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Accordo per la costituzione
del Santuario per i mammiferi marini
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Noise impact on sperm whale (*P. macrocephalus*) and Cuvier's beaked whale (*Z. cavirostris*), estimated from the marine traffic

Final report

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Table of contents

Figures

Tables

0. Abstracts of the project in different languages

0.1. Abstract in English

The project aims to pool together four datasets in order to obtain a large dataset able to describe the distribution of Cuvier's beaked whale (CBW) and sperm whale (SW) in the Pelagos Sanctuary. This dataset covers 25 years of surveys (1998-2013), a very long time frame. In total, the distance surveyed on-effort was 247,008km allowing to collect 522 sightings of SW and 236 of CBW. The successive analysis consisted to plot the dataset on a grid of 5minx5min covering the Pelagos Sanctuary (with a buffer area of 15km on its border). This grid is made of 4,103 cells and the effort is distributed on only 2,622 cells (representing 64% of Pelagos area, Figure 8). SW occurs in 272 cells (range=1-15; average sightings per cell=1.92) and CBW in 121 cells (range=1-10; average sightings per cell=1.95). The encounter rate of CBW is clustered predominantly within the Genoa canyon system with two satellite clusters: west of Cape Corse and in the Caprera canyon (Figure 11). The encounter rate of SW is higher on the steep continental slope off north-western coasts of the Pelagos Sanctuary. It is interesting to note how the two distributions do not overlap. Looking at the seasonal distribution of the effort, it is obvious that summer months (June-September) are much more prospected than the others, implying automatically a bias on the encounter rates between the two periods. SW encounter rate is almost always higher than CBW one, excepted for November and December which had no SW sightings at all. This result confirms the seasonal movement out of Pelagos, supposed to occurred, in winter. It is also possible that CBW presence is relatively uniform and year round and the encounter rate variations are only a bias of the effort heterogeneity between the two periods. The yearly trends indicate two different patterns: SW appears to have peaks for some years (1994, 2003, 2012) and a encounter rate much higher from 2007 onwards. The encounter rate of CBW is much lower than SW one and seems to display a bimodal distribution with two periods of higher encounter rates (2004-2006 and 2011-2014). The gap analysis indicates that all remote areas have significantly much less effort (west and east of Corsica and over the continental shelf). The effort distribution over months changes also a lot: the summer months (July, August and September) have significant and regular effort while from May to October, the effort is less intense with a discontinuous coverage and in November and December have very effort.

The assessment of the marine traffic of the Pelagos Sanctuary was realized using the AIS data collected by an antenna based in Savona, during 18 months. A total of 4,205 vessels transiting in the sanctuary (once or more than once) were identified. The two most predominant vessel types were cargo ships (41.8%) and pleasure crafts (31.8%). Commercial vessels (passenger, cargo and tanker) represented 63% of the unique vessels. However, considering the number of transits or the total distance realized by each vessel, passenger and

cargo were predominant (30% and 26% in the first case and 37% and 38% in the second case). Commercial vessels represented 70% of all transits and 85% of covered distances. These results identify the sea users (and their relative role) that have to be involved into any mitigation strategy. Crossing AIS data with on-line databases, it is also possible to calculate statistics about dimension and age per type of vessels, and both resulted to be significantly different in function of vessel type. Obviously, age is a main parameter acting on ocean noise and chemical pollution. Transit speed is another parameter influencing ocean noise and acting on whale-collision occurrences and lethality. The results confirm that ferries travel on specific routes (considering their spatial distribution) and at higher speeds respectively to the others vessels. The top 5 countries with the highest quantities of vessel were Italy, Cayman Island, Malta, UK and Panama; 51% of vessels were under Flag of Convenience (FOC). Looking at the flags according to number of transits and covered distances, FOC still represented respectively 25% and 31%. This can be interpreted as the quantity of vessels with a higher risk of accidents (FOCs have less stringent conditions). Focusing on vessels with Pelagos flags, they were a majority, with respectively 60% and 50% according to transits and covered distances. This shows how much Pelagos states 1) are able to act significantly through their national laws to effectively mitigate the impacts on cetaceans and 2) need measures approved by the International Maritime Organization to mitigate the remaining impacts due to vessels under non-Pelagos flags. In this last case, this work provides information about the baseline of the shipping supporting the proposal for the creation of a Particularly Sensitive Sea Areas. The map of the shipping lanes (Figure 36) produced by this work indicates that 68% of the sanctuary is within a distance of 7km of a shipping lanes, explaining the difficulties for Pelagos to implement mitigation measures. The temporal analysis indicates three main results: 1) over a period of 18 months, it is not possible to establish an increase of shipping; 2) a significant seasonal trend is established (with a principal increase of summer passenger ships transiting in the area); 3) a significant daily trend (with a maximum in the early morning at 6-8 AM UTC+2). This information points out the possibility to set up specific measures during summer.

The integration of the maps of the indicators of marine traffic has allowed the definition of the acoustic classification of anthropogenic noisemakers based on vessel categories and the noise weighting depending on density of traffic in the various maritime transport corridors identified. Data has been correlated with the aim of assigning to the main corridors of marine traffic, a model of anthropogenic noise for each acoustic class. The modelling of acoustic classes is based on the mechanical drive train and the size of the vessels. Each class has then been simulated in the software ChrisarSIM. These simulations were used to extract the frequency distribution of noise for different port areas based on site activity and for each acoustic class of vessels. A map of bathymetric and bathy-celemetric data has been realized, based on different acoustic sites identified in Pelagos area. This data allowed to map the anthropogenic noise using the software suite ACSRAY for the prediction range and noise propagation. A series of seasonal static maps of anthropogenic noise expressed with various indicators in function of 12 bandwidths has been generated taking into account the areas of port activities and the maritime corridors in the Pelagos area. It is important to remember that the fluctuation of the noise level, for a particular point on the map, depends on the range to shipping routes (propagation loss), the shipping density, the ship type (electro-mechanical characteristics) and the power-speed characteristics of a ship class. The maps highlight the quantity of energy present in the Pelagos Sanctuary. The adopted approach was to not limit the analysis to lower frequencies recommended for characterization of ambient noise nor to limit to bandwidths of audiograms known for the two studied species but to provide as much information as it is possible for the global analysis of anthropogenic noise risk on the distribution of SW and CBW.

The first step of the analysis of the impact of marine traffic and its associated noise on the species distribution consisted in a correlation analysis performed between the two species encounter rates and some predictors ("Sea Surface Temperature", "chlorophyll-a", "chlorophyll-a peak month", "chlorophyll-a maximum" and "year") in order to rule out any potential implication of the environmental variability on the species distribution patterns. This analysis confirms the relevance of environmental drivers of change in shaping the distribution of the two species although this changes are mostly related to Chl-a and they are apparently the direct or indirect effect of the decreasing trend of the primary productivity in the study area. For this reason, the temporal predictor (i.e. the year) can be considered equivalent for modelling purposes to the Chl-a predictor. The second step consisted in a K-means Cluster Analysis (CA) used to analyse the similarities among the traffic density profiles and composition within the study area. A 4-cluster solution was obtained and have been used as reference for zoning the traffic and to evaluate the cell differential traffic value for every ship type. The third step consisted in the binary logistic regression analysis used to correlate presence/absence data of the species to naval traffic density and noise indicators. As the presence/absence dataset is zero-inflated, the number of absence cells was balanced to the number of presence cells. The extraction of the subset of absence cells was obtained through the Mersenne Twister random number generator. The two models outline the different characteristics of the habitat of the two species: 1) for SW, it identifies a higher presence probability in the area where tanker passage is higher 2) for CBW, it outlines the higher preference in more pelagic habitat characterized by a lower presence of fishing and service ships. For both species, the "year" predictor is a significant in the model as it was suggested during the first step. The fourth step aimed to run on the optimal habitat a correlation analysis assessing the effect of the marine traffic and its associated noise on the use of the habitat by the two species. To do so, presence/absence habitat models developed on independent datasets were used to predict the optimal habitat whereas the present study sightings were instead used to investigate the correlations with naval traffic and noise within the optimal habitat. Probability predictions were produced for every cell unit and, depending on the model accuracy, different threshold probability values were selected. The optimal habitat predictions obtained from the two models "external to this study" were tested versus the encounter rates of the two species. A Mann-Whitney test was applied to compare the encounter rate of the two species between the optimal habitat and the unsuitable habitat conditions. The encounter rates were found significantly higher for both species in the optimal habitat cell units ($P<0.001$). At this point, an additional logistic regression analysis was performed to correlate the presence/absence of the two species within the identified optimal habitat with both the traffic and noise indicators. Both types of indicators were evaluated as predictors either considering their absolute and relative values with respect to the traffic-noise cluster zoning. Both models indicate a inverse correlation between the marine traffic with the species presence. A lower SW presence probability was found correlated with a higher "number ship/km tracks" ratio and a lower CBW presence probability was found associated with a ship track length higher than the zone average (i.e. "Diff_km_tot ships"). The noise indicators were also selected as significant predictors for the two models although showing both direct (i.e. "Su_L10_global" for SW; "Diff_Su_L01_global" for CBW) and inverse relationships (i.e. "Su_L01_global" for SW; "Diff_Su_L10_global" for CBW), probably due to the colinearity of these two modelled parameters ("Su_L10_global" and "Diff_Su_L01_global").

Grounding on the results previously described, risk maps were developed for both species considering their presence probability as "species exposure" and the naval traffic density as the "magnitude of the impact". The risk maps were evaluated by multiplying the normalized species presence probability to the normalized ship traffic density and normalized again to the unitary scale. Figures 68 and 69 outline the zones where collisions and all the other traffic-related impacts are higher for the two species. It can be observed that the continental slope areas are areas of significant risk for both the species whereas concerning SW there is also a significant risk associated with the open basin.

A series of dissemination actions was planned in order to use the materials produced by the research. These actions were set differently for public at large and scientific community; they includes for instance communications through social networks, a temporal exhibition, scientific events, scientific papers and conferences and a platform to share spatial data.

0.2. Abstract in Italian

Il progetto ha come obiettivo la condivisione di 4 dataset per ottenere un unico dataset più completo, che permetta di descrivere al meglio la distribuzione di zifio (CBW) e capodoglio (SW) nel Santuario Pelagos. Questo dataset comprende survey effettuati in 25 anni (1998-2013), una finestra temporale molto ampia. In totale, sono stati campionati 247,008 km che hanno permesso di raccogliere 522 avvistamenti di SW e 236 di CBW. Successivamente, il dataset è stato "plottato" su una griglia di dimensione 5'x5' estesa su tutto il Santuario Pelagos (con una area buffer di 15km ai confini laterali). La griglia in totale conta 4103 celle e lo sforzo

di campionamento ne copre 2622 (che rappresentano il 64% dell'area di Pelagos, Figura 8). Il SW è stato avvistato in 272 celle (range=1-15; numero medio di avvistamenti per cella = 1,92) e il CBW in 121 celle (range=1-10; numero medio di avvistamenti per cella = 1,95). Il tasso di incontro di CBW è maggiormente concentrato all'interno della zona del canyon di Genova con due gruppi satellite: uno a ovest di capo corso e uno nel canyon di Caprera (Figura 11). Il tasso di incontro di SW è maggiore sulla scarpata continentale al largo della costa nord occidentale del Santuario Pelagos. È interessante notare come le due distribuzioni non si sovrappongano. Per quanto riguarda la distribuzione stagionale dello sforzo di campionamento, ovviamente i mesi estivi (da Giugno a Settembre) risultano essere maggiormente campionati rispetto al resto dell'anno. Ciò porta inevitabilmente ad un errore sistematico nel computo del tasso d'incontro nelle due diverse stagioni. Il tasso d'incontro di SW è sempre maggiore rispetto a quello di CBW, ad eccezione dei mesi di novembre e dicembre, durante i quali non sono stati effettuati avvistamenti di SW. Questo risultato conferma lo spostamento stagionale della specie al di fuori di Pelagos, che si suppone avvenga proprio nei mesi invernali. La presenza di CBW invece sembra essere piuttosto uniforme anche durante tutto l'anno, dato che le variazioni del tasso d'incontro parrebbero essere dovute al bias nell'eterogeneità di sforzo di campionamento tra le due stagioni. I trend annuali indicano due diversi andamenti: SW mostra dei picchi di presenza in alcuni anni (1994,2003 e 2012) ed in generale un tasso d'incontro più elevato a partire dal 2007. Il tasso d'incontro di CBW è molto più basso rispetto a quello di SW e mostra una distribuzione bimodale, con due periodi di tasso d'incontro più elevato (2004-2006 e 2011-2014). La gap analisi indica che le aree più remote hanno uno sforzo di campionamento decisamente minore (aree a ovest e est della Corsica e zona della piattaforma continentale). La distribuzione dello sforzo di campionamento nei diversi mesi è molto eterogenea: durante i mesi estivi (luglio, agosto e settembre) lo sforzo di campionamento è significativo e regolare, Maggio e Ottobre sono mesi con sforzo meno intenso e con una copertura discontinua della area, infine nei mesi di Novembre e Dicembre è molto poco.

L'analisi del traffico marino nell'area del Santuario Pelagos è stata realizzata utilizzando dati AIS raccolti da un antenna collocata a Savona, nell'arco di 18 mesi. In tutto, sono stati identificati 4205 diverse imbarcazioni che hanno transitato nel Santuario. I due principali tipi di imbarcazione erano navi da carico (41.8%) e le imbarcazioni da diporto (31.8%). Le navi commerciali (navi passeggeri, da carico e petroliere) rappresentano il 63% delle imbarcazioni identificate. Ad ogni modo, considerando il numero di transiti o la distanza totale percorsa da ciascuna imbarcazione, i tipi predominanti sono le navi passeggeri e da carico (30% e 26% rispettivamente nel primo caso e 37% e 38% nel secondo). Le navi commerciali rappresentano il 70% di tutti i transiti e l'85% della distanza percorsa in totale. Questi risultati sono utili per identificare i differenti utilizzatori del mare che devono essere coinvolti in eventuali strategie di mitigazione (ed il loro impatto rispettivo). Integrando i dati AIS con delle database on-line, è inoltre possibile calcolare diverse statistiche tenendo in considerazione il tipo di imbarcazione.

