vazquez JA. 2019. The ACCOBAMS Survey Initiative: The first synoptic survey of the Mediterranean Sea. In: *World Marine Mammal Conference WMMC*.

Panigada S, Lauriano G, Burt L, Pierantonio N, Donovan G. 2011. Monitoring winter and summer abundance of cetaceans in the Pelagos Sanctuary (Northwestern Mediterranean Sea) through aerial surveys. *PLoS ONE* 6:e22878.

Panigada S, Lauriano G, Donovan G, Pierantonio N, Cañadas A, Vázquez JA, Burt L. 2017. Estimating cetacean density and abundance in the Central and Western Mediterranean Sea through aerial surveys: Implications for management. *Deep-Sea Research Part II: Topical Studies in Oceanography* 141:41–58. DOI: 10.1016/j.dsr2.2017.04.018.

Panigada S, Notarbartolo Di Sciara G. 2012. Balaenoptera physalus (Mediterranean subpopulation).

Panigada S, Notarbartolo Di Sciara G, Zanardelli Panigada M, Airoldi S, Borsani JF, Jahoda M. 2005. Fin whale (Balaenoptera physalus) summering in the Ligurian Sea: distribution encounter rate, mean group size and relation to physiographic variables. *Journal of Cetacean Research and Management* 7:137–145.

Panigada S, Pesante G, Zanardelli M, Capoulade F, Gannier A, Weinrich MT. 2006. Mediterranean fin whales at risk from fatal ship strikes. *Marine Pollution Bulletin* 52:1287–1298.

Peltier H, Beaufils A, Cesarini C, Dabin W, Dars C, Demaret F, Dhermain F, Doremus G, Labach H, Van Canneyt O, Spitz J. 2019. Monitoring of Marine Mammal Strandings Along French Coasts Reveals the Importance of Ship Strikes on Large Cetaceans: A Challenge for the European Marine Strategy Framework Directive. *Frontiers in Marine Science* 6:1–6.

DOI: 10.3389/fmars.2019.00486.

Sciacca V, Viola S, Pulvirenti S, Riccobene G, Caruso F, De Domenico E, Pavan G. 2016. Shipping noise and seismic airgun surveys in the Ionian Sea: Potential impact on Mediterranean fin whale. *Proceedings of Meetings on Acoustics* 27. DOI: 10.1121/2.0000311.

Wright AJ, Cosentino AM. 2015. JNCC guidelines for minimising the risk of injury and disturbance to marine mammals from seismic surveys: We can do better. *Marine Pollution Bulletin* 100:231–239. DOI: 10.1016/j.marpolbul.2015.08.045.

Figure 1

Map of the monitored routes

(1) Toulon (FR) – Alcudia (ES). (2) Toulon (FR) – Ajaccio (FR). (3) Toulon (FR) - Ile rousse (FR). (4) Toulon (FR) – Bastia (FR). (5) Nice (FR) – Calvi/Ile Rousse (FR). (6) Nice (FR) – Bastia (FR). (7) Savona (IT) - Calvi/Ile Rousse (FR). (8) Savona (IT) – Bastia (FR). (9) Livorno (IT) – Bastia (FR). 10 Livorno (IT) - Golfo Aranci (IT). (11) Civitavecchia (IT) – Barcellona (ES). (12) Catania (IT) – Civitavecchia (IT). (13) Palermo (IT) – Tunisi (TU). (14) Tunisi (TU) – Civitavecchia (IT). (15) Cagliari (IT) – Palermo (IT). (16) Ancona (IT) – Patras (GR)

