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

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A B S T R A C T

International shipping, although considered a safe and environment-friendly form of transportation, has many direct and indirect impacts on cetaceans in many ways, particularly in the Mediterranean Sea, one of the world’s busiest waterways. An AIS receiver located at 44.30°N and 8.45°E, operating between 3 May 2013 and 31 October 2014, provided a detailed description of the distribution, number, type and operation of vessels within the Pelagos Sanctuary, an international protected area dedicated to the conservation of marine mammals. A total of 3,757,587 km of vessel traffic was recorded from 82,831 transits by 4205 distinct vessels. The spatial and temporal distribution of traffic was not uniform and dependent on vessel type (0.00 < r < 0.7); the level of shipping differed spatially between day and night. Passenger vessel traffic was predominant, with 20,853 transits totalling 1,385,361 km, followed by cargo (12,384 transits totalling 1,427,681 km). Transit speed significantly differed amongst vessel types ($F = 12621, \ d.f. = 5, \ p-value < 0.0001$) with passenger vessels the fastest (mean $15.47 \pm 4.40$ kn). Hazardous cargo transits accounted for 435,116 km. Vessels within the sanctuary navigated under the flags of 90 different states, in variable proportion depending on vessel type ($X^2=1231, \ d.f.=10, \ p-value < 0.0001$). The data presented in this study on high density shipping corridors and hazardous cargo supplies information for the identification of areas at higher risk from shipping. This data once integrated with available ecological data, can be used to inform ecosystem based management within a Marine Spatial Planning framework.

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1. Introduction

The Mediterranean Sea is one of the busiest waterways in the world, despite covering less than 1% of the world’s oceans; it accounts for around 15% of the global shipping activity by number of port calls, 10% by vessel deadweight tonnes [1] and 8% of the global fleet underway at any given point [2]. Although considered a safe and environmental form of goods transport, the impacts from maritime traffic are recognised as an anthropogenic threat to cetaceans in the Mediterranean Sea [3]. In February 2002, an agreement between France, Italy and Monaco: the “International Sanctuary for the Protection of Mediterranean Marine Mammals” also known as the “Pelagos Sanctuary” entered into force, with the specific goal to protect marine mammals and their habitats from negative impacts [4]. However, the conservation goals of the Pelagos Sanctuary are impeded by the international nature of the agreement and the few mitigation measures in place do not directly address the anthropogenic threats posed by marine traffic to cetaceans.

Marine Spatial Planning (MSP) is recognised as an important management tool that provides a comprehensive framework for managing multiple activities within the marine environment [5]. It is defined by UNESCO as a “public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that are typically specified through the political process”. MSP is one of the key tools in Ecosystem Based Management (EBM), an approach which is widely accepted as a key framework for delivering sustainable development in the marine environment [6]. During the planning phase of MSP, the spatial and temporal data of...
the biological aspects and the anthropogenic pressures should be mapped and their interactions understood [7]. Many anthropogenic stressors on cetaceans in the Mediterranean Sea are directly or indirectly associated with the activities of maritime traffic [3] and most activities in the marine environment are in some way linked to shipping.

Automatic Identification System (AIS) is a ship-to-ship and ship-to-shore system intended to enhance the safety of life at sea [8], the efficiency of navigation and the protection of the marine environment under the International Maritime Organization’s (IMO) 1974 International Convention for the Safety of Life at Sea (SOLAS). Since December 2004, it has been mandatory that all vessels over 299 gross tonnage and all passenger vessels must carry an AIS transponder. AIS data is used to track vessel movements in real time and represents a powerful ship monitoring and surveillance tool. It is now recognised that AIS can form an integral part of MSP [9] and there are several examples of its use for this purpose [9–13].

There already exist several studies that have recorded the maritime traffic in the Mediterranean Sea [1,2,14–16]. However, their primary objective was not MSP and as such these studies and their data may be limited in their applicability for this purpose. For instance, the recorded shipping levels do not represent the actual spatial distribution of the maritime traffic [1] or the spatial resolution used may be too large (100 km in [2]) or the temporal scale too small (63 days in [16]). Several works did not consider all vessel types [1,15,16], did not analyse the density by different vessel types [16] or consider any spatio-temporal analyses [14,15]. Thus this study aims to supply detailed information relating to the level and spatio-temporal distribution of shipping in the Pelagos Sanctuary for incorporation within a MSP framework.