Ovviamente, l'età dell'imbarcazione è un parametro che influisce sul rumore e sull'inquinamento chimico. La velocità del viaggio è un altro parametro che influenza il rumore sottomarino e che ha un ruolo nella frequenza e gravità degli eventi di collisione con cetacei. I risultati confermano che i traghetti viaggiano su determinati corridoi (considerandone la distribuzione spaziale) e con maggiori velocità rispetto agli altri tipi di navi. Le 5 nazioni con la maggior quantità di imbarcazioni che transitano nel santuario sono Italia, Isole Cayman, Malta, Inghilterra e Panama; 51% delle imbarcazioni ha una bandiera di comodo (FOC). Considerando le bandiere in funzione del numero di transiti e della distanza percorsa, le navi FOC rimangono un'alta percentuale (rispettivamente il 25% ed il 31%). Questo dato può essere interpretato come indicativo della quantità di imbarcazioni con un maggior rischio di incidenti (le imbarcazioni FOC hanno meno restrizioni). Concentrando l'attenzione sulle imbarcazioni battenti bandiera degli stati membri di Pelagos, questi rappresentano la maggioranza, con rispettivamente il 60% ed il 50% secondo numero di transiti e distanza percorsa. Questo dimostra come le autorità di gestione di Pelagos 1) possano agire significativamente attraverso leggi nazionali per mitigare in modo efficace gli impatti sui cetacei e 2) necessitino anche di misure approvate dall'International Maritime Organization per poter mitigare gli impatti dovuti alle imbarcazioni battenti bandiera non di stati membri di Pelagos. In quest'ultimo caso, questo lavoro fornisce informazioni riguardo lo stato del traffico marittimo utili a supporto della proposta di creazione di una Particularly Sensitive Sea Area. La mappa dei corridoi di traffico (Figura 36) prodotta attraverso questo lavoro indica che il 68% del santuario si trova ad una distanza di 7km da un corridoio di traffico, dimostrando la difficoltà per Pelagos nell'implementazione di misure di mitigazione. L'analisi temporale indica 3 risultati principali: 1) nell'arco di 18 mesi, non è stato possibile determinare un incremento nel traffico; 2) è evidente un significativo trend stagionale (con un incremento del numero di navi passeggeri in transito nell'area durante l'estate); 3) un significativo trend giornaliero (con un massimo nelle prime ore del mattino 6-8 AM UTC+2). Questa informazione evidenzia la possibilità di implementare specifiche misure di restrizione durante la stagione estiva.

L'integrazione delle mappe degli indicatori di traffico marittimo ha permesso la definizione della classificazione acustica delle fonti di rumore antropiche basate sulla categoria di imbarcazione e il peso del rumore in base all'intensità di traffico nel diversi corridoi di transito individuati. I dati sono stati correlate con l'obiettivo di assegnare ai principali corridoi di traffico marino, un modello di rumore antropico per ciascuna classe acustica. La modellazione delle diverse classe acustiche è basata sull'asse di trasmissione e sulla dimensione dell'imbarcazione. Ogni classe è stata poi simulata nel software ChrisarSIM. Queste simulazioni sono state utilizzate per estrarre la distribuzione di frequenza del rumore per le differenti aree portuali in base all'attività del sito e per ciascuna classe acustica. È stata realizzata una mappe con dati batimetrici e dati bati-celemetrici, basata sui diversi siti acustici identificati nell'area Pelagos. Questi dati hanno permesso di mappare il rumore di origine antropica, utilizzando il software

ACSRAY per la previsione e propagazione del rumore. Sono state prodotte diverse mappe stagionali statiche del rumore antropico espresso secondo diversi indicatori in funzione di 12 bande di frequenza, tenendo in considerazione le aree ad attività portuale e i corridoi di traffico nell'area Pelagos. È importante ricordare che le fluttuazioni del livello di rumore, per un punto nella mappa, dipendono dal range della tratta (propagation loss), dall'intensità di traffico, dal tipo di imbarcazione (caratteristiche elettro-meccaniche) e dalle caratteristiche di potenza-velocità dell'imbarcazione. Le mappe evidenziano la quantità di energia presente nel Santuario Pelagos. L'approccio adottato è stato di non limitare l'analisi alle frequenze più basse solitamente raccomandate per la caratterizzazione del rumore nell'ambiente né a determinate bande di frequenza o audiogrammi noti per le due specie oggetto dello studio, bensì di fornire quante più informazioni possibili per l'analisi globale del rischio derivante da rumore di origine antropica sulla distribuzione SW e CBW.

La prima fase della valutazione dell'impatto del traffico marittimo e del rumore emesso sulla distribuzione delle due specie target ha previsto l'analisi della correlazione tra i tassi d'incontro delle due specie e alcuni predittori (temperatura di superficie, concentrazione di clorofilla, mese di maggior concentrazione di clorofilla (Chl-a), concentrazione massima di clorofilla e anno "year") con l'obiettivo di escludere ogni potenziale ruolo della variabilità ambientale sulla distribuzione delle specie. Questa analisi conferma l'importanza di parametri ambientali nel provocare cambiamenti nella distribuzione delle specie, nonostante questi cambiamenti siano principalmente correlati con la Chl-a e siano apparentemente un effetto diretto o indiretto del trend decrescente di produzione primaria nell'area di studio. Per questa ragione, il predittore temporale ("year") può essere considerato, ai fini del modello, equivalente al predittore Chl-a. La seconda fase ha riguardato una K-means Cluster Analysis (CA), utilizzata per analizzare le somiglianze tra i profili di densità del traffico e la loro composizione all'interno dell'area di studio. Come risultato sono state ottenuti 4 diversi gruppi, che sono stati utilizzati come referenza per la zonazione del traffico e per valutare, per ciascun tipo di imbarcazione, il valore di traffico per ciascuna cella. Nella terza fase è stata effettuata un'analisi con regressione logistica binaria per poter correlare i dati di presenza/assenza delle specie all'intensità di traffico marittimo ed agli indicatori di rumore. Dato che il dataset di presenza/assenza è zero inflated, il numero di celle di assenza è stato bilanciato secondo il numero di celle di presenza. L'estrazione del subset di celle di assenza è stata effettuata utilizzando Mersenne Twister random number generator. I due modelli sottolineano le differenti caratteristiche dell'habitat per le due specie: 1) per SW, il modello identifica un maggior probabilità di presenza nell'area a maggior traffico di petroliere 2) per CWB, evidenzia una preferenza della specie per un habitat maggiormente pelagico e caratterizzato quindi da una minor presenza di imbarcazioni da pesca o di servizio. Per entrambe le specie, il predittore "year" è risultato essere significativo, come previsto già dalla prima fase di analisi. La quarta fase ha avuto come obiettivo la realizzazione di una analisi di correlazione effettuata sull'habitat ottimale, in modo da poter stimare l'effetto del traffico marino e del rumore ad esso associato sull'uso dell'habitat delle due specie. A tal fine, è stato sviluppato un modello habitat presenza/assenza utilizzando dataset indipendenti e utilizzati per predire l'habitat ottimale delle specie, mentre i dati relativi al progetto sono stati utilizzati per analizzare la correlazione tra traffico marittimo e rumore all'interno dell'habitat ottimale. Predizioni di probabilità sono state calcolare per ciascuna cella e, a seconda dell'accuratezza del modello, sono state applicati diversi valori soglia. Le predizioni di habitat ottimale ottenute dai due modelli "esterni a questo studio" sono state testate con il tasso di incontro delle due specie. Per paragonare il tasso di incontro delle due specie nell'habitat ottimale e nell'habitat impattato è stato utilizzato il test di Mann-Whitney. Per entrambe le specie, i tassi di incontro nelle celle di habitat ottimale sono risultati essere significativamente maggiori ($P<0.001$). A questo punto, un'ulteriore analisi di regressione logistica è stata effettuata per correlare la presenza/assenza delle due specie nell'habitat ottimale con gli indicatori sia di traffico che di rumore. Entrambi gli indicatori sono stati valutati come predittori sia considerando il loro valore assoluto, sia rispetto alla zonazione di traffico-rumore. Entrambi i modelli evidenziano una correlazione inversa tra il traffico marino e la presenza della specie. La minor probabilità di presenza per SW è correlata con il maggio numero di imbarcazioni per km percorso, mentre una minor presenza di CBW è associata ad un intensità di traffico maggiore alla media della zona (ovvero "Diff_km_tot ships"). Gli indicatori di rumore sono stati anche selezionati come predittori significativi per i due modelli, avendo effetti diretti ("Su_L10_global" per SW e "Diff_Su_L01_global" per CBW) e indiretti ("Su_L01_global" per SW e "Diff_Su_L10_global" per CBW). Questi effetti sono probabilmente legati alla colinearità dei parametri modellati ("Su_L10_global" e "Diff_Su_L01_global").

In base ai risultati precedentemente descritti, vengono generate delle mappe di rischio per entrambe le specie considerando il tasso di incontro come "esposizione della specie" e la densità del traffico navale come "grandezza dell'impatto". Le mappe di rischio vengono valutate moltiplicando il tasso di incontro normalizzato delle specie con la densità di traffico navale normalizzata, il tutto normalizzato su scala unitaria. Le figure 68 e 69 evidenziano le zone dove le collisioni e tutti gli altri impatti legati al traffico marittimo sono più elevati per le due specie. Si può osservare come la scarpata continentale sia un area con rischio significativo per entrambe le specie mentre per SW vi è anche un rischio significativo associato nel bacino aperto.

Una serie di azioni di divulgazione sono state pianificate per diffondere i risultati della ricerca. Queste azioni hanno come target il grande pubblico e la comunità scientifica includendo ad esempio la comunicazione attraverso i social media, una esibizione temporanea, eventi scientifici, articoli scientifici e conferenze oltre ad una piattaforma di condivisione dei dati spaziali.

0.3. Abstract in French

Le projet a pour objectif de rassembler quatre jeux de données afin d'obtenir un grand ensemble de données capable de décrire de manière plus précise la répartition des baleines à bec de Cuvier (CBW) et des cachalots (SW) dans le Sanctuaire Pelagos. La base de données obtenue couvre ainsi 25 ans (1998-2013), une fenêtre de temps assez longue. Au total, le suivi a couvert une distance de 247'008 km permettant de recueillir 522 observations de SW et 236 de CBW. L'analyse successive a consisté à représenter les données sur une grille de 5minx5min couvrant le Sanctuaire Pelagos (avec une zone tampon de 15 km sur ses limites). Cette grille est constituée par 4'103 cellules et l'effort n'a couvert que 2'622 d'entre elles (ce qui représente 64% de la superficie de Pelagos, Figure 8). Le SW a été observé dans 272 cellules (intervalle=1-15 ; nombre moyen d'observations par cellule=1,92) et le CBW dans 121 cellules (intervalle=1-10 ; nombre moyen d'observations par cellule=1,95). Le taux de rencontre de CBW est plus élevé au niveau de la zone du canyon de Gênes et au niveau de deux zones satellites : à l'ouest du Cap Corse et dans le canyon de Caprera (Figure 11). Le taux de rencontre de SW quant à lui est plus élevée sur la pente abrupte du plateau continentale au large des côtes nord-ouest du Sanctuaire Pelagos. Il est intéressant de noter que les deux distributions ne se chevauchent pas. En regardant la répartition saisonnière de l'effort, il est évident que les mois d'été (de juin à septembre) sont beaucoup plus prospectés que le reste de l'année ce qui implique inévitablement un biais sur les taux de rencontre obtenus entre les deux périodes. Les taux de rencontre de SW sont presque toujours supérieures à eux de CBW, excepté pour novembre et décembre pour lesquels aucune observation de SW n'a été faite. Ce résultat confirme le mouvement saisonnier de SW supposé quitter le sanctuaire en hiver. Il est également possible que la présence de CBW soit relativement uniforme tout au long de l'année et que les variations du taux de rencontre ne soit qu'un biais de l'hétérogénéité de l'effort entre les deux périodes. Les tendances annuelles indiquent deux situations différentes: SW présente des pics durant certaines années (1994, 2003, 2012) et de manière général un taux beaucoup plus élevé à partir de 2007. Le taux de CBW est beaucoup plus bas que celui SW et semble afficher une distribution bimodale avec deux périodes de taux de rencontre plus élevés (2004-2006 et 2011-2014). La "gap analysis" indique que toutes les régions éloignées des côtes ont beaucoup moins d'effort (Ouest et Est de la Corse et généralement sur le plateau continental). La répartition de l'effort au cours des mois change également beaucoup : les mois d'été (juillet, août et septembre) ont un effort important et régulier, mai et octobre ont un effort moins intense avec une couverture discontinue et novembre et décembre sont des mois avec peu de suivi.

L'évaluation du trafic maritime du Sanctuaire Pelagos a été réalisée en utilisant les données AIS recueillies par une antenne située à Savona, pendant 18 mois. Un total de 4'205 bateaux identifiés transitant dans le sanctuaire (une fois ou plus) a été obtenu. Les deux types les plus fréquents étaient des cargos (41,8 %) et des bateaux de plaisance (31,8 %). Les navires

commerciaux (transport de passagers, cargo et citerne) représentaient 63% du total des bateaux en transit. Toutefois, les catégories transport de passagers et cargos deviennent prédominantes quand on considère le nombre de transits ou les distances parcourues par transit par navire, (soit respectivement par type 30 % et 26 % dans le premier cas et 37 % et 38 % dans le second cas). En globalisant, les navires commerciaux représentent 70 % de tous les transits et 85% de la distance parcourue. Ces résultats permettent d'identifier les usagers de la mer qui doivent être impliqués dans toute stratégie d'atténuation (et leur impacts relatifs). En croisant les données AIS avec des base de données en ligne, il est également possible de calculer les statistiques sur la dimension et l'âge par type de bateaux. Ces deux caractéristiques se révèlent être significativement différentes en fonction du type de navire. De toute évidence, l'âge est un paramètre agissant sur le bruit émis et sur la pollution chimique émise. La vitesse de transport est un autre paramètre influençant le bruit émis et agissant sur la fréquence des événements de collisions avec les cétacés et sur leur létalité. Les résultats confirment que les ferries se déplacent à des vitesses plus élevées sur des principaux axes. Les 5 premiers pays les plus représentés en nombre de navires sont l'Italie, les îles Cayman, Malte, le Royaume-Uni et Panama et 51% des navires sont sous pavillon de complaisance (FOC). En regardant les drapeaux selon le nombre de transits et les distances parcourues, les FOCs représentent encore respectivement 25 % et 31%. Cela peut être interprété comme la quantité des navires présentant un risque majeur d'accidents (les FOCs ont des conditions moins strictes que les autres pavillons). En se concentrant sur les navires avec des drapeaux Pelagos, ils sont majoritaire, avec respectivement 60% et 50% selon les transits et les distances parcourues. Cela indique comment les autorités de gestion de Pelagos 1) sont en mesure d'agir significativement par le biais de leurs lois nationales pour atténuer efficacement les impacts sur les cétacés et 2) ont besoin de mesures approuvées par l'Organisation Maritime Internationale pour atténuer les impacts restant des bateaux sous pavillon non-Pelagos. Dans ce dernier cas, ce travail fournit des informations sur les conditions initiales du trafic maritime soutenant la proposition de la création d'une Zone Maritime Particulièrement Vulnérable. La carte des couloirs de navigation (Figure 36) produites par ce travail indique que 68% du sanctuaire se trouve à 7 km ou moins d'un couloir expliquant les difficultés pour Pelagos à mettre en œuvre des mesures d'atténuation d'impact négatif du trafic sur l'environnement. L'analyse temporelle indique trois résultats principaux : 1) sur une période de 18 mois, il n'a pas été possible de mettre en évidence une augmentation du trafic maritime ; 2) une tendance saisonnière significative avec une augmentation des navires transportant des passagers en été ; 3) une tendance quotidienne significative avec un maximum en début de matinée (6-8 UTC+2). Cette information souligne la possibilité de mettre en place des mesures spécifiques pendant l'été.