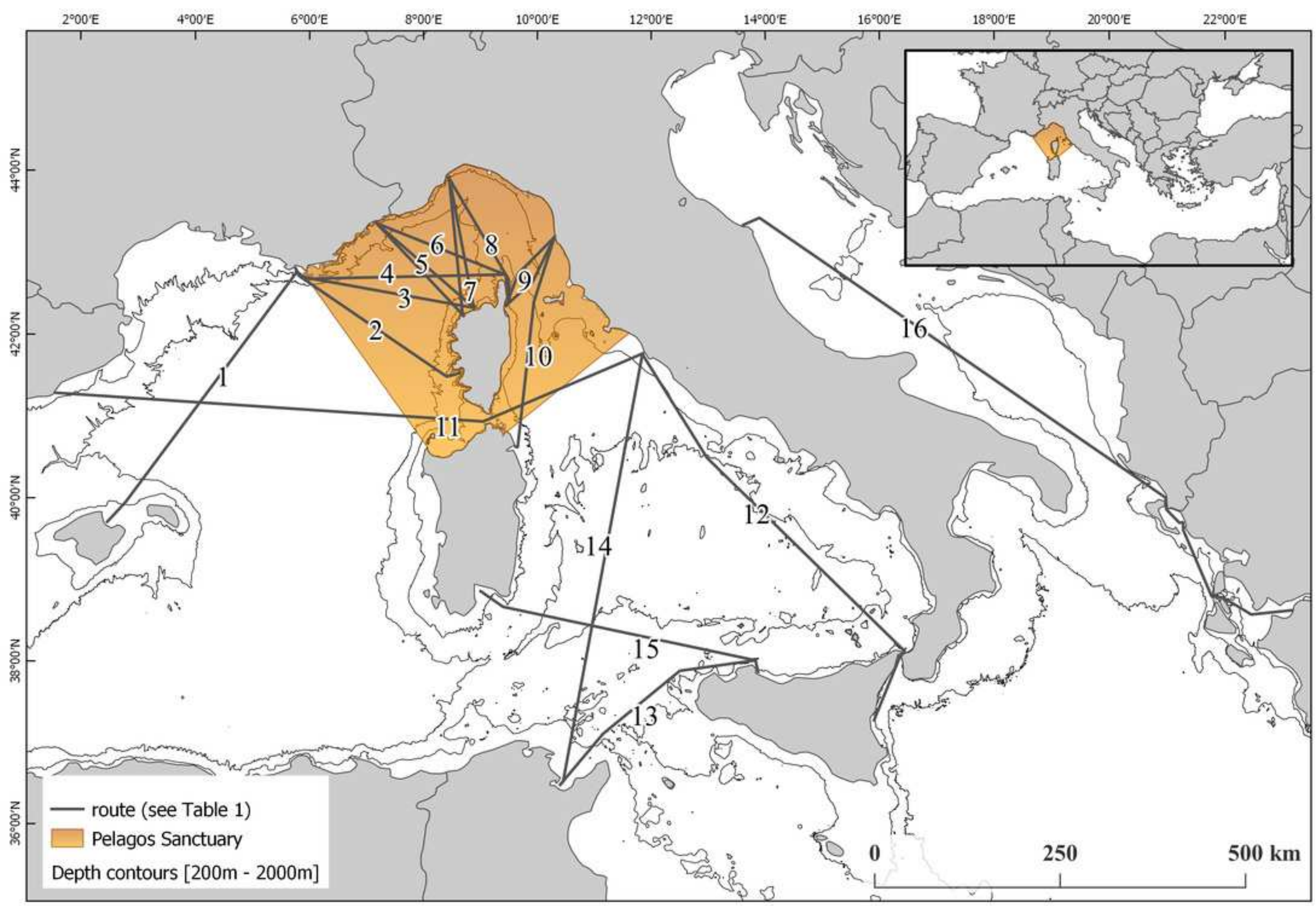

Figure 2

Map of sub-areas and surveyed transects

(WP) Western Pelagos sub-area, including transects from groups TAL and W_CVBA. (PS) the Pelagos Sanctuary sub-area, including transects from groups TI, TB, NC, NB, SC, SB, N_LB, S_LB, LGA and E_CVBA. (SEP) the South-Eastern Pelagos sub-area, including transects from groups CTCV, PATU, N_TUCV, S_TUCV and CAPA. (AD) the Adriatic and Ionian, including transects from groups N_AP and S_AP.