2. Methods

2.1. Raw data tables

An AIS receiver was installed at the geographic coordinates of 44.30°N and 8.45°E at a height of approximately 25 m above sea level. The raw NMEA data packets and their associated database timestamp were parsed using an ad hoc service written in C# language following the NMEA AIVDM/AIVDO protocol decoding¹. The analyses within this article represent the data parsed from the 3rd of May 2013 to the 31st of October 2014. Not all the data encoded in the 27 AIS message types was considered essential or desirable and only the dynamic, static and voyage related data encoded in message types 1, 2, 3, 5, 18, 19 and 24 were incorporated (see Refs. [8,17] for message descriptions and details). The raw data were amalgamated into two separate tables, the “Raw dynamic messages” table of every recorded Position Report Class (PRC) and the “Raw static and voyages” table that contained all vessel specific and voyage related data for both type A and B AIS transponders (Fig. 1).

2.2. Vessels table

The reliability of the static and voyage related data from AIS was considered to be moderate to poor but of desirable usefulness [9] and the creation of a vessel information table was considered for quality control. The “Vessels” table was created from the “Raw static and voyages” table and based on the unique identification of each vessel: Maritime Mobile Service Number (MMSI) and contained its dimension (width and length) and vessel classification (Fig. 1). All fields were double checked against online databases². Seven vessel types: passenger, cargo, tanker, fishing, service, pleasure and unclassified were considered and passenger, cargo and tanker were combined into a commercial vessel category. Additional information not present in the AIS message was added for every ship pertaining to its flag state, build year, gross tonnage and dead weight from the previously mentioned online databases and data relating to a vessel’s activity (number of filtered PRCs recorded and, maximum, mean and modal vessel speeds over all PRCs). This data through the unique MMSI can be linked to the other tables.

2.3. Filtered positions table

AIS data is notoriously unreliable due to faulty equipment, human related errors or omitted values [18–20] and as such requires data quality control procedures. Only the PRCs within the extent of the Pelagos Sanctuary from the “Raw dynamic messages” table were inserted into the “Filtered positions” table. Geometric calculations were then conducted between consecutive PRCs (pgAdminIII POSTGIS extension) to obtain a PRC’s heading in degrees, time in seconds, distance in metres and speed in kilometres per hour (Fig. 1). These calculations provided an additional value to the “Raw dynamic messages” that could be used to identify ambiguous or missing data.

A quality control procedure adapted from the Marine Management Organization [12] was used to remove and filter erroneous PRCs. The first step was to remove any vessel and their corresponding PRCs with an erroneous MMSI number from the “Vessels” table; these included MMSIs with more or less than 9 digits and those with repetitive or sequential number strings (i.e. 111,111,111 or 123,456,789 according to Ref. [21]). Unique vessels with a low number (< 5) of recorded PRCs were also removed as these were considered as data noise [22]. The second step of the quality control was to remove from the “Filtered positions” table the moored or anchored vessels and PRCs with erroneous locations. PRCs relating to moored or at anchor vessels, i.e. any vessels that had both a recorded and calculated speed less than 1 knot (1.852 km/h) and a subsequent PRC within 1 km were removed. Erroneous PRCs were removed by deleting any subsequent PRC that had a geometrically calculated speed that exceeded the “Vessels table” maximum speed and whose geometrically calculated heading differed from the AIS recorded heading by 30°.

2.4. Transits table

The “Filtered positions” table was connected to a Quantum GIS platform (QGIS) to create the “Transits” table, that contains the individual transits created from the PRCs using the QGIS PointstoPaths plugin. The transits’ start time and end time, the duration in minutes and the length in kilometres were added using the raster calculator. The “Raw static and voyages” table and “Filtered positions” table were used where possible to update the “Transits” table with information on the transit’s destination, the hazardous classification of its’ cargo and the mean, modal and maximum speeds (Fig. 1).