L'intégration des cartes des indicateurs de trafic maritime a permis la définition de la classification acoustique des bruiteurs anthropiques en fonction des catégories de navires et la pondération du bruit en fonction de la densité du trafic dans les différents couloirs de transport maritime identifiés. Les données ont été corrélées avec l'objectif d'attribuer aux principaux couloirs du trafic maritime, un modèle de bruit anthropique pour chaque classe acoustique. La modélisation des classes acoustiques est basée sur l'axe de transmission et sur la taille des bateaux. Chaque classe a ensuite été simulée dans le logiciel ChrisarSIM. Ces simulations ont été utilisées pour extraire la distribution de fréquences du bruit pour différentes zones portuaires, basées sur l'activité du site, et pour chaque classe acoustique des navires. Une carte de données bathymétriques et bathy-celemetric, basée sur différents sites acoustiques identifiés dans la zone Pelagos, a été réalisé. Ces données ont permis de cartographier le bruit anthropique en utilisant la suite de logiciel ACSRAY pour la gamme de prédiction et la propagation du bruit. Une série de cartes statiques saisonnières de bruit anthropique exprimées avec différents indicateurs en fonction de 12 largeurs de bande a été générée en tenant compte des zones d'activités portuaires et les couloirs maritimes dans la zone Pelagos. Il est important de rappeler que la fluctuation du niveau de bruit, pour un point particulier sur la carte, dépend de la propagation au niveau du couloir (propagation loss), la densité du trafic du couloir, du type de navire (caractéristique électro-mécanique) et des caractéristiques puissance-vitesse du navire. Les cartes mettent en évidence la quantité d'énergie présente dans le Sanctuaire Pelagos. L'approche adoptée a été de ne pas limiter l'analyse aux fréquences inférieures recommandées pour la caractérisation du bruit ambiant, ni à se limiter aux bandes passantes des audiogrammes connues pour ces deux espèces mais de fournir le plus d'informations possible pour l'analyse globale du risque de bruit anthropique sur la distribution de SW et CBW.

La première étape de l'évaluation de l'impact du trafic et du bruit sur la distribution des deux espèce a consisté à évaluer les possibles corrélations entre les taux de rencontre deux espèces et des prédicteurs (tels que la température de la mer en surface, la chlorophylle a, le mois du pic de chlorophylle, la chlorophylle maximum, l'année "year") afin d'exclure ces relations potentielles des modes de répartition des deux espèces. Les résultats confirment l'importance des facteurs environnementaux sur la distribution des deux espèces, impact principalement lié à Chl-a, de manière directe ou indirecte, et à la baisse de la productivité primaire dans la zone d'étude. Pour cette raison, le prédicteur temporel (à savoir "year") peut être considéré comme équivalent aux prédicteurs Chl-a pour modéliser la distribution des espèces. La deuxième étape s'est intéressée à réaliser la *K-means Cluster Analysis* (CA) pour analyser la densité du trafic maritime et la composition spécifique au sein de la zone d'étude. Une solution à quatre clusters a été obtenu et a été utilisée comme référence pour le zonage du trafic et évaluer la valeur différentielle du trafic sur chaque cellule pour chaque type de navire. La troisième étape a eu comme objectif de décrire la régression logistique binaire par la corrélation entre présence/absence des deux espèces et les indicateurs du trafic maritime et du bruit anthropique. Sachant que l'ensemble de données de présence/absence est à inflation de zéros, le nombre de cellules d'absence a été équilibré au nombre de cellules de présence. L'extraction du sous-ensemble de cellules d'absence a été obtenue par générateur de nombres aléatoires selon Mersenne Twister. Les deux modèles présentent les différentes caractéristiques de l'habitat des deux espèces: 1) pour SW, il identifie une probabilité de présence plus élevée dans la zone où le passage des pétroliers est plus élevé 2) pour CBW, il met en évidence une préférence pour un habitat pélagique, caractérisé par une présence inférieure de bateaux de pêche et de service. Pour les deux espèces, le prédicteur "year" est un significatif comme cela a été souligné lors de la première étape. La quatrième étape a visé à exécuter l'analyse de corrélation effectuée à partir de l'habitat optimal pour évaluer l'effet du trafic maritime et de son bruit associé à l'utilisation de l'habitat par les deux espèces. Pour ce faire, les modèles d'habitat présence/absence ont développés à partir de jeux de données indépendants utilisés pour la prédiction de l'habitat optimal alors que le jeu de données de la présente étude a été utilisé pour étudier les corrélations entre trafic naval et le bruit au sein de l'habitat optimal. Les prédictions de probabilité ont été calculées pour chaque cellule, et en fonction de la précision du modèle, différentes valeurs de seuil de probabilité ont été appliquées. Les prédictions d'habitats optimaux obtenus par les deux modèles "externes à cette étude" ont été testés par les taux de rencontre des deux espèces. Un test de Mann-Whitney a été appliqué pour comparer les taux de rencontre des deux espèces dans leur habitat optimal et dans leur habitat impacté. Pour les deux espèces, les taux de rencontre obtenus dans les cellules de l'habitat optimal sont significativement plus élevés ($P < 0{,}001$). À ce stade, une analyse complémentaire de régression logistique a été réalisée pour établir une corrélation entre présence/absence des deux espèces au sein de l'habitat optimal et les indicateurs de trafic et de bruit. Les deux types d'indicateurs ont été évalués comme prédicteurs aussi bien en tant que valeurs absolues qu'en tant que valeurs relatives des zones cluster trafic-bruit. Les deux modèles indiquent une corrélation inverse entre le trafic maritime avec la présence de l'espèce. Une probabilité de présence de SW plus faible a été trouvée dans les zones de plus hauts ratio "number ship/km tracks" et une probabilité de présence de CBW inférieure là où l'intensité du trafic (en distance parcouru) est supérieure à la moyenne de la zone ("Diff_km_tot ships"). Les indicateurs de bruit ont également été sélectionnés comme prédicteurs significatifs pour les deux modèles avec un effet direct (soit "Su_L10_global" pour SW et "Diff_Su_L01_global" pour CBW) et un effet inverse (soit "Su_L01_global" pour SW et "Diff_Su_L10_global" pour CBW), probablement en raison de la colinéarité de ces deux paramètres modélisés ("Su_L10_global" et "Diff_Su_L01_global").

Basés sur les résultats décrits précédemment, les cartes de risques sont établies, pour chacune des espèces, en fonction de la probabilité de présence d'une des deux espèces soit le paramètre "exposition" et de la densité du trafic maritime soit le paramètre "magnitude". Les cartes des risques ont été évaluées en multipliant la probabilité normalisée de la présence de l'espèce à la densité du trafic maritime normalisée et le résultat est lui-même normalisé. Les figures 68 et 69 indiquent les zones où les collisions et tous les autres impacts liés à la circulation sont plus élevés pour les deux espèces. Il est possible de constater que les zones du talus continental sont plus à risque pour les deux espèces, et que pour SW, les zones de bassin ouvert présentent également un risque important.

Une série d'actions de divulgation a été planifiée pour diffuser les produits de la recherche. Ces actions ont été calibrées différemment en fonction de l'audience visée (grand public ou communauté scientifique). Elles comprennent des communications "brèves" par le biais des réseaux sociaux, une exposition temporaire, des événements scientifiques, des articles scientifiques et des contributions lors de conférences et une plate-forme pour partager des données spatiales.

1. Introduction of the topic background

The auditory systems of cetaceans have evolved in quiet oceans with limited fluctuations in noise levels from natural sources. However, since the 1950s maritime shipping traffic has caused the ambient noise levels at frequencies below 100 Hz to increase by 15 dB in the deep ocean (Ross 1987, 1993, Mazzuca 2001, Andrew et al. 2002). Consequently there is a growing concern that anthropogenic noise could affect the hearing abilities and behaviour of cetaceans (Richardson et al. 1995). Concerns about the impact of noise from maritime shipping traffic has been traditionally focused on the baleen whales (Mysticetes) as they emit sounds that overlaps with that of the low frequency noise generated by ships (Payne & Webb 1971, Richardson et al. 1995, Castellote et al., 2012, article published in 'The Sydney Morning Herald January 18, 2014, showing the results of an ongoing project at the James Cook University).

Underwater noise generated by propeller cavitation has been identified as an important ship based noise pollution as it contains a high frequency noise component. The noise produced by propeller cavitation increases in frequency as the ship's speed increases (Arveson and Venditis 2000) and this high frequency noise component has increased in the world's oceans due to the inclination towards progressively faster ships (Frisk 2004). Modern cargo ships travelling at speed of 16 knots or greater can generate noise levels of 150 dB and above, including high frequency noise (rms re 1 Pa at 1 m 30 kHz). This high frequency noise pollution is in the frequency range of the vocalizations and hearing of many toothed whales (Odontocete) species.

Species that are known to be particularly susceptible to the harmful effects of noise pollution are the deep-diving, acoustically orientated sperm whales and beaked whales. Direct mortality through mass strandings of these species has been recorded occurring spatially and temporally correlated with military manoeuvres and seismic surveys, using mid frequency active sonar and air guns respectfully (ie Simmonds & Lopez Jurado 1991; Frantzis 1998; Balcomb & Claridge 2001; Malakoff 2002; Jepson et al. 2003, Cox et al. 2006).

It has been shown that the high levels of high frequency noise caused by ship traffic has the effect to disturb the diving behaviour of a deep diving cetacean. Aguilar Soto and colleagues in September 2003 recorded the diving behaviour of a Cuvier's beaked whale in the Ligurian Sea (equipped with DTAG), located about 24 nautical miles southwest of Genoa. The noise generated from the transit of a large cargo vessel, roughly 700m from the animal increased the background noise, within the frequency range of the echo-location clicks of the Cuvier's beaked whale (30-50 kHz), by 15 decibels.

This resulted in a reduction of the maximum range of echo-location (required for capture prey) by more than 50% and the maximum range of communication (necessary to detect the presence of conspecifics) by 80%. On this occasion the noise pollution caused the animal to prematurely end the deep feeding dive by rising to the surface early. It is evident that beaked whales cannot adapt to noise pollution of this type, because it interferes directly with the limits imposed by the system of eco-localization of the animal itself.

Italy ranks as the top country in the Mediterranean to transport goods by sea and as the first European country for the transport of passengers by sea (Studi e Ricerche per il Mezzogiorno, 2012.). In the Pelagos Sanctuary, there is intense maritime traffic transiting both in North-South and East-West directions as they travel to and from the French and Italian Ports of Marseille, Savona-Vado, Genoa, La Spezia, Livorno, Ajaccio and Bastia. Marine traffic is an industry that continues to expand (UNCTAD, 2014; Lloyd’s Marine Intelligence Unit, 2008) so it is essential to assess the environmental impacts caused by maritime traffic. This is most evident for areas identified as important for sensitive species such as Cuvier's beaked whale and the sperm whale. Sperm whale (*Physeter macrocephalus*) and Cuvier's beaked whale (*Ziphius cavirostris*) are "key-species" for the characterization of the marine ecosystem and biodiversity of cetofauna in the waters of the Pelagos Sanctuary. The Mediterranean population of sperm whales is classified as ENDANGERED in the classification of the 2012 Red List of IUCN, while very little is known about the Mediterranean population of Cuvier's beaked classified as DATA DEFICIENT in the same classification of the IUCN Red List. Identify and quantify impacts and risks for sperm whales and Cuvier's beaked related to vessel traffic is therefore the primary objective of this project.

2. Objectives of the study

This project therefore has the following main objectives:

• obtain a comprehensive spatial dataset for mapping the relative abundance of sensitive species, such as sperm whales and Cuvier's beaked whales, within the Pelagos Sanctuary;

• use AIS (Automatic Identification System) data collected directly from vessel traffic to produce spatial maritime traffic maps of the actual shipping levels in the area;

• utilize the maritime traffic maps and associated vessel statistics to produce reliable estimates of the emitted anthropogenic noise in the Pelagos Sanctuary from vessel traffic;

• assess the impact of noise pollution on the distribution of the target species;

• produce spatial risk maps of the overlapping areas of the projects susceptible species habitat and the anthropogenic noise pollution.

The objectives of this proposal respond to the recommendations set out in the RESOLUTION 2:16 - ASSESSMENT AND IMPACT ASSESSMENT OF MAN-MADE NOISE - ACCOBAMS. Moreover, the results obtained from the project will be integrated directly with the provisions of the document "GUIDELINES TO ADDRESS THE IMPACT OF NOISE ON ANTHROPOGENIC CETACEANS ACCOBAMS IN THE AREA" issued by ACCOBAMS.

The maps of noise pollution generated from marine traffic, and the modeling of the impact on the distribution of sensitive species such as cetaceans, respond to the needs identified by the European Directive MSFD 2008/56/EC as regards the descriptor 11 "Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment".

In parallel, the project allows for the creation of a large dataset, combining the contributions of both Italian and French partners, on the distribution of sperm whales and Cuvier's beaked whales, two species of which current knowledge is still very limited at both a regional and basin wide level in the Mediterranean Sea. Descriptive maps of maritime traffic and noise levels produced, together with the risk maps, will be of interest to various stakeholders and has the potential to be applied to other species at risk from maritime traffic (e.g. ship strikes with fin whales).

Finally, a key component of the project will be the dissemination of the information to the public: by displaying the projects work at exhibitions to the Pelagos states. These events aim to raise public awareness about the challenges faced in the project. It is estimated that the dissemination of this projects data will reach an audience of over 200,000 people.

3. INSPIRE compliancy

3.1 Generalities about the EU Inspire Directive

The EU INSPIRE Directive, adopted on 15 March 2007, aims at establishing an INfrastructure for SPatial InfoRmation in Europe (INSPIRE) for policies and activities that can have an impact on the environment. Once fully implemented the Directive aims at ensuring the interoperability of all geospatial data in the European Union. Furthermore, it requires the provision of network services to facilitate the sharing of spatial data and is based on spatial data themes deemed necessary for environmental applications (EU, 2013). On a biological point of view, the INSPIRE Directive can be seen as an interface between the biodiversity policies and the strategies and frameworks evolving around interoperability and sharing of data. As such, it also gives effect to parts of the global strategy on biodiversity in an European context and serves as an example for the protection of the environment across borders.

To facilitate the European infrastructure for spatial information, the Directive requires Implementing Rules (IR) to be adopted with regard to several aspects, as there are: Metadata, Data Specifications, Network Services, Data and Service Sharing, and Monitoring and Reporting (INSPIRE, 2013c).

The Metadata describes the spatial data sets and spatial data services and makes it possible to "discover, inventory and use" such data and services (EU, 2007). There is an INSPIRE Geoportal which allows the publication of metadata in the required format (INSPIRE, 2013d).

The Data Specifications refer to the three Annexes of the INSPIRE Directive which comprise the 34 spatial data themes needed for environmental applications. Annex I has 9 themes, Annex II 4 and Annex III 21. Each theme is elaborated in the respective Data Specification. To ensure the coherence between the different themes, the Data Specification Drafting Theme has developed a framework that has to be followed while drafting the data specifications. The structure of the data specifications follows "ISO 19131 Geographic Information - Data product specification".

All data specifications include a technical documentation of the application schema, the spatial object types (including their properties), and some other specifics of the data themes. Both natural language and conceptual schema language are used. The technical guidelines for the data specification form the basis for the Implementing Rules and the requirements laid out in the Implementing Rules are legally binding for Member States (INSPIRE, 2013a).