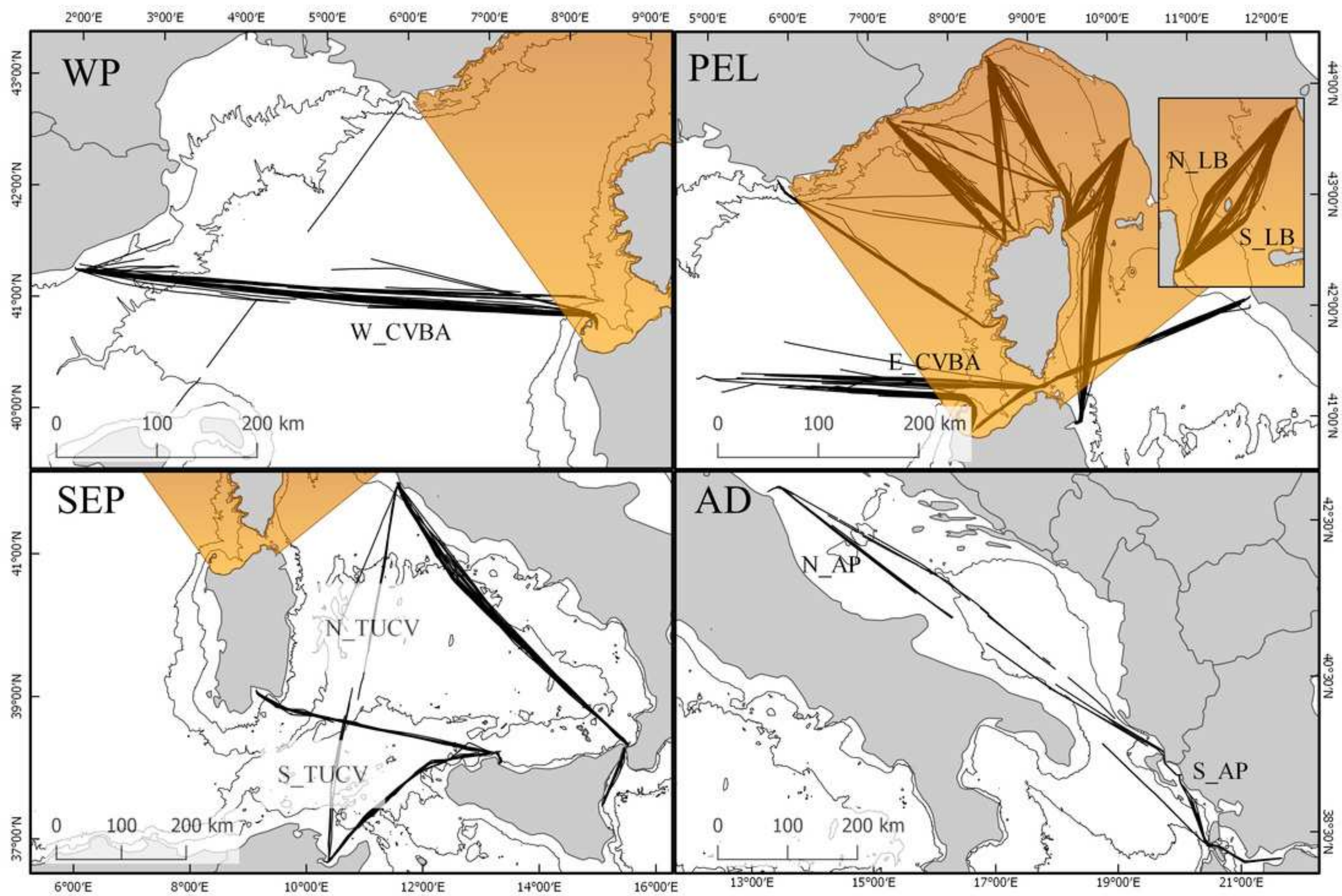

Figure 3

Frequency distribution of fin whale group sizes among sub-areas and per year

(A) Frequency distribution of fin whales group sizes among sub-areas. (B) Frequency distribution of group sizes among years in the WP sub-area. (C) Frequency distribution of group sizes among years in the PEL sub-area. (D) Frequency distribution of group sizes among years in the SEP sub-area.