2.5. Polygon grids table

The spatial and temporal shipping density was calculated as the number of vessels, number of transits and covered distance of transit per grid cell area per unit time. This was done by summarizing the “Transits” table into numerous composite “Polygon

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¹ http://catb.org/gpsd/AIVDM.html
² www.marinetraffic.com; www.fleetmon.com; www.aishub.net
2.6. Statistics

Various statistical analyses were conducted to test if the observed differences between vessel types, spatial distributions and temporal distributions were significant. All statistical analyses were conducted in R version 3.1.0 (R Core Team 2014). Differences between the vessel dimensions, their mean transiting speeds and number of vessels present during the different hours of the day were conducted using the parametric one-way analysis of variance (ANOVA) or non-parametric equivalent Kruskal-Wallis tests. A chi-Squared goodness of fit test was used to assess for the proportional differences between a vessels’ type category and its’ member flag state.

The spatial and temporal distributions were analyzed using spatial correlations over a reduced extent. The reduced extent, from hence forth “Genoa Canyon System” was considered as all grid cells located within 55 km of the receiver, as the referenced terrestrial receiver coverage at sea level is 55 km [8] and was used to eliminate the bias caused by reception. Temporal gaps in the operation of the AIS receiver required the use of a temporal subsample (the same 8 d time frame within a month). Temporal analyses were conducted using a nested ANOVA on a random sample of 10 5 km-grid cells, to avoid violating the independence assumption caused by spatial autocorrelation, with month as the nested factor. Model assumptions were validated by refitted the data as a linear mixed model with month as a random effect. If the residuals did not validate the response, variable transformations were conducted. The temporal differences in fishing and service vessels were conducted on selected 6 cells due to the highly localized nature of these vessel types.

3. Results

3.1. Raw tables

From the 3rd of May 2013 to the 31st of October 2014, a total of 42,354,450 NMEA data packets were collected and parsed and the majority inserted into the “Raw dynamic messages” table (78.6%) and the “Raw static and voyages” table (5.1%). After quality control a third (33.3%) of “Raw dynamic messages” PRCs (11,084,553) were available within the “Filtered positions” table that related to 4268 “Vessels” table records, 82,831 “Transits” table records and 3,757,587 km of vessel traffic amalgamated into the “Polygon grids” table.

The receiver has been in continuous operation throughout this time frame; however, logistical problems resulted in 16 temporal gaps, i.e. when the receiver was non-operational and no new NMEA data packets were received for thirty minutes. The temporal gaps ranged from just over 1 h to 57 days with a total accumulated missing reception time of 183 days. The effects of these gaps did not affect the overall conclusions of the analysis but resulted in an incomplete temporal coverage for 12 of the 17 months.

3.2. Vessel table

All 4268 vessels within the “Vessels” table were classified to one of the seven vessel types. Sixty three (1.5%) vessels and their associated PRCs (924,223: 8%) were excluded from further analysis as they were unclassified. The predominant remaining vessel types were cargo (41.8%) and pleasure vessels (31.8%) and over half (62.9%) of the unique vessels were classed as commercial vessels (Table 1). The dimensions, transit speed and number of the vessels were found to be dependent on the vessel type classification (Table 1). All vessel types were found to be significantly different (1) in length except between tanker and cargo vessels; (2) in gross tonnage and dead weight except between fishing and service vessels.

Service (c) 1759 174 25 27,416 29,858 19 2010 2002 21 21,753 1,427,618

Tanker (c) 597 171 28 28,100 48,434 18 & 18 2009 2005 16 18,746 73,716

Fishing 117 21 5 279 45 9 2010 2002 9 1846 212,858

Pleasure 134 0 40 8 944 208 3 & 2 & 2010 2002 20 8587 289,006

Passenger (c) 106 37 10 2908 2197 9 2005 1997 11 8401 73,716

Cargo (c) 597 171 28 28,100 48,434 17 & 18 2009 2005 16 18,746 73,716

Table 1

Summary statistics of the level number and mean values of the shipping data from the "Vessels (v), Transits (t) tables. The final three rows of passenger, cargo and tanker combined relate to the commercial vessel classification (c).
member states (Appendix Table A.2).