Network Services are described in the Directive as "necessary for sharing spatial data between the various levels of public authority in the Community" (EU, 2007). According to the Directive, the network services should be designed to "discover, transform, view and download spatial data and to invoke spatial data services and e-commerce electronic" (EU, 2007). Furthermore, the Network Services should enable the publication of spatial data sets and services by public authorities. The Directive specifies which network services are required to be established by the Member States. First of all discovery services shall be established in order to search for spatial data sets and services based on the content of the metadata and the metadata should be displayed (as a result of the search). View services shall make it possible to perform basic tasks on viewable spatial data sets (such as display, navigate, zoom in/out etc.), legend information as well as relevant metadata should be displayed. Download services shall be established to enable the download of (parts) of spatial data sets or the direct access. Transformation services shall enable spatial data sets to be transformed to achieve interoperability. Lastly, services shall be made available to invoke spatial data services. The services should be easy to use and be available to the public via the Internet (EU, 2007).

Member States are furthermore required to monitor and report the implementation of the INSPIRE Directive. The monitoring and reporting have to cover four fields: metadata, spatial data sets and services, network services, and data sharing.

3.2. INSPIRE reference grids

Several grids of different spatial resolutions were available, based on the recommendations at the 1st European Workshop on reference grids in 2003 and later INSPIRE geographical grid systems, at 100, 10 and 1km[1]. The grids covered the country boarders and marine Exclusive Economic Zones (EEZ) of each European country plus a 15km buffer are based on ETRS89 Lambert Azimuthal Equal Area Projection (ESPG:3035). The Italian and French grids of every available resolution were combined into one shape file using the QGIS Merge shapefile tool so as to cover the extent of the entire survey area, which encompasses the EEZ of France, Italy and Monaco.

An extra grid was also created at a 5km resolution, using the guidelines set out by the INSPIRE compliancy document because this resolution seems to be the more adapted to analyze cetacean datasets, considering both the quantity of sightings and the habitat variability. During the meeting held on September the 2nd with all partners of the project, it has been decided to use both 5km and 10 km resolution grids (Figure 1).

[1] http://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2#tab-gis-data.

The attribute tables of the reference grids are organized in the same way, according to the additional information about the reference grids[1] (Figure 2):

- the cell code identifier is the unique identifier for each cell, for any of the recommended resolutions (for instance 1kmE5432N4321);
- the Easting values of the lower left cell corner called EofOrigin;
- the Northing values of the lower left cell corner called NofOrigin.

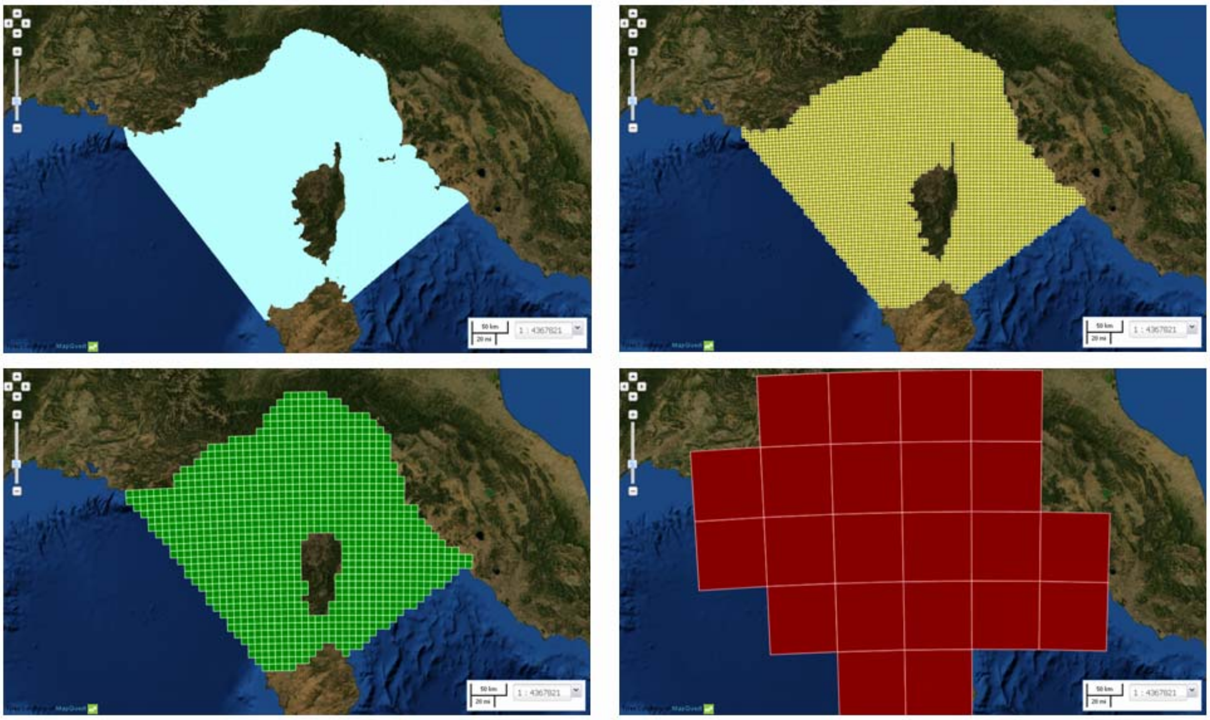


Figure 1. The three reference grids proposed by EEA at resolution 1km, 10 and 100 and the 5km grid created by CIMA Foundation covering the Pelagos Sanctuary with 15km buffer.

Figure 2. Fields of the EEA grids.

3.3. Network services for the project

The project proposes to use SEAWETRA as network service for the project. SEAWETRA is an integrated system for the monitoring of the marine ecosystem and for the management of marine natural resources and protected areas, born in 2013. The system allows for synthesis, integration and comparison of information necessary for instrumental monitoring, protection and the assessment of risk scenarios and their possible evolution.

The initial project, called DEWETRA, was developed as part of the agreement between the Department of Civil Protection and the CIMA Foundation and it is now operational at the Department of Civil Protection. SEAWETRA uses a hybrid architecture that combines an integrated server to back up data on a local basis and web applications that allow widespread distribution of this information. The application aims to provide, through a graphical interface, high-resolution and regularly updated information in order to allow the user to monitor oceanographic data and data collected in the field, build detailed risk scenarios and assess the potential human impact on the marine environment.

SEAWETRA allows each computer connected to the Internet to use, via the geographical mode, all data of the system, independently from the source. The application manages, in fact, both the data owned by the users and all territorial and geospatial dataset published as WMS - Web Map Service from other platforms. Thanks to WMS, the data in SEAWETRA are interoperable and can easily, in agreement with the supplier of the data, be accessed from any other GIS platform (eg ArcGIS, QGIS), in full compliance with the provisions of European legislation INSPIRE. SEAWETRA is able to load and display geo-referenced static layers (e.g. administrative boundaries, topographic structures) and dynamic layers (e.g. maps of environmental variables such as sea surface temperature, sightings collected during scientific surveys) and to consult the data associated to geographical information such as the metadata. It provides to users interactive tools and features for later analysis.

In this context, SEAWETRA hosts the static layers produced by the project in order to be consulted. These layers are organized in folders with a prefix, a suffix and square brackets. The prefix refers to the specific INSPIRE Data Specification theme, the suffix refers to the specific dataset and the square brackets refer to the project short name. For instance, the layers about the marine traffic data are stored into a folder named "TransportNetworks_Marine Traffic [Noise impact Pm Zc]". Similarly, SEAWETRA hosts already other geographic information, some with restricted access (as the daily maps of fin whale cumulated habitat produced by EC JRC - Jean Noel Druon) and others with public access (for instance, some of the MyOcean products). We invite the Pelagos International Secretary to be inform about the data available in SEAWETRA.

The credits of the Pelagos International Secretary to log into SEAWETRA in order to consult specifically the static layers will be communicated by email to Pelagos International Secretary (at secretariat@sanctuaire-pelagos.org).

3.4. Metadata of the static layers

All static layers elaborated for the project have their metadata sheet. The metadata sheet is created and consultable through the GeoNetwork portal of CIMA Foundation http://geoserver.cimafoundation.org/geonetwork/ or using SEAWTRA.

In the webGIS, a right-click on the layer makes appear a context menu where it is possible to select "Metadata". This selection will automatically open a pop-up window with the specific metadata sheet of the layer on GeoNetwork. The fields of the metadata of INSPIRE Directive are represented in Figure 3.

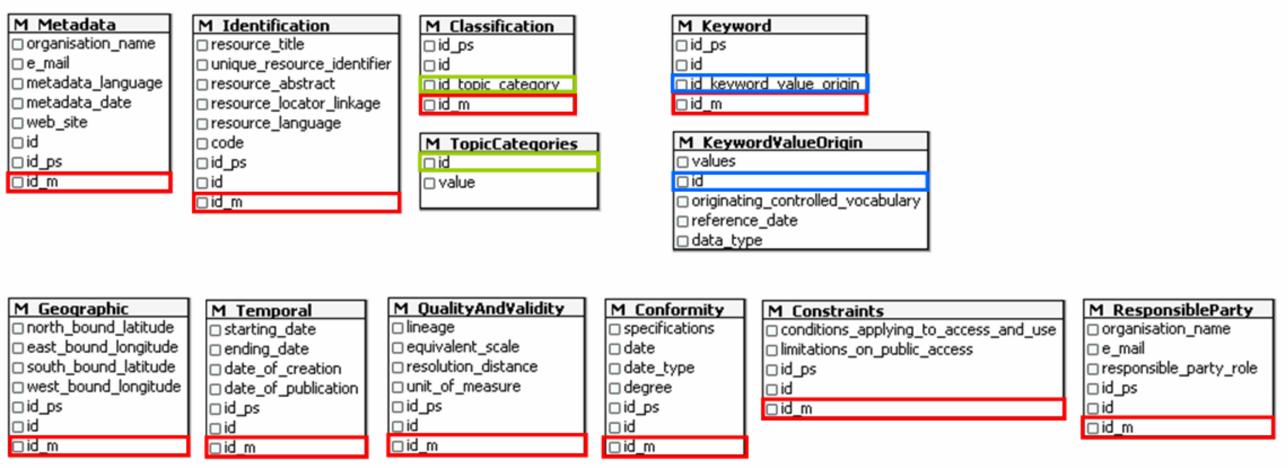


Figure 3. Metadata elements according to the INSPIRE Directive Implementing Rules organized in 10 main tables and 2 tables with code values (M_TopicCategories,M_KeywordValueOrigin).

3.5. Data structure according to the INSPIRE Directive Data Specifications.

The attribute tables of the final static layers are extracted from the database that contains the elements required by the INSPIRE Directive Data Specifications according to the specific themes that regards the datasets and other elements useful for the dataset description. For the project, the two INSPIRE Directive Data Specification themes used to organize the database are:

- Species Distribution;
- Transport Networks.

It is important to report that the INSPIRE Directive is not fully applicable for marine environment yet, especially for Transport Networks. In this case, the INSPIRE Directive recommends to implement the proposed schema following the concept of the global organization of the datasets.

4. Objective 1, relative abundance estimation and seasonal distribution of sperm whale and Cuvier's beaked whale in the Pelagos Sanctuary

4.1. Dataset preparation

4.1.1. Data providers and heterogeneity of the data

Four data providers decided to combined their datasets in order to realize the present study:

- EcoOcéan Institute
- WWF France
- Tethys research Institute
- CIMA research Foundation

These providers were identified according to the high quantity of data they own on sperm whale and Cuvier's beaked whale. However, each of the four partners have collected data on these species at different periods and during surveys planned for different studies (not necessarily targeting these species). Thus, sampling strategies (random or regular sampling, dedicated sampling to study a specific habitat or a specific species *etc.*), sampling protocols (strictly visual vs acoustical surveys, number of MMO searching at a same time, *etc*.), sampling platforms (dedicated/opportunistic, boat/airplane/helicopter), data elaboration procedures (definition of the *on-effort* transects, definition of good weather state *etc.*) and data quantities change between partners. Therefore, the initial step of the project was to define a common procedure to create a unique dataset, harmonized for the common objectives of the project.

4.1.2. Creation of the dataset

The virtual meetings, organized between partners in the very first days of September allow to take crucial decisions about the dataset.

1. Data collected aboard ferries was excluded of the final dataset.

On one side, sperm whale and Cuvier's beaked whale are deep-divers and collecting data aboard ferries (that travel at high speed) may not be totally adapted to analyse their distribution and relative abundance. Moreover, the datasets collected aboard ferries mismatch between partners (temporally, spatially and in quantity). CIMA Foundation has a dataset of 6-year period on 2/3 lanes limited to summer months; EcoOcéan Institute has a dataset of 2-year period on a lane all year round.

2. Data collected aboard air crafts was excluded of the final dataset.

The sampling strategies for aerial surveys or based-boat surveys are different so using a limited quantity of aerial surveys mixed to based-boat surveys may introduce a important biased, especially considering that the only dataset available (from EcoOcéan Institute) is spatially limited to the western part of the Pelagos Sanctuary. Moreover, as it has been explained for ferries, aerial surveys may not be totally adapted to analyse the distribution of deep-diver species.

3. Acoustical data were included into the final dataset.

Tethys Research Institute is the only partner providing acoustic data, and in this case, sperm whale being one of their target species, it has been assumed that most of the sperm whales acoustically detected were successively visually encountered, so the results of both surveys is supposed to be quite similar.

4. Settings about the dataset.

The *on-effort* transects are transects with effective visual detection effort from MMOs. All the track pieces recorded during a sighting when a species is approached (cetacean or not) is *off-effort*. The weather conditions are known to affect the ability to detect cetacean species so it has been decided to use the *on-effort* pieces of track with wind strength <4 Beaufort. The coordinates of the animal (/group of animals) are the one once the animal is reached at a distance of at least 500m. In case, the animal (/group of animals) has (/have) not been reached, the coordinates remain the one at the moment of the detection. Moreover, each provider organized its own dataset in function of the platform description (boat length, eye height and method used for sampling).

4.1.3. Effort density calculation

The first step of the data preparation was to attribute an unique identifier of each piece of *on-effort* transect. Successively, the coordinates of the *on-effort* points were extracted and plot into QGIS and then used as input into the plugin "Points to Path". The polylines were thus created using the identifier of the *on-effort* transect and the time field. The third step consists to projected the data into the reference geographic system, here ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035), according to INSPIRE Directive. Then, the effort density was calculated using the QGIS built-in function "Calculating line lengths". To do so, a batch process allows to cross the polygon grid (the INSPIRE grid with 5km resolution, see *3.2. INSPIRE reference grids*) with each polyline obtained for each day of survey. All the distances calculated per cell for each survey (with a unique identifier called "station") were finally inserted into a unique table. The structure of the table is presented in Figure 4.

Figure 4. Fields of the effort table.

4.1.4. Sighting distribution

All sighting coordinates of the two species were pooled together into one table. Then, using the QGIS "Join Attributes by Location" tool, the INSPIRE cell code was attributed for each sighting Figure 5.