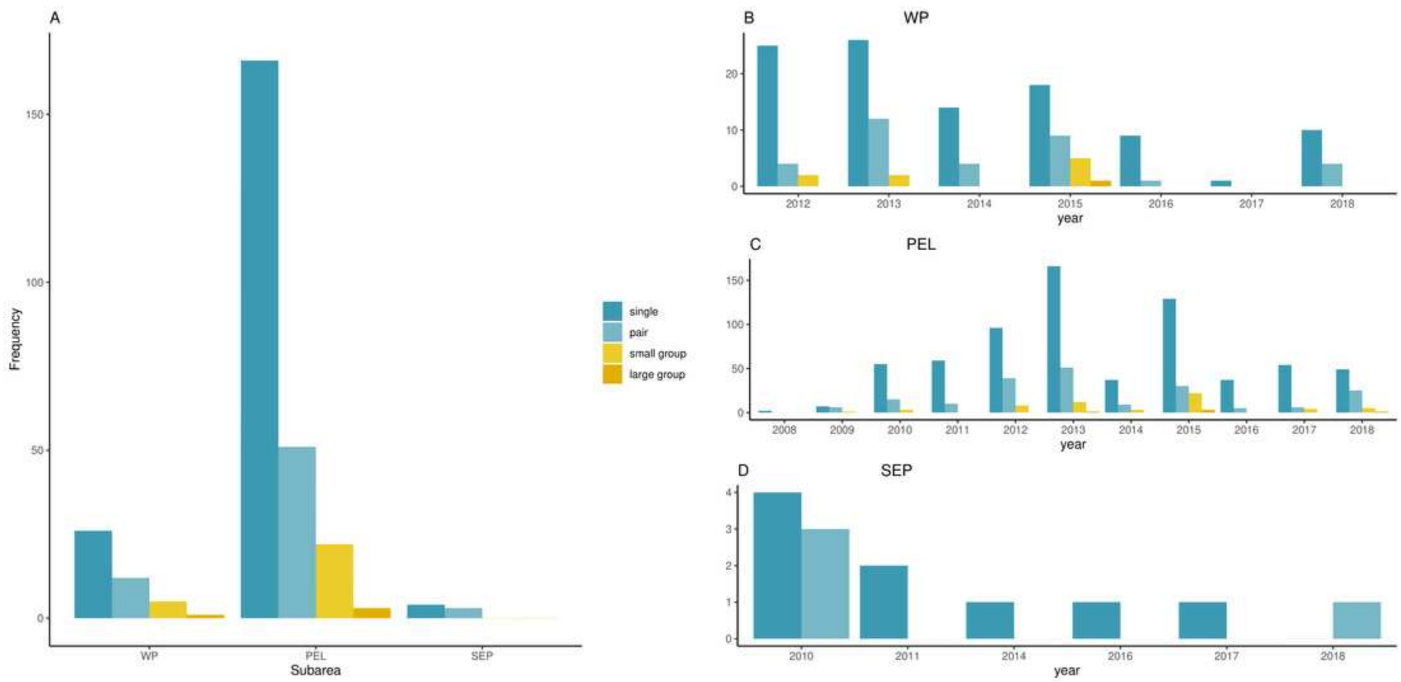

Figure 4

Density of fin whales in the study area and in the considered sub-areas

(A) Mean density of fin whales per year in the Western Mediterranean basin (B) Mean density of fin whales per year in the Western Pelagos (WP), Pelagos Sanctuary (PS) and South Eastern PEelagos (SEP) sub-areas. Error bars represent 95% Confidence Intervals