### 3.4. Polygon grid spatial analysis

The “Polygon grids” table, with transit distance per grid cell per total time frame, clearly displayed that the spatial distribution of shipping traffic is not uniform (Fig. 2). The spatial distribution of shipping density was found to be vessel type dependent, with different vessel types localized to specific areas or utilising different shipping corridors (Fig. 3). The analyses on the reduced extent clearly demonstrated that the spatial distribution of passenger and cargo vessels was similar to each other (R = 0.70) but different to the other vessel types (0.01 < R < 0.48) with passenger and cargo vessels contributing most to the overall spatial distribution of the shipping levels in the area (R = 0.89 & R = 0.88 respectively). Despite their similarities, there were several distinct corridors used by passenger vessels and not by cargo: for instance, passenger vessels had a high density corridor between Genoa in the direction of West Corsica and Porto Torres (northwest Sardinia: Fig. 3(b) and Fig. 2 for port labels). There was also found a distinct corridor used solely by pleasure vessels travelling between Portoino and the Western Mediterranean ports (Fig. 3(c) and Fig. 2 for port labels). There was also found a distinct corridor used solely by pleasure vessels travelling between Portoino and the Western Mediterranean ports (Fig. 3(c) and Fig. 2 for port labels). The spatial distribution of hazardous cargo transits did not display any distinct spatial distribution and followed the spatial distribution of cargo (R = 0.92) and to some extent tankers (Fig. 3(g)) vessels (R = 0.59).

The spatial distribution of the vessel transit speeds were also found to not to be uniform and the areas of fast and slow speeds were dependent on vessel type (Fig. 4). It highlights a clear difference in the operational characteristics of each vessel type. Passenger vessels once again have been shown to be the fastest vessels type, with the fastest mean speeds localized within distinct corridors. To a similar degree but not quite as dramatic are the other two commercial vessel types, (cargo and tanker). Cargo and tanker vessels displayed slower speeds close to the coast and near ports, where passenger vessels did not. Despite not being a strong correlation, the commercial vessels contributed most to the overall spatial distribution of mean speed in the area (R = 0.61, R = 0.57 & R = 0.58 for passenger, cargo and tanker respectively). The non-commercial vessels were, with the exception of pleasure craft, much slower on average than their commercial counterparts. Service vessels were found to be faster in coastal areas (less than 200 m deep) than further offshore. Fishing displayed distinct areas of slow transits between the 200 and 1000 m isobaths, perhaps indicative of trawling grounds. Most interestingly was the almost homogenous distribution of fast travelling pleasure craft, which were slower in the vicinity of the coast and port areas.

### 3.5. Polygon grid temporal analysis

The spatial distribution of the shipping density was found to differ at several temporal scales. The inter-annual analysis was conducted on the total kilometres of vessel transits located within the reduced temporal and spatial extent. May, June, August and September have data from both years and were used to test for inter-annual differences. The spatial correlation (R > 0.873) and overall shipping density was not found to differ significantly between the years of 2013 and 2014 (nested ANOVA: F = 0.091, d.
f. = 1, p-value = 0.76). However, there appears to be monthly and seasonal differences within a year (Figs. 5 and 7). When comparing the two seasons: summer (June, July & August 2013) and winter (December 2013, January & February 2014) the nested ANOVA indicated that the difference was significant for the pleasure (F = 17.7, d.f. = 1, p-value = 0.014), passenger (F = 6.5, d.f. = 1, p-value = 0.0135) and fishing vessels (F = 37.5, d.f. = 1, p-value < 0.0001) but not for the cargo (F = 0.151, d.f. = 1, p-value = 0.7), tanker (F = 0.137, d.f. = 1, p-value = 0.9) and service vessels (F = 2.874, d.f. = 1 p-value = 0.11).

The spatial distribution and level were also found to differ between the daylight and night time (Figs. 6 and 2 for port labels) and also between the individual hours of the day (Fig. 7). The most noticeable night time daytime spatial change was that of the Genoa–Porto Torres and the Cape Corsica–West Ports corridors, where a higher night time level of shipping was found compared with the daylight hours (Fig. 6). Within the daylight hours, the number of boats recorded in the reduced extent were found to be significantly different between the hours of the day (F = 39.66, d.f. = 14, p < 0.0001). Post-hoc analysis found 3 temporal groupings that were not significantly different between themselves but distinctly different from the other groupings. The early morning (6–8

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**Fig. 3.** The spatial distribution of the different vessel types (a) fishing, (b) passenger, (c) pleasure, (d) cargo, (e) service, (f) tanker and (g) total hazardous cargo within the Pelagos Sanctuary at 1 km-grid cell resolution within the whole timeframe of this study. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035) with the 200, 1000 and 2000 m isobaths.
UTC+2) that was significantly higher than the other 2 with a median number of 12 boats, morning to midday (9–12 UTC+2) with significantly less vessels, median 8 and the rest of the daylight hours (13–20 UTC+2) with a median of 10 vessels; a pattern that can be seen in all the months analyzed (Fig. 7).