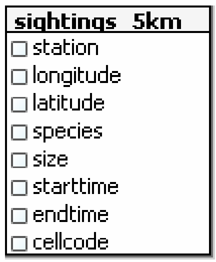


Figure 5. Fields of the sighting table.

4.1.5. Encounter rate calculation

A final table was created in order to calculate the gather together the encounter rate per cell code per day of survey (Figure 6). Successively, the encounter rates per month or per year were calculated using the PostgreSQL functions and operators.

Figure 6. Fields of the final table.

4.1.6. Data organization according to INSPIRE Directive

According to the INPIRE Data Specification on Species Distribution, 24 tables have been created to organize the dataset. The main tables are represented in Figure 7.

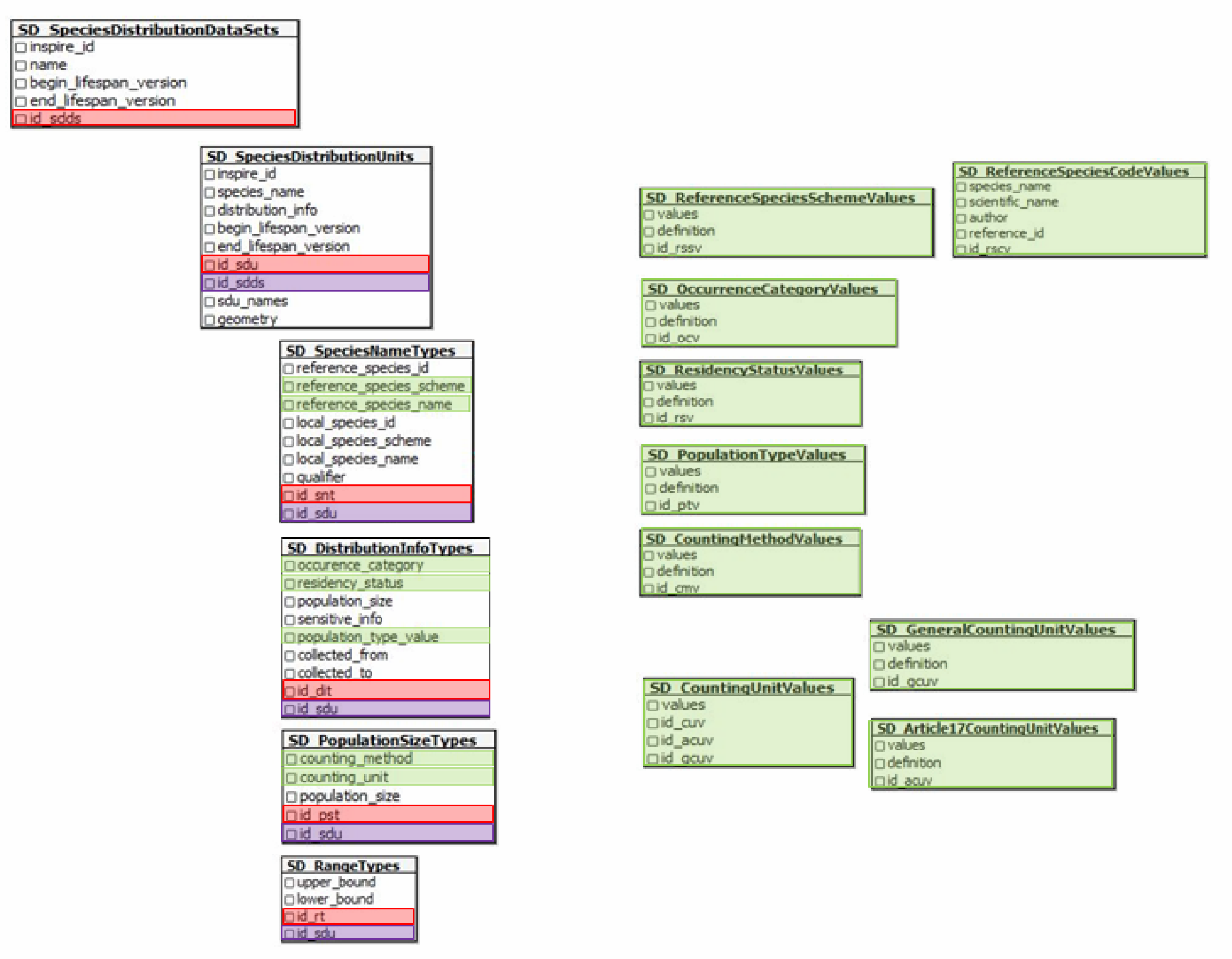


Figure 7. Tables describing the cetacean dataset, according to INSPIRE Directive. The fields in purple are the foreign keys, the fields in red are the primary keys and the fields in green are code lists.

4.1.7. Final dataset characteristics

Compared to the project proposal, the final dataset includes surveys from 1990 to 2014 instead of 1998 to 2013; so the final dataset is covering 25 years. The resulting time frame is very long so gives good perspectives for the analysis of the project. We can expect that the project will give significant results covering a lot of years with an inter and intra-variations between years. The time frame may be fundamental to establish if the data shows any regular dynamic pattern considering environmental conditions.

The total amount of *on-effort* distance covered is also really intense; the total effort reaches 247,008km (instead of the estimated 192,500km of the proposal). The significant quantity of effort over time and space is a direct consequence of pooling together four groups of research working on different areas. The final dataset is distributed indeed about 64 % of the Pelagos Sanctuary (Figure 8).

The total quantity of sighting analyzed for the project is 522 sightings of sperm whale and 236 sightings of Cuvier’s beaked whale. Some of the sightings included in the proposal have been excluded of the final dataset (as it has been explained in the section 4.1.2. Creation of the dataset) in order to limit the heterogeneity of the final dataset. Other sightings (27 for Cuvier's beaked whale and 65 for sperm whale) from the years absent in the proposal have been included contrasting with the data exclusions. The total amount of sightings of both species obtained in the project are particularly high. It is important to remember that Cuvier's beaked whale in the Mediterranean sea is classified as "Data Deficient" in the IUCN Red List so the project will give important information about the species distribution (with its 236 sightings) and how the population is impacted by man-made underwater noise (list by IUCN as a major threat). At the same time, sperm whale is classified as "Endangered" so the results from the 522 sightings (and their relative effort) should give significant information for the conservation of the species in the Pelagos Sanctuary.

4.2. Spatial results

4.2.1. Total amount of effort

The total amount of survey effort collected by the providers from all platforms is 247,008km of *on-effort* survey data.

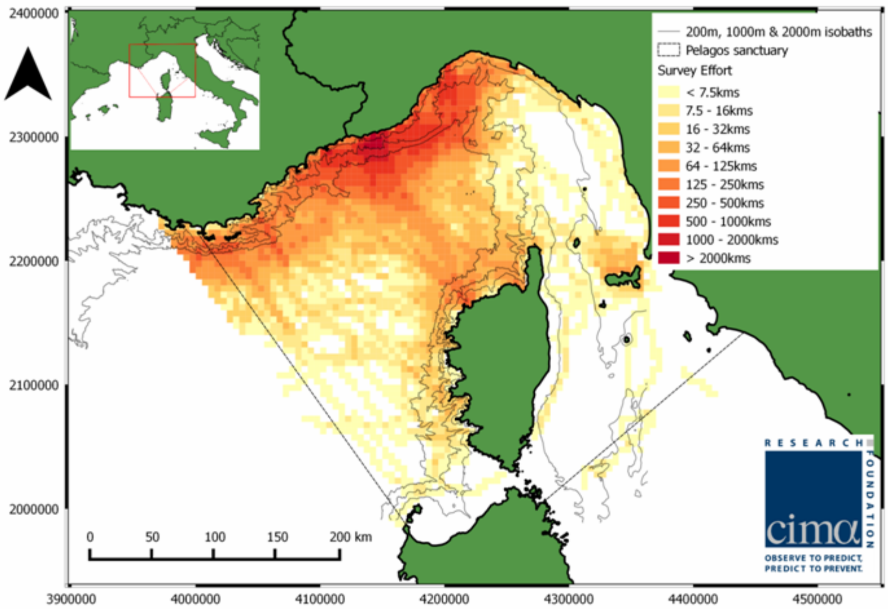


Figure 8. The total combined effort from all providers displayed as kilometres of *on-effort* transects within a 5km INSPIRE compliant spatial grid. The Pelagos Sanctuary (with a buffer of 15km) is distributed over 4103 cells and the effort is distributed on 2622 cells (representing 64% of the total area). Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG:3035).

When compiled into the 5km INSPIRE grid, the effort is distributed over 2,623 cells of the total grid cells (4,103) covering 64% of the surface of the Pelagos Sanctuary. The mean and the standard deviation of the survey effort are 94±230km per cell (Figure 8). The effort cover is not homogeneous and there is a distinct bias towards the north west particularly close to the north coast of the Pelagos Sanctuary.

The total effort displayed in Figure 8 is an amalgamation of the effort from the three partners. The Figure 9 displays the on-effort from the individual partners. The data of WWF is displayed with the data of EcoOcéan Institute as GIS3M dataset. The spatial distribution of the three partners is quite complementary.

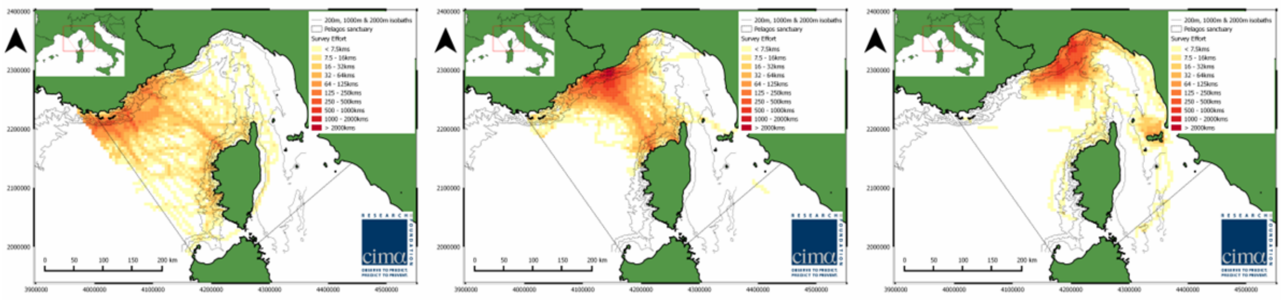


Figure 9. The effort from the three partners displayed as kilometres of *on-effort* transects within a 5km INSPIRE compliant spatial grid (on the left, GIS3M dataset, on the middle Tethys Research Institute and on the right, CIMA Foundation). Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG:3035).

4.2.2. Total amount of sightings

Associated with the survey effort, there was a total of 522 sperm whale sightings that occupied 272 cells, with the number of sighting per 5km cell ranging from 1 to 15 (Figure 10, on the left). The mean value per occupied cells was 1.91.

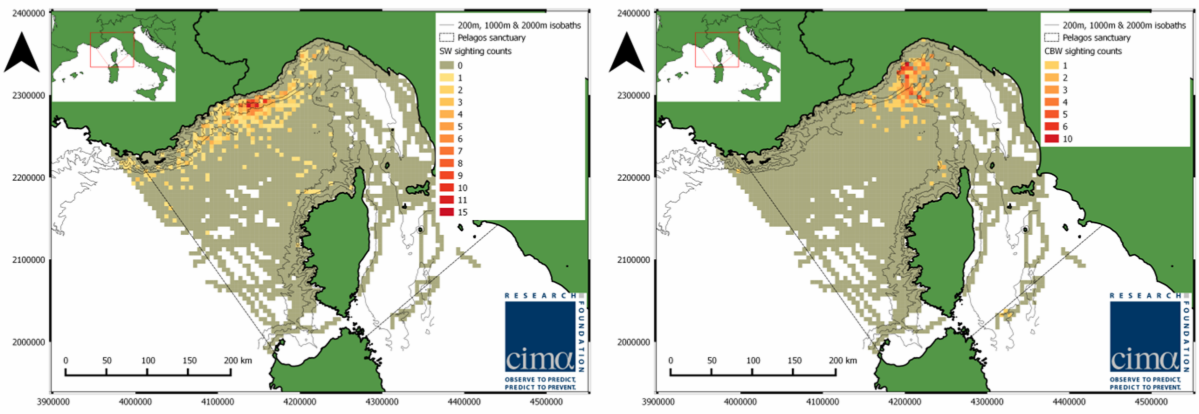


Figure 10. The number of sightings for (left) sperm whales and (right) Cuvier's beaked whales. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG:3035).

There were 236 sightings of Cuvier's beaked whale that occupied 121 different cells with the number of sightings ranging from 1 to 10 (Figure 10, on the right). The mean value per occupied cells was 1.95. The distribution of the sightings of the two species display two areas of occupation that appear to be spatially distinct.

4.2.3. Encounter rate distributions

Cuvier's beaked whales have encounter rates that are spatially clustered predominantly within the Genoa canyon system, with two satellite clusters west of cape Corse and the Caprera canyon (Figure 11). The importance of these satellite clusters may be down biased as they are in areas of relatively low survey effort, resulting in relatively high encounter rates. Sperm whales on the contrary, despite being found in the Genoa canyon system, appear to have a higher predominance on the steep continental slope area along the north-western coasts of the Pelagos Sanctuary. Neither species was recorded in the Eastern part of the Pelagos Sanctuary, perhaps due to lower survey effort or maybe due to a shallow bathymetric regime.

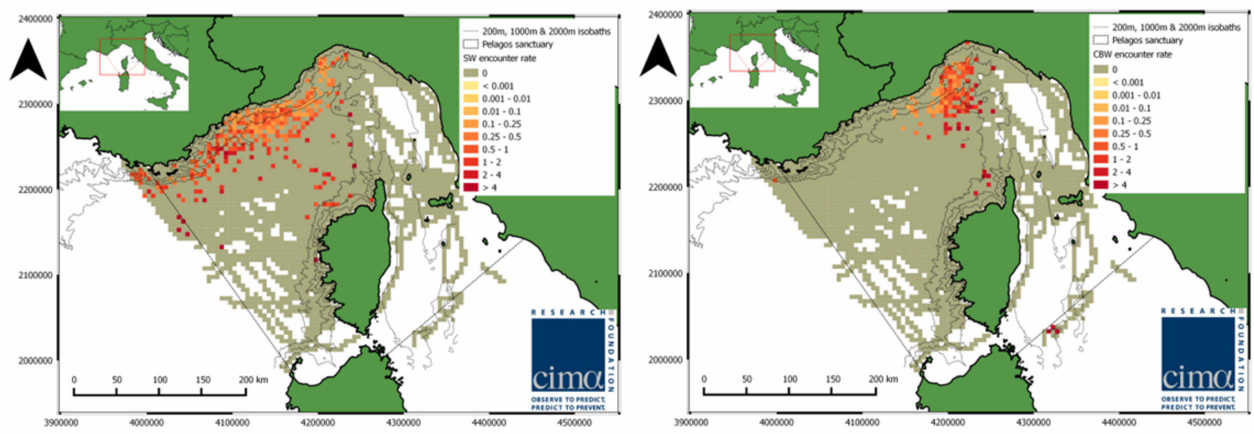


Figure 11. The calculated encounter rates for (left) sperm whales and (right) Cuvier's Beaked whales, as the number of sightings divided by the kms of effort multiplied by 100 for each 5km INSPIRE compliant grid cell. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG:3035).