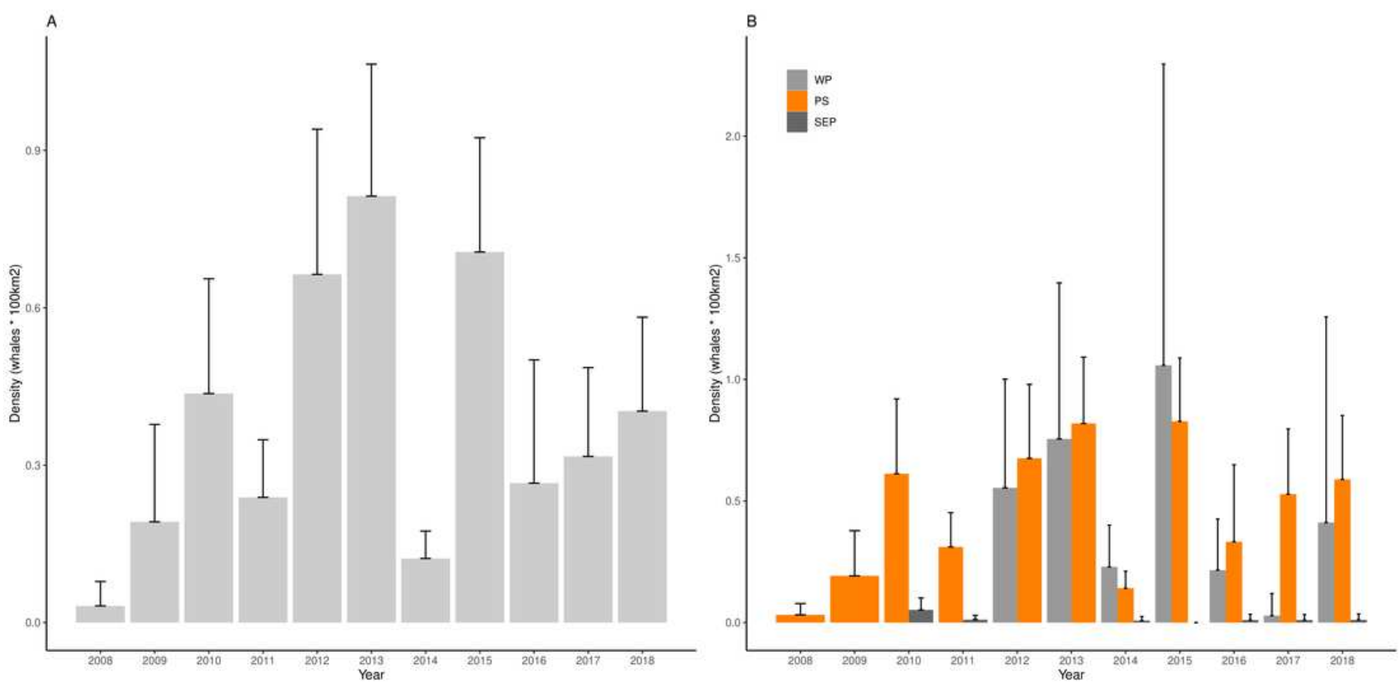

Figure 5

GAM plots showing fin whale density as a function of the year

Generalized additive model (GAM) predicted smooth splines of the fin whale density as a function of the year. Tick marks above the x-axis indicate the distribution of observations. Shaded area represents the 95% confidence interval of the smoothspline function. This plot can be used to understand trends of species abundance in the Western Mediterranean Basin (A) as well as for the three sub-areas : Western Pelagso (B), Pelagos Sanctuary (C) and South-Eastern Pelagos (SEP).