4. Discussion

The Pelagos Sanctuary is bordered by coastlines that are densely inhabited, and where urban, industrial, touristic and agricultural activities carry significant economic importance. As a consequence, and as demonstrated in this study, its waters are crisscrossed by intense maritime traffic from a variety of vessel types. Considering that the presence of traffic in this Marine Protected Area is unavoidable, the only option available is to develop and implement traffic impact mitigation measures. This approach can be effectively implemented through the use of a Marine Spatial Planning framework to identify the spatial overlap between cetacean distributions and anthropogenic pressures [25].
4.1. Shipping impacts and possible mitigation measures

Maritime shipping traffic is known to have many direct and indirect impacts on marine life, and in particular can be a source of anthropogenic pressures on cetaceans. These include disturbance, noise, collisions and chemical pollution in these mammals’ critical habitat. Two of the main threats to marine mammals from maritime traffic are the increasing anthropogenic noise pollution [26] and the direct mortality through ship whale collisions [27]. Underwater noise pollution is known to have several detrimental effects on marine mammals [26, 28–32] and their prey [33]. Collisions with ships are also a known cause of cetacean mortality [34] and it is a special concern in the Pelagos Sanctuary [47] where 1–1.7 fin whale hits per year were estimated [35].

Knowledge of the ecology of cetaceans found in the Pelagos Sanctuary has made significant progress in recent decades. Information is available on the modelled spatial distributions [36, 37] and the oceanographic and topographic relationships on the presence and abundance of many of the regularly occurring cetacean species [38, 39]. This existing knowledge on cetacean habitat, soon to be mapped as Important Marine Mammal Areas (IMMA: [40]), can be combined with the shipping data to identify the spatial overlap of the environmental and anthropogenic conflicts in the Sanctuary and determine the priority management areas [41]. This is especially important for vessels carrying dangerous cargo which should avoid ecologically Sensitive Areas.

Several regulatory measures exist that can be implemented and numerous nations have previously applied to the IMO to reduce the risk from maritime shipping on cetaceans. (1) A slight displacement of a Traffic Separation Scheme (TSS) in the Stellwagen Bank National Marine Sanctuary in the north-eastern USA to induce ship traffic to and from the Boston harbour to avoid crossing high density whale areas [42]. (2) An area specific ship speed reductions implemented within a security area in the Strait of Gibraltar to avoid hitting sperm whales [43]. (3) The establishment of Areas To Be Avoided (ATBAs) such as the voluntary ATBA in the Roseway Basin area, which was found to reduce the risk of collisions with right whales by 82% [44]. The declaration of the IMO’s Particularly Sensitive Sea Area (PSSA) would allow for several mitigation measures to be put in place. The straight of Bonifacio in the Pelagos Sanctuary, between Sardinia and Corsica, has already been designated as a PSSA and has TSS, mandatory pilotage, ATBA around reefs and vessel traffic system measures in place [45].

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Fig. 5. The monthly covered distances in kilometres in the Genoa Canyon System where the AIS antenna is receiving perfectly for each vessel types (data from all sub-sampled months were exhaustive and expressed by the average when the sub-sampled was available from both years(*)).

Fig. 6. The spatial distribution of the shipping levels between the (a) day light and (b) night time hours at 1 km-grid cell spatial resolution and presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035) with the 200, 1000 and 2000 m isobaths.

** IMO Resolution A.927(22): “MARPOL 73/78, in Annexes I, II and V. defines certain sea areas as Special Areas in relation to the type of pollution covered by each Annex. A Special Area is defined as “a sea area where for recognised technical reasons in relation to its oceanographical and ecological conditions and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution by oil, noxious liquid substances, or garbage, as applicable, is required.”

4.2. Findings

This study highlights the heterogeneous spatial distribution of the shipping density in the Pelagos Sanctuary, with the majority of the vessel transits localized within distinct shipping corridors. Moreover, the speeds at which the vessels navigate within them, the time of day they are used and the vessel types which predominantly use them has been shown to differ. This includes a corridor predominantly used by pleasure vessels and one mostly used during the hours of darkness. This study has also identified the spatial distribution of the vessels transiting with hazardous cargo and areas frequented by fishing vessels. Thus the high resolution spatio-temporal distribution and characteristics of one of the most influential marine activities within the Sanctuary is a main asset for integration into a MSP framework for effect EBM.