4.3. Temporal distribution

4.3.1. Effort distribution over time

The distribution of effort over time is not homogeneous. Within a year there is a very distinct pattern that the amount of effort in kilometres is much higher in the summer months (June to September) than in the winter months (Figure 12). This is not surprising as cetacean surveys are very weather dependent and thus the number of possible surveys during the more clement summer weather is higher.

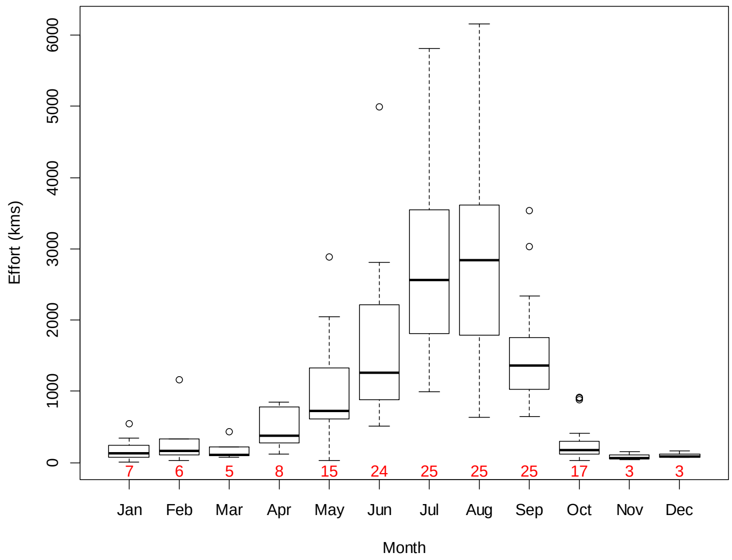


Figure 12. The distribution of survey effort between months, according to month values. The red numbers indicate the number of year with effort from that month.

The inter-annual distribution of effort appears to have 2 distinct distributions before and after 2004. The overall mean effort was 9,879±4,948km but the mean before 2004 was 6,603±1,745km and 14,048±4,545 after 2004. Moreover, the range of value per year depends on the survey distribution over month: some years have their effort concentrated on the summer months while other years have a nearly year round sampling (red numbers in Figure 13).

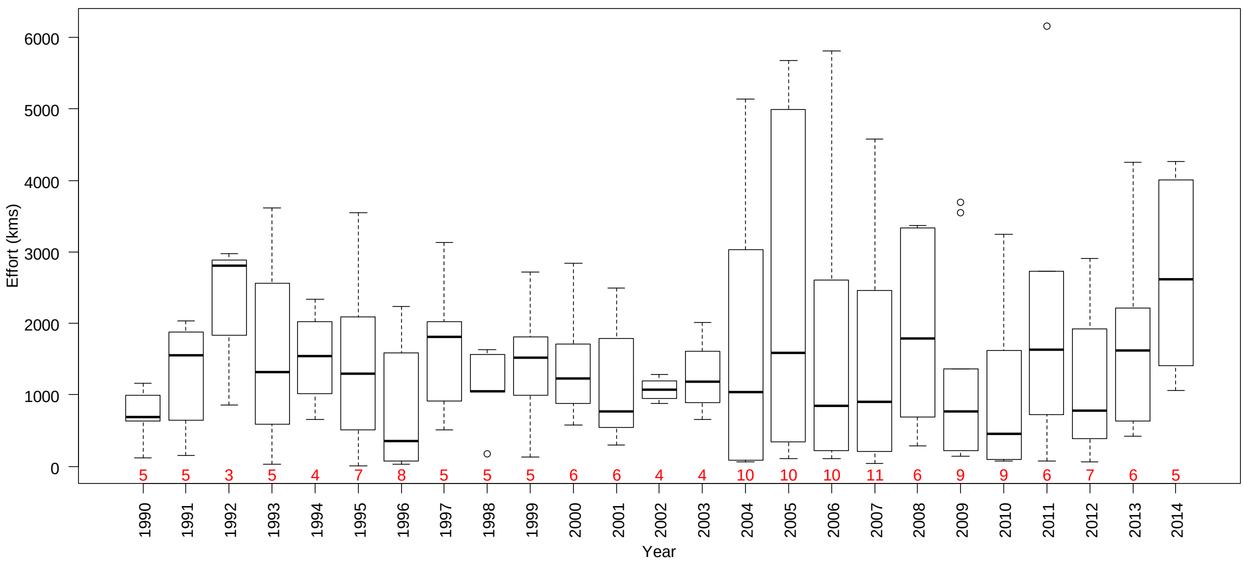


Figure 13. The distribution of survey effort between years, according to month values. The red numbers indicate the number of months with effort from that year.

4.3.2. Relationship between the number of sightings and the amount of effort

When looking at the number of sightings relative to the amount of effort it is not surprising to find that for months intensively surveyed, more sightings of both species are realized (
Figure 14).

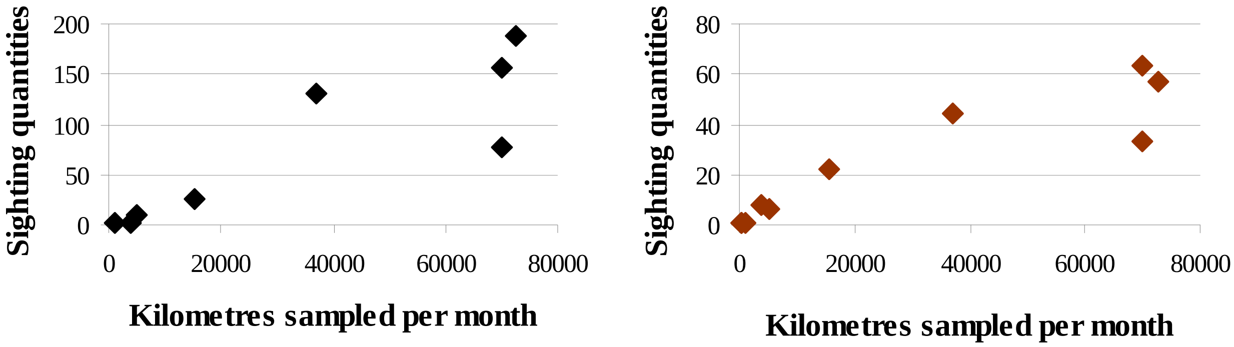


Figure 14. Relationship between the number of sightings and the amount of effort by month.

4.3.3. Encounter rate distribution over time

The encounter rate relative to the level of effort appears to stabilize in the months with effort greater than 15,000kms (Figure 15). If using only these high effort months (May, June, July, August & September), the mean encounter rate for sperm whales per month was 0.2217 and 0.1057 for CBW.

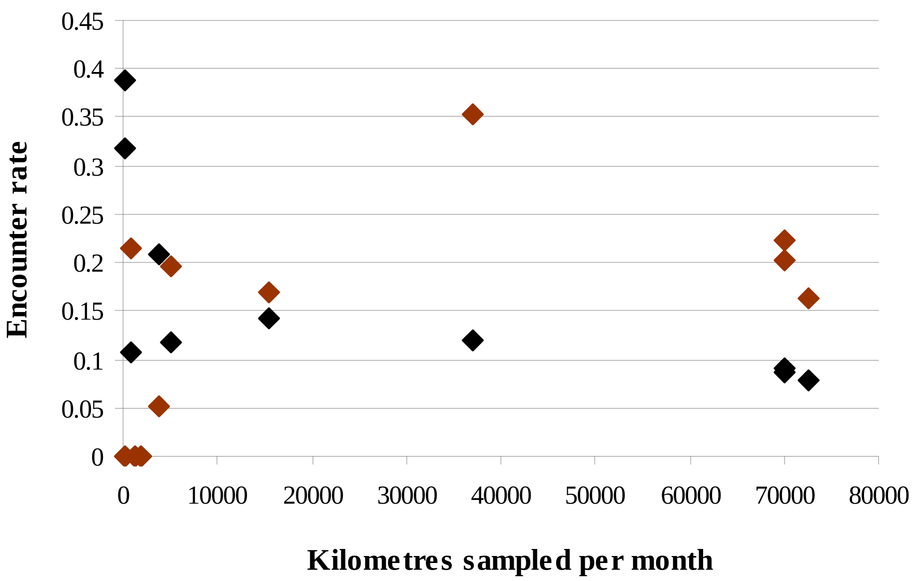


Figure 15. Relationship between the encounter rate and the amount of effort by month (sperm whale in back; Cuvier's beaked whale in brown).

The summarized encounter rates between the years and months display possible differences between both the species and the temporal timeframes of the project (Figure 16).

The difference between the species is quite apparent with the sperm whale encounter rate almost always higher than Cuvier's beaked whale in the temporal groupings. The exceptions being the years of 2004 to 2006 and the month of April, plus the months of November and December which had no sperm whale sightings. This may display a seasonal movement out of the area by sperm whales as has been previously speculated by Drouot-Dulau and Gannier (2007). This may also indicate a possible relatively uniform abundance and year round presence of Cuvier's beaked whale, with only the effort being the reason for the change in encounter rate, and a possibly uniform distribution of sperm whale encounter rates between March and October and their subsequent absence outside of these months.

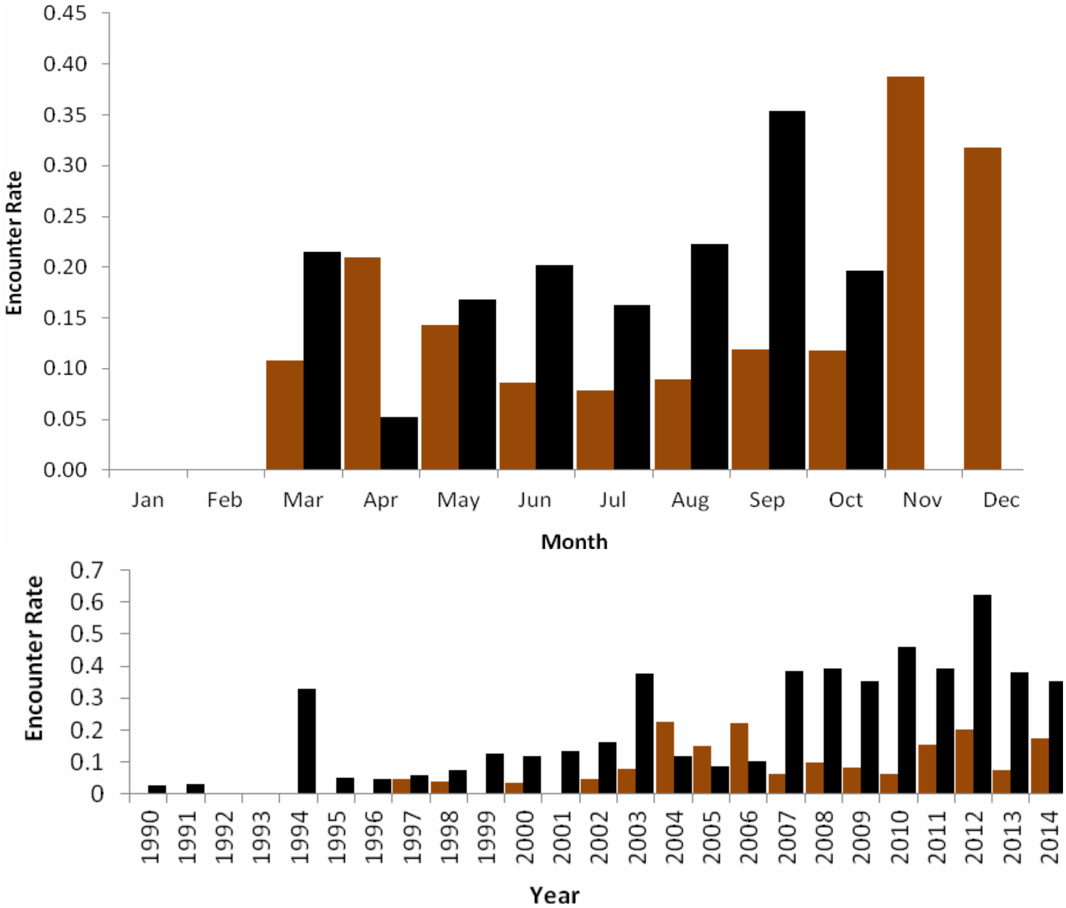


Figure 16. The calculated encounter rate as the number of sightings of Cuvier's beaked whale (brown) and sperm whales (black) divided by the total kilometres of survey effort multiplied by 100 for each year of the project, between years and over months.

The yearly trends seem to show two distinctly different patterns between the years and between the two species. Sperm whales appear to have peaks in 1994, 2003, 2012 and an encounter rate much higher years from 2007 onwards.

It is possible that the increased effort observed in 2004 to 2006 may be a reason why the encounter rates dropped here. Cuvier's beaked whales had in respect to sperm whale a lower encounter rate but it appears to have a bimodal distribution with two distinct regions where the encounter rates were higher and lower in 3 to 4 years, displaying and inter annual pattern. A pattern that is not explicitly linked with the pattern of effort. However, it is not possible at this stage to differentiate or speculate either of these patterning to a biological or a effort orientated observed difference.

4.4. Gap analysis

It is logical that even with the final dataset constituted by the partners, some gaps over time and space remain. Looking at the spatial distribution of the effort (Figure 17), some areas are not sampled at all and other areas have a very low sampling (inferior to 10km per cell).

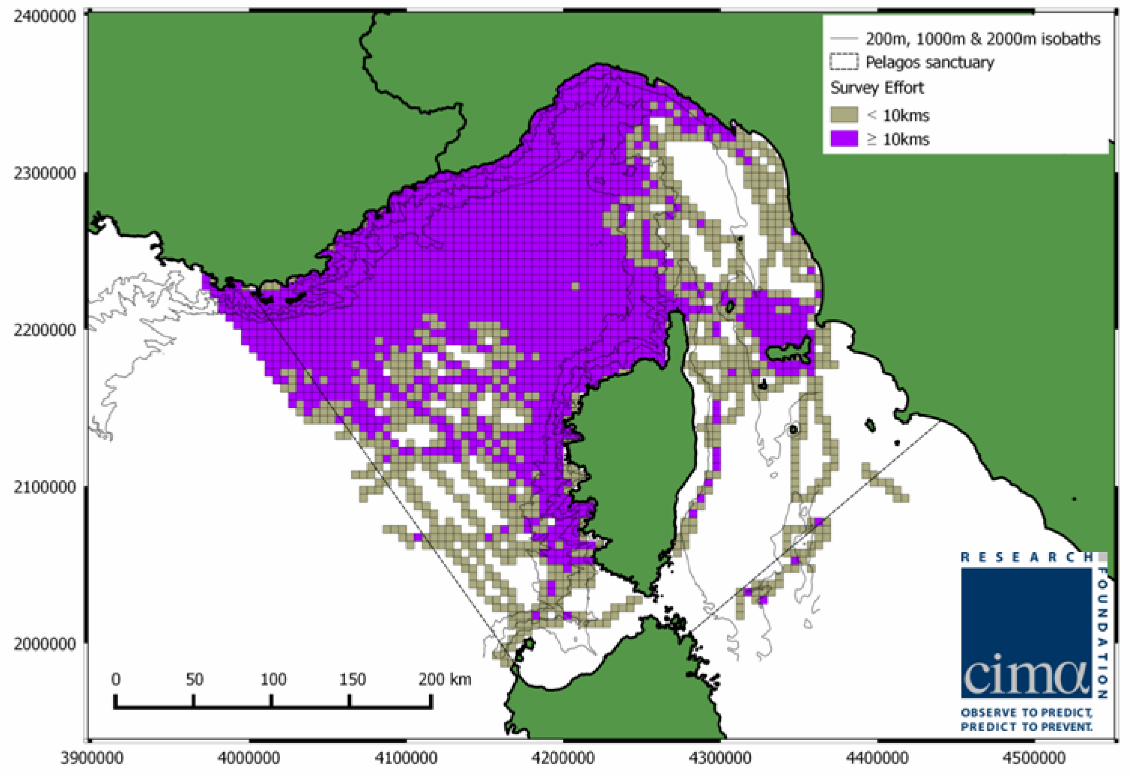


Figure 17. The total effort distribution (distributed over 2622 cells; representing 64% of the the Pelagos Sanctuary with its 15km buffer) and areas where the effort is superior to 10km (distributed on 1673 cells; 41% of the Pelagos Sanctuary). Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG:3035).