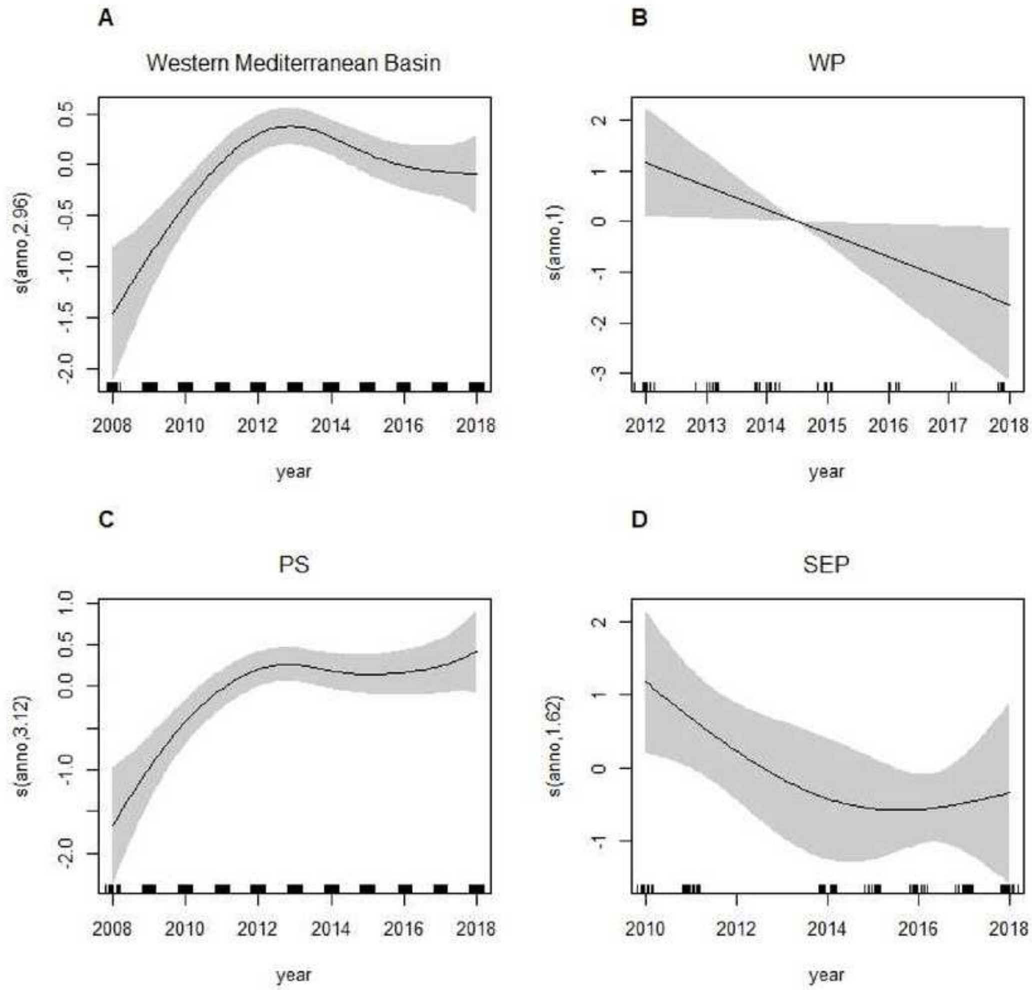
A
Western Mediterranean Basin
s(anno,2.96)
year
B
WP
s(anno,1)
year
C
PS
s(anno,3.12)
year
D
SEP
s(anno,1.62)
year

Table 1(on next page)

Summary of routes and transect groups.

Summary of routes (see Figure 1 for reference), transect groups, sampled years, total number of transects monitored, number of transect discarded as not reaching the threshold value, maximum length of transects in the transect group and total km sampled along the route

Route		Transect group	Years	N° transects [discarded]	Maximum – Total Length (km)
1	Toulon - Alcudia	TAL	2018	1	287.2 – 287.2
2	Toulon – Ajaccio	TAJ	2011; 2014-2018	34	265.26 – 7,664.89
3	Toulon - Ile rousse	TI	2018	2	159.9 – 294.3
4	Toulon - Bastia	TB	2018	1	195.8 – 195.8
5	Nice – Calvi/Ile Rousse[1]	NC	2009-2018	193 [8]	165.71 – 26,409.85
6	Nice - Bastia	NB	2017-2018	7	217.33 – 1,286.85
7	Savona- Calvi/IleRousse	SC	2013-2015; 2018	52	178.01 – 7,954.03
8	Savona - Bastia	SB	2008-2018	260 [27]	189.32 – 38,127.85
9	Livorno - Bastia	N_LB	2008; 2010-2016	73	115.03 – 7,874.55
		S_LB	2008-2018	141 [1]	119.32 – 14,531.67
10	Livorno - Golfo Aranci	LGA	2012-2018	110 [1]	298.49 – 26,051.97
11	Civitavecchia-Barcelona	W_CVBA	2012-2018	61 [1]	529.29 – 26,793.5
		E_CVBA		62 [2]	537.17 – 24,698.46
12	Catania-Civitavecchia	CTCV	2010-2011	43	631.82 – 17,324.55
13	Palermo-Tunis	PATU	2014-2018	27	349.26 – 6,423.87
14	Tunis-Civitavecchia	N_TUCV	2014-2015	5	342.42 – 1,337.61
		S_TUCV		4	275.92 – 1001.96
15	Cagliari - Palermo	CAPA	2014-2018	52 [1]	396.59 – 13,577.55
16	Ancona - Patras	N_AP	2015-2017	11 [1]	439.83 – 2,785.84
		S_AP		9 [1]	410.01 – 2,635.21