Despite the global and Mediterranean trend towards increasing shipping with time [1,46] and its close link with global economic effects [47] the temporal distribution of the shipping density in the area was not found to differ significantly between the studied years. This is likely due to the short time frame and the current global economic situation. However, this work displayed a significant seasonal trend which is in concordance with the finding of [16]. It also confirms their assumption that it is primarily due to the increase of summer passenger vessel transits in the area. Moreover, this study has also found a summer increase in fishing and pleasure vessels. The other vessel types were found to remain relatively constant between seasons indicating a consistent level of trade traffic and associated service vessel traffic throughout the year.

The vessel transiting speeds in the Pelagos Sanctuary were found to be high and dependent on vessel type with specific spatial distributions. A similar result was found by [16,48] whom both found that the Pelagos Sanctuary was transited by an abundant number of high speed vessels. They attributed this finding to the numerous high speed ferries in the area, despite not separating shipping densities into type. This work confirms their finding as passenger vessels were the fastest navigating vessel type and contributed the most to the overall spatial speed distribution. On another hand, this study gives for the first time indications about pleasure vessel speed: they have an almost spatially uniform distribution of fast vessels (20–25 km/h) across the entire reduced extent.

Globally, the proportion of the cargo and tanker vessels found in this study were similar to that of the world fleet, however, the proportion of passenger vessels was found to be much higher (6.8% relative to 0.3%: [46]). This coincides with the description of the Mediterranean Sea as a global cluster of passenger vessels [2]. Moreover, the proportion of the commercial transits made by cargo (37%) and tanker vessels (18%) were lower (72% and 20% respectively), and passenger transits much higher (45% relative to 6%), than what has previously been recorded in the whole Mediterranean Sea [1]. A large number of transits were found to be navigating under a Pelagos state or Mediterranean state flag (60% & 64% respectively) and this is also higher than what was reported previously in the Mediterranean Sea [1]. However, a large number of transits especially those of cargo, tanker and pleasure vessels were flagged to non-Mediterranean flag state and a quarter of the transits were found to be navigating under a FOC. It was also found that 76% of all transits were destined for a Mediterranean state, which again is higher than what was previously quoted [1].

The lesser studied vessel types: service, fishing and pleasure crafts have been found to contribute considerably to the overall shipping traffic in the area with 37% of all vessels, 30% of the total number of transits and 15% of the total kilometres of transits. As pointed out by [9] the contribution of these vessels, which have often been excluded from previous Mediterranean studies [1,15,16], are an important component of the shipping, especially considering that for both pleasure and fishing crafts are obviously underestimated due to the absence of AIS transmitters on high portion of crafts. Indeed, the spatial distribution of fishing and pleasure vessels have an important socioeconomic use of the marine environment.

Fig. 7. The number of vessels found in the Genoa Canyon System where the AIS antenna is receiving perfectly during the different daylight hours for each month and combined total.
4.3. Use of the findings for MSP and EBM

The findings of this study indicate that the shipping in the Pelagos Sanctuary is not representative of the Mediterranean as a whole. A large proportion of the transits were intra-Mediterranean passenger transits navigating under a Mediterranean state flag. Given that, a vessel is bound by the laws of its flag state, unless in the territorial waters of another flag state [24]. The majority of the vessels and a certain surface of the Sanctuary are already covered by the national jurisdiction of Mediterranean states and international agreements. Indeed, the Sanctuary lies within the jurisdictional boundaries of several national and international legal agreements, including: the Regional Activity Centre for Specially Protected Areas (RAC/SPA), the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and the contiguous Atlantic Area (ACCOBAMS), the French Exclusive Economic Zone, the Italian Ecological Protection Zone and the Pelagos Agreements itself. Agreements’ whose combined objectives are to manage and improve the conservational status of marine life (including cetaceans) and their habitats from the detrimental effects of anthropogenic pressures.