All the partners have mostly surveyed the Sanctuary from the continental coast (between Toulon and Portofino) so all remote areas, far from the French coasts are significantly less prospected, especially on the West of Corsica.

Another less prospected area is the one at the East of the 9th meridian east of Greenwich. This area is characterized: 1- at North of the Elba Island, by a large continental shelf and a gentle slope where both the studied species are supposed to be less observed than in the habitat with steep slope; 2- at South of the Elba Island, where the slope is steep and where the habitat is possibly more favourable for both species (for Cuvier's beaked whale, see Gannier 2011). The third area with non representative effort is the strait of Bonifacio. Here again, the presence of both species can not be described from the dataset of the project but both species may be present considering that the strait connects two close areas where both species have seen observed significantly in the canyon of Caprera within the Tyrrhenian sea (Bittau et al. 2013) and where sperm whale have been observed off the Island of Asinara (Lauriano, G. & Notarbartolo di Sciara, G. 1996).

Looking at the effort distribution over years, as it is quoted in section 4.3.1. Effort distribution over time, the inter-annual distribution of effort appears to have 2 distinct intensities before and after 2004 and this difference have a direct impact on quantities of sightings. Before 2004, in 14 years, the relative effort is 92,442km with a mean of about 6,600km per year, while after 2004, in 11 years, the relative effort is 154,528km with a mean of about 14,000km per year. With more than a double of effort per year, we obviously have a different coverage in space between both periods and the results on the period after 2004 is more widely distributed over of the Pelagos scale than on the period before 2004. Analyzing the quantities of sightings for the 2 periods, we have 76 sightings of sperm whales and 15 of Cuvier's beaked whales before 2004 (with an average per year of 5 sightings of sperm whale and 1 of Cuvier's beaked whale) and, after 2004, we have 446 sightings of sperm whales and 221 sightings of Cuvier's beaked whales (with respectively an average of 41 and 20). This huge contrast highlights how effort intensity impacts on quantities of sightings for both species and the relative gaps of effort over space especially before 2004. For instance, CIMA research Foundation provides data from 2004 to 2014, and its relative coverage is more Eastern than the coverage of other partners (Figure 9). Similarly, in this area, the encounter rate of Cuvier's beaked whales is higher (Figure 11) so, in case of less intense effort in this area (as before 2004), the sightings number is logically lower.

The effort distribution over months changes also a lot: some months (July, August and September) are very well represented with effort each year of the total period (Figure 12) but other months (November and December) have been sampled very few time (3 years). Only from May to October, the effort have been repeated for 12 years (half of the total period) so it can be considered as significant but for the other periods (January-April and November-December), the final dataset suffers of effort gaps.

5. Objective 2, creation of a web catalogue of thematic maps describing the marine traffic of the Pelagos Sanctuary

Most of the results of this section are extracted from: Coomber F. 2016. The ecological impacts of maritime traffic and its noise pollution on Cuvier's beaked whales (Ziphius cavirostris: Cuvier, 1823) in the northwest Mediterranean Sea: An environmental impact assessment. PhD thesis University of Genoa.

5.1. Generalities about global shipping

5.1.1. Shipping for the global trade

Oceanic shipping is one of the most energy efficient modes of long distance goods and bulk transport and as such it is not surprising that around 90% of all global trade is by sea. Given that shipping by its nature is a global operation, it can only operate efficiently and safely under regulations and standards that are agreed, adopted and implemented on an international basis and this is provided by the regulatory framework developed and maintained by the International Maritime Organization (IMO, www.imo.org).

The IMO is an international body devoted exclusively to all maritime matters with the main objectives to improve maritime safety and security and the prevention of marine pollution. It was adopted by a United Nations (UN) convention in 1948 and entered into force in 1958 and now consists of 170 member states governed by a central assembly that coordinates the work carried out by committees and sub-committees. In order to achieve its main objectives the IMO has promoted the adoption of many conventions, protocols, codes, guidelines and recommendations. Most notable among the conventions are:

- The International Conventional on Safety of Life at Sea (SOLAS:1974)
- The Convention on International Regulations for Preventing Collisions at Sea (COLREG:1972)
- The International Convention for the prevention of Pollution from Ships (MARPOL:1978).

Under the IMO guidelines and conventions, special areas can and have been set up in order to reach these objectives.

In January 2013 the world fleet of vessels (100 Gross Tonnage –GT- and greater) consisted of 86,942 vessels with a combined Dead Weight Tonnage (DWT) of 1.63 billion, average age of 20.3 years and an estimated worth of US$ 809 billion (UNCTAD, 2013). It's possible that 75% of the world fleet may be underway at any given time (Eiden & Martinsen, 2010).

The level of worldwide shipping has continued to increase with time and 2012, despite showing a noticeable decrease to the past 10 years still saw a 1.8% growth in international trade.

A shipping vessel in order to prove its nationality and thus be able to travel internationally, crossing international borders must be registered to a flag state. Ship registration is the process of documenting a ships nationality and allows the vessel to travel to countries where citizens of that country are allowed to travel as well as being allowed to use the ship as security in order to obtain a marine mortgage. A ship is bound by the laws of its flag state, unless in the territorial waters of another flag state and the country to which is responsible for the ship as far as international law is concerned. Ship registration to particular flags offer other specific advantages to the vessel and it has been found that particular vessel types are usually registered under a specific flag state (UNCTAD, 2014). Among many of the advantages include lost cost fees and registration, naval protection, tax exemptions and reductions, customer assistance, likely hood of port state control inspections, dual registry, legal platform, consular services and reduced costs of particular amenities. However, there are many open registries or flags of convenience (FOC) and are defined by the International Transport Workers' Federation (ITF) as "where a beneficial ownership and control of a vessel is found to lie elsewhere than in the country of the flag the vessel is flying" (UNCTAD, 2014). The ITF currently recognises 33 flag states as FOC. Eight out of the top 20 flag states by number of vessels and gross tonnage are classified as FOC, included in these is the single largest flag state fleet, Panama and the largest growing fleet, Marshall Islands (UNCTAD, 2014).

There are several important factors that relate to a flag state, it is a fact that some flag states are better than others in their acceptance and ability to comply to safety and environmental conventions. There are particular problems of FOCs who have little or no actual jurisdictional control and as such the safety inspection standards and the rigorousness of maintenance reputation of FOC open registry vessels has been questioned. FOA registered vessels have been linked to higher accident incidences, casualties, loss of vessels, reporting of incidences, running non-seaworthy vessels and have be found to increase the probability of an accident. Some of the highest attention marine incidences have been linked with FOC states, e.g. the prestige tanker in Spain November 19 2002.

Although there is no universally applicable definition of ship type, categorisation societies and organisations have various definitions and categories for the applications of marine regulations. A merchant vessel is basically any ship, of any shape or size that is engaged in active commercial transportation of passengers or cargo. The categories of vessel used in this project are:

- Tanker: oil, chemical, gas or other bulk liquid carriers
- Cargo: dry bulk carrier, general cargo including Ro-Ro, containers, reefer, HSC cargo

- Passenger: transporting more than 12 passengers
- Fishing vessel: any vessel commercially used for catching fish or other living resources
- Service craft: pilot vessels, search and rescue, tenders, anti-pollution vessels and ship with specific non commercial services
- Pleasure craft: private craft.

The Mediterranean was historically an important route for merchants and travellers, being at the crossroads of Africa, Europe and Asia, and today it is still an important area notable for global and economic trade. The Mediterranean Sea is one of the world's busiest waterways (Figure 18), with a high relative vessel density (Eiden & Martinsen, 2010) that accounts for 15% of the shipping activity in number of port calls or 10% by DWT (LMUI, 2008). Despite having 480 ports and 16,000 unique intra-Mediterranean routes there are also major transit routes with vessels travelling through the access points at the Strait of Gibraltar, Bosporus Strait and the Suez Canal with 70,000, 55,000 and 16,000 transits respectfully in 2006 (excluding ferries and vessels with less than 100GT, LMIU, 2008). The Mediterranean traffic density is dominated by high frequency ferry intra-Mediterranean passenger traffic (LMUI, 2008) and also a global hotspot for this vessel type (Eiden & Martinsen, 2010). The flagged vessel within and transiting the med are 40-50% flagged by a Mediterranean country where 80% of the transiting traffic is flagged by a non-Mediterranean country (LMIU, 2008).

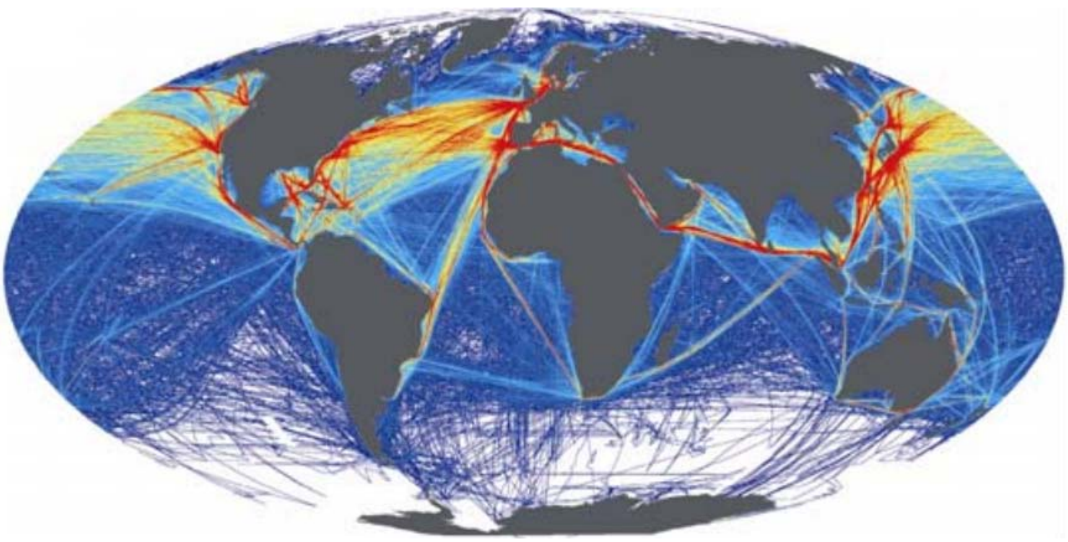


Figure 18. The worldwide shipping impacts taken from Halpern et al (2008) as the impacts.

5.1.2. Direct and indirect shipping monitoring services

5.1.2.1. Vessel Traffic Service (VTS)

The Vessel Traffic Service (VTS) is a designated area set up within the territorial seas of any contracting government, where the possible risks caused by high levels of shipping traffic could warrant traffic services and measures.

A VTS contributes to safety of life at sea and efficiency of navigation and protection of the marine environment, adjacent shore areas, work sites and offshore installations from the possible adverse effects of maritime traffic. Many, including Genoa and Savona have a mandatory reporting system, where vessels entering and leaving must contact the VTS authorities to inform them of their destination and cargo etc.

5.1.2.2. Voluntary Observing Ships' (VOS) scheme

In 1853 an international voluntary scheme was set up by the National Meteorological services (NMS) to use ships as platforms for the collection of meteorological data called the World Meteorological Organization (WMO) Voluntary Observing Ships' (VOS) scheme. The aim of the scheme was to collect and disseminate real time maritime weather conditions to support SOLAS. Collecting data from the data sparse areas of open ocean to help define global climate extremes and variability over a long time scale, as well in later years for use in calibration of meteorological satellite data. Currently there are an estimated 4,000 ships in the VOS fleet with peak fleet numbers 7,700 in 1984/85.

5.1.2.3. Long Range Identification Tracking (LRIT)

The IMO Long Range Identification Tracking (LRIT) is a satellite based system that can relay messages from ships to shore stations anywhere in the world. The regulation was adopted in 2006 and all ships should be fitted with appropriate equipment by 2009. However, ships are only required to transmit data 4 times per day and it is not an open system and to date IMO regulations state that the use and sharing of data is currently only available for LRIT Data Centres.

5.1.2.4. Automatic Identification System (AIS)

AIS is a ship-to-ship and ship-to-shore system intended to enhance the safety of life at sea, safety and efficiency of navigation and protection of the marine environment objectives of the IMO. It is used to identify vessels, assist in target tracking, simplify information exchange and provide addition information to assist in situational awareness of maritime authorities and personnel such as the Officer on Watch or VTS personnel. Since December 2004, it has been mandatory that all vessels over 299 Gross Tonnage and all passenger vessels independent of size must carry an AIS transponder (SOLAS Chapter 5 regulation 19 paragraph 2.4). However, not all vessels are required to be fitted with AIS, e.g. warships, naval auxiliaries, governmental vessels, small vessels, leisure craft and fishing vessels do not require AIS equipment. Moreover, ships fitted with AIS may have the equipment switched off. Therefore, the information provided by AIS may be biased or not a complete picture of the actual shipping within an area (SOLAS, 1974).

AIS data can be received through a land based terrestrial AIS antennae (T-AIS), such as is used in VTS areas or since 2008 through the use of AIS receivers on satellites (S-AIS). Even though the two AIS data collection methods can be assumed to be equal, there are specific differences that must be taken into account. T-AIS is primarily used by the VTS areas for safety of navigation in areas of high shipping intensity. TDMA techniques ensure that all AIS messages are collected but the data collection is confined to coastal areas and line of sight (Eiden & Martinsen, 2010) with a range that depends on antenna height and atmospheric conditions (Leaper & Panigada, 2010). S-AIS on the other hand has a larger geographic range and is suitable for a global ocean overview, however it can become quickly saturated in areas of intense shipping and AIS messages go unrecorded.