[1] Give the proximity of the two ports of Calvi and Ile-Rousse, trips directed to either of the two ports were considered as belonging to the same transect group

Table 2(on next page)

Results from Pearson's Correlation test

Results from Pearson’s correlation test among transects of the same group performed the same day or the same week. Empty cells indicate no occurrences, light gray cells indicate where not enough cases were available to perform the test, ‘na’ indicate that not enough data were available to perform the test

	DAY			WEEK		
	df	r (95% ci)	p-value	df	r (95% ci)	p-value
TAL						
TAJ				8	-0.34 (-0.80 – 0.37)	0.336
TI						
TB						
NC	77	0.61 (0.45-0.73)	2.31e-09	66	0.08 (-0.15 – 0.31)	0.5
NB						
SC	23	0.67 (0.37-0.84)	0.0002	17	0.44 (-0.02 – 0.74)	0.06
SB	108	0.51 (0.35-0.63)	1.338e-08	93	0.31 (0.12 – 0.48)	0.002
N_LB	13	na	na	23	0.45 (0.07 – 0.72)	0.02
S_LB	46	na	na	29	-0.04 (-0.39 – 0.31)	0.80
LGA	48	0.17 (-0.11 -0.42)	0.233	25	-0.14 (-0.49 – 0.25)	0.49
W_CVBA				18	0.66 (0.31 -0.85)	0.001
E_CVBA				18	0.16 (-0.3 -0.56)	0.49
CTCV	19	-0.15 (-0.55 – 0.29)	0.5	33	-0.12(-0.44 – 0.21)	0.46
PATU						
TUCV						
CVTU						
CAPA				10	-0.09 (-0.63 – 0.51)	0.78
N_AP						
S_AP						

Table 3(on next page)

Dunn’s test results for the Western Mediterranean basin.

P-values of the Dunn’s test are reported. Bold cells highlight significative differences among years. Along the diagonal, the number of differences from the reference year are summarized.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2008	3	1	0.1939	1	**0.0057**	**0.0001**	1	**0.0021**	1	1	0.1801
2009		3	0.4901	1	**0.0067**	**0.00005**	1	**0.0018**	1	1	0.4510
2010			0	1	1	0.1974	0.7982	1	1	1	1
2011				3	**0.0166**	**0.00003**	1	**0.0033**	1	1	1
2012					4	1	**0.0025**	1	0.0780	0.7188	1
2013						6	**0.000001**	1	**0.0005**	**0.0154**	0.2214
2014							3	**0.0004**	1	1	0.7224
2015								5	**0.0226**	0.2879	1
2016									2	1	1
2017										1	1
2018											0

Table 4(on next page)

Dunn’s test results for the Pelagos Sanctuary sub area.

P-values of the Dunn’s test are reported. Bold cells highlight significative differences among years. Along the diagonal, the number of differences from the reference year are summarized.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
2008	7	**1**	**0.027637**	1	**0.029422**	**0.000832**	1	**0.000328**	1	**0.045233**	**0.007669**
2009		4	0.054164	1	**0.049821**	**0.000521**	1	**0.000185**	1	0.103224	**0.012606**
2010			1	1	1	1	0.170257	1	0.881121	1	1
2011				2	1	**0.039803**	1	**0.014264**	1	1	0.445769
2012					2	1	0.148748	1	1	1	1
2013						5	**0.000781**	1	**0.030216**	1	1
2014							3	**0.000269**	1	0.327285	**0.037238**
2015								5	**0.01134**	1	1
2016									2	1	0.266354
2017										1	1
2018											3