However, a proportion of the shipping is under the flags of non-Mediterranean states (64%) particularly cargo and tanker vessels, which are also more likely to be carrying hazardous cargo and navigating beyond the 12 nautical mile territorial waters. This means that a proportion of the maritime traffic is beyond Mediterranean state jurisdiction, and are bound by the laws of the vessel’s flag state due to freedom of navigation [49]. It is a fact that some flag states are “better” than others in their acceptance and ability to comply to safety and environmental conventions [50] and the reporting of incidences [51]. Thus an international body must be involved in order that all shipping traffic is to be targeted. The IMO represents this international governing body, as it is the primary authority responsible for all international maritime interests. Once an IMO shipping policy or environmental mitigation method is in place, all vessels, regardless of their flag state, fall under the jurisdiction of the IMO. Thus the IMO represents one of the key components in mitigating shipping and marine mammal mitigation methods [52]. However, once again the control falls upon the Mediterranean and Pelagos state governments as a formal proposal must be made to the IMO by member state governments only [43]. The proposal of mitigation actions requires documentation, supplied by this study, describing the problem caused by maritime traffic, the associated adverse affects, the associated nature of the vessel traffic [43].

The level of the impacts of both collisions and acoustic pollution are closely linked with the type and operational behaviour of the shipping. The level, spectral shape and frequencies of the emitted underwater noise from shipping has been directly linked to the type, age, size and speed of a vessel [53–55]. Moreover, the speed of a vessel affects directly the frequency of occurrence and the lethality of a whale ship collision [34,35,44,56]. Despite all vessel types being found to be linked with ship whale collisions [34,35,57] high speed passenger vessels have been implicated with a higher frequency of ship strikes [35].

Many cetacean species are also subject to diurnal behavioural changes [58–60] or changes in seasonal presence and abundance [61,62]. Thus the temporal overlap, for instance the coincidental increase of both fin whale and shipping during the summer, can be used to propose temporary management areas and indicate when it should be introduced. The identification of these priority management areas are fundamental in the Pelagos Sanctuary due to its large size (87,500 km²) and will facilitate conservation efforts allowing to be more concentrated when and where it is needed and less restrictive when and where possible.

4.4. Implications about the methodology

The methods used in this study have several methodological implications towards previous studies on the distribution and levels of shipping. Firstly the clear differences found between the recorded levels of shipping as the number of vessels, transits and covered transit distance has distinct outcomes. These differences were caused by the multiple transits conducted by each unique vessel and it is of special importance because of the predominance of passenger vessels in the Sanctuary. For instance, [2] recorded the number of unique vessels in a 100 km² cell over 8 days, as a consequence, one vessel in this time and at this scale may conduct several, if not tens, of transits. Also the use of a “snap-shot”, brief temporal windows, have been used in previous shipping studies [2,16], due to the amount of AIS data and the associated processing time but they may not be adequate to discover the small time scale or seasonal differences that were found in this study. Moreover, this study, along with [9] have demonstrated that AIS data processing times are not extensive and the benefits of this highly detailed data source are incredibly useful in shipping management. It has been seen in this study and previously stated by the [8] that the reception of terrestrial AIS receivers is limited beyond 55 km, due to unreceived PRCs. However, the inferred transit method of the [12] used here has allowed for a reliable description of the shipping beyond this distance. Providing confident descriptions and identification of high use areas beyond this referred distance that can be used in successful management purposes.

5. Conclusion

This long term AIS monitoring study has analyzed at a high resolution the spatial and temporal distribution of the shipping levels by type in an established MPA, information which is essential for the successful management of shipping [63]. Moreover, it has identified several key stakeholders (passenger vessel companies and fishermen) and managerial authorities (Mediterranean state governments and the IMO) that should be involved in future sanctuary decisions. Furthermore, these findings have provided the relevant authorities with a necessary component required for IMO’s mitigation measure proposals [64] and the study’s methods can be used to regulate, control and assess the proposed mitigation measures in the future. As such, the work of this study represents highly relevant information for future management of the Pelagos Sanctuary. However, the data provided cannot be used in isolation, and requires integration into a MSP framework with the available spatial distributions of the biological, ecological and socioeconomic data in the area. This will allow for coordinated decisions on managing multiple uses within this marine environment with the aim to minimize the user-user and user-environmental conflicts. In conclusion this study relates to the planning and future development of the EBM approach that the sanctuary authorities had in mind during its conception [65].

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