5.1.3. AIS data

5.1.3.1. Description of the data

Raw AIS data is received from an antenna or a base station as a raw NMEA AIS string of AIS data packets. The National Marine Electronics Association (NMEA) was founded in 1957 and has created a uniform interface standard that is used for all digital data exchange between different marine electronic products. AIS data is transmitted in NMEA0183 serial protocol at a high 38,400 baud rate (NMEA=4800baud). There are two NMEA0183 sentences reserved for AIS !AIVDM and !AIVDO that provide data from other and own vessel respectfully. The first and last part of each data packet is in ASCII coding but the data payload, the bulk of the sentence uses a 6 bit binary encoding in order to reduce data load. The following is an example of an individual AIS NMEA data packet:

*!AIVDM,1,1,,B,14he2J002NP`j@4II6PaNGa>0@Gc,0*02*

Contained within these data packets are 7 fields and a suffix, separated by a comma, which purvey information contained within the packet.

Field 1 –(*!AIVDM*) – identifies this as an AIVDM packet
Field 2 – (*1*) – is the number of fragments of this sentence
Field 3 – (*1*) – is the fragment number of this sentence
Field 4 –() - is a sequential message ID for multi-sentence messages
Fields 5 – (*B*) – is a radio channel code
Field 6 – (*14he2J002NP`j@4II6PaNGa>0@Gc*) – is the data payload
Field 7 – (*0*) – is the number of fill bits required
Suffix–(*02*) – is the data integrity checksum

The AIS data transmitted and received from ship-to-ship and ship-to-shore includes a variety of information. There are a total of 27 message types and can be grouped into 4 categories primarily dynamic (vessel navigational), static (vessel dimensions), voyage related (destination and Estimated Time of Arrival -ETA) and VTS information (Bošnjak and Claridge, 2012). Moreover, there are addition message types relating to addressed and broadcast messages, time and date information, aid to navigation position and information.

The vast majority of AIS messages (approximately 50%) belong to the Position Report Classes (PRC). These messages are broadcast by a vessel every 2-10 seconds depending on the vessels' speed and maneuver. They contain positional and navigational information, including longitude and latitude, navigational status, Speed Over Ground (SOG), Course Over Ground (COG) and Rate of Turn (ROT) along with a ships unique identifier, or Maritime Mobile Service Identity (MMSI) 9 digit number. These messages originates from two AIS devices the class A transponder and the older and cheaper class B transponder. Class B is less detailed with fewer features compared to the class A transponder and omits data on navigational status and ROT. Class B transponder only transmits PRCs every 30seconds to 3 minutes. Static and Voyage Related Data is available for both classes of AIS report and is primarily used to transmit destination data. They are broadcast roughly every 6 minutes and include destination, ETA, ship type, vessel dimensions, name, call sign and the unique IMO number and MMSI number.

5.1.3.2. Data reliability

Issues about the data transmitted by boats

The data received and transmitted between ships and shore may not be fully reliable, due to electronic or operational issues. Poorly configured non-calibrated or un-operational ship sensors may lead to transmission of false information (Bošnjak and Claridge, 2012). Messages, especially relating to Static and Voyage Related Data such as ETA are manually input by the crew and may have falsified or erroneous data input (Harati-Mokhtari et al., 2007). Bošnjak and Claridge (2012) found that between 30-50% of voyage and static data had errors. Different vessels may broadcast under the same MMSI number (MMSI 1193046, was broadcast by 26 different ships), wrong dimensions, port calls or simply missing information (Bošnjak and Claridge, 2012). Plus AIS classification of ship type has less categories than IMO and ISACs classifications, only general cargo, tanker *etc*. It may be for this reason that the IMO's MSC have condemned the publication of freely available AIS data on the world-wide-web or elsewhere.

Issues about the data reception

AIS messages only have a time in seconds recorded for each AIS messages. This is not such a problem as a timestamp is created for each message as it enters the database and can be calibrated against the message 4, base station report UTC time, but problems arise in areas or times of high message density.

5.2. Generalities about the shipping within the study area

The Pelagos Sanctuary includes high shipping intensity with many large industrial and touristic ports and respective trade and passenger shipping routes. The Figure 19 represents the shipping ports listed into the World Port Index with a regular commercial activity; 28 are into the Pelagos Sanctuary and 16 of them have AIS receivers. Genoa which in 2006 was the 3rd and 4th busiest port in the Mediterranean in relation to number of calls and DWT respectfully is predicted to continue to be an important Mediterranean port (LMIU, 2008).

Numerous shipping lanes run between these ports and other ports outside of the Pelagos Sanctuary. Most notably would be the passenger routes that regularly transit between the mainland ports and the Island ports of Sardinia and Corsica.

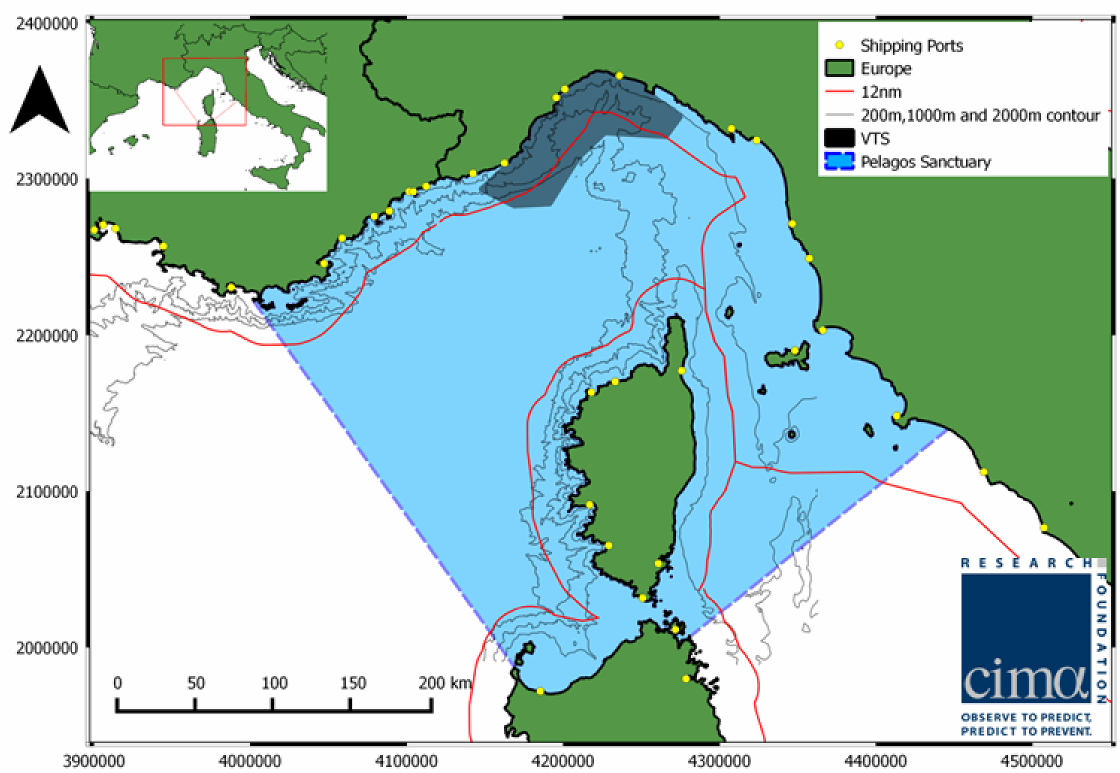


Figure 19. The shipping ports present within the Pelagos Sanctuary as well as the VTS area of Savona and Genova and the 12 nm territorial waters of Italy, France and Monaco. Port shapefile taken from the World Port Index. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

5.3. Methodology

5.3.1. The AIS system used in this study

The collection of AIS data from the NW Mediterranean Sea begun on the 3rd of May 2013 through the use of an AIS receiver station based at the Savona University campus at the geographic coordinates of 44.30°N and 8.45°E at a height of 20 meters, installed by CIMA research Foundation. The raw NMEA data packages are directly stored into the CIMA Foundation's PostgreSQL database. It is primarily this data that has been used for the subsequent methods and analyses in this study.

The raw data collected through the AIS receiver were raw NMEA data packages, which required parsing, translating the data payload into a meaningful value and insertion into separate database tables. A parser is a program that receives input from a sequential source and breaks them up into parts that can be used and managed by other programs.

The raw NMEA data package string, from here on referred to as spooler, was parsed, thanks to a parser programmed by Logness srl using the Integrated Develop Environment Microsoft Visual Studio Express 2012 for windows desktop using C# language, to a pgAdmin III PostgreSQL database.

The parser works of three steps:
- codes the executable file, allowing to run the programming code;
- splits the message into its consecutive parts and converts the data payload into binary code;
- creates the structure of the database tables for each message type, connects to the database, converts the binary code into the correctly formatted data and inserts the data into the tables.

5.3.2. Routine to filter, clean and complete decrypted data AIS data

Once all the raw AIS data was parsed and inserted into a PostgreSQL database it was required to perform data filtering, additions and quality control procedures. The raw AIS data was truly vast with the number of NMEA data packages numbering in the 10's of millions, however, not all the message types were necessary for this study. So the first step was a filtering procedure was to remove all message types that did not relate to dynamic or voyage related data.

5.3.2.1. Static and Voyage Related messages

A vessel database was created using the Static and Voyage Related Data to store dimensional and other static information on every vessel that had been recorded at least once by the Savona AIS receiver throughout its total operational time.

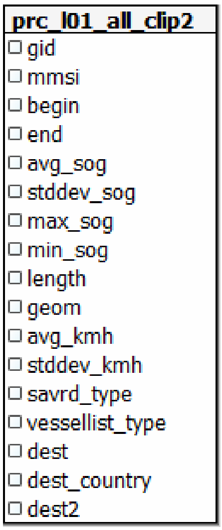


Figure 20. Static and Voyage Related Data table.

The Static and Voyage Related Data, despite being broadcast every 6 minutes to relay information about destination, was only required for the static information and thus only one record from each unique vessel (MMSI) was kept and inserted into an AIS vessel list.

From the Static and Voyage Related Data table, the AIS vessel list table has been created (Figure 21). It includes a variety of information relating to many aspects of a vessel dimensions, type, identification, class, country, behaviour and number of recorded PRCs. Not all of the AIS vessel list fields was sourced from the Static and Voyage Related Data, extra data was calculated using the dynamic PRC messages or extracted from online vessel databases.

The most important field checked was the vessel AIS ship type classification field and every vessel was cross checked using the online vessel databases information and attached photographs to ensure that each vessel ship type was correctly identified. During the cross checking it was possible to add addition data relating to each unique vessel that was present in the online databases but not in the Static and Voyage Related Data. Data relating to a vessels operational flag (country state), it gross tonnage (a vessels overall internal volume) and Dead Weight (how much weight a ship can safely carry, including cargo, passengers, fuel, ballast etc.) and any of the previous fields that were missing, ambiguous or had no data values were also added or amended using the unique identification MMSI number.

Additional fields that related to the calculated maximum and average speeds of each unique vessel was added to the AIS vessel list (Figure 21). A SQL script was written that calculated and updated the maximum and average recorded SOG from all the dynamic messages for each unique vessel to the AIS vessel list.

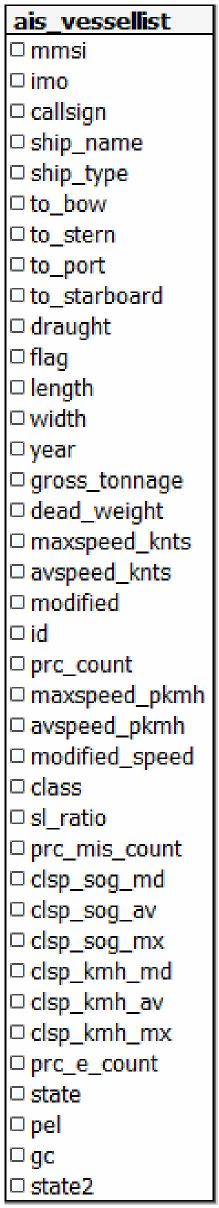


Figure 21. AIS vessel list table.

5.3.2.2. Dynamic messages

The dynamic data used to plot the ship positions was a combination of the raw type 1,2 and 3 PRCAs and the type 18 PRCB. The first step in the dynamic data preparation was to amalgamate all the recorded PRCs into one database table. Next, an addition geometry point field were added to each individual PRC using POSTGIS extension in PostgreSQL and the month and day were also extracted from the received time field (recvtime). The geometry column could then be used to calculate geometric properties between subsequent vessel geometry points, including azimuth in degrees, time in seconds, distance in meters and thus speed in kilometers per hour.

The cleaned PRCs could then be compiled into a variety of composite tables, depending on the type of vessel, temporal grouping and speed filtrations i.e. all passenger vessels for the month of May travelling over 10knts.

5.3.3. Routine to draw the tracks of shipping data

The temporal filtered composite points were used to draw the transits using a GIS platform, QuantumGIS 2.2.0 – Valmiera (QGIS). Using the "points2path" plugin, every consecutive shipping PRC point within 30 minutes, grouped by month, day and unique vessel (MMSI) was used to create a multiline string shapefile. The shapefile attributes included the MMSI number, transect start and end time and were subsequently added into the database where minimum, maximum, mean and standard deviation speed attributes were calculated. Additional data was possible to combine into the transit dataset using the Voyage Related Data. This included data relating to the destination and the presence of hazardous cargo.

Successively, shipping density was calculated using the QGIS zonal statistics batch process to calculate the kilometers of transect per grid cell per unit time and the number of transects per grid cell per unit time. As it has been written in the section *3.2. INSPIRE reference grids*, the grids used in the project were INSPIRE compliant grids from the European Environmental Agency (EEA). The grid resolution used to do the initial calculation is 1kmx1km. The number and measure of distance of shipping transects for each grid cell were then calculated using the sum line length batch process vector analysis tool in QGIS for every vessel type at every time frame. Successively, the results of the 1km grid was summed according to cell correspondences on the 5km grid.

5.3.4. Identification of shipping lanes

The shipping density 1km grid resolution of the total shipping vessel transit density for all types was used to create a shipping lane line shapefile. Current maps of shipping lanes for the Ligurian Sea on Google maps were found to not accurately represent the actual level of shipping in the area with many misplaced or omitted entirely. The line shapefile was created in QGIS by joining the centroid points of relative high shipping densities, compared with surrounding vessel densities, that followed distinct linear directions especially along known shipping lanes and between ports in the Pelagos Sanctuary. In areas where AIS reception was low and the stated methodology was found to be inadequate, due to relative low levels of shipping (i.e. the southern half of the Pelagos Sanctuary), shipping lanes were extrapolated under the assumption that vessels, in order to reduce fuel costs will always travel in the most direct straight line. A further shipping impact variable was calculated using the distance of a grid cells centroid point to the nearest shipping lane using the methods explained in full in the following paragraph.

5.3.5. Statistics

All statistical analysis was conducted in R version 3.1.0 (R Core Team, 2014). In order to test if any of the observed differences between the vessel statistics were significant a combination of a One-way Analysis of variance (ANOVA) and Kruskal Wallis test were applied to the distributions between vessel statistic. During the analysis the assumptions of the parametric tests were tested to check that the assumptions were met. A Shapiro-Wilks test was applied to the models residuals in order to test for normality, if the results indicated that the residuals were not normal the non-parametric test was applied. All results were considered significant to an alpha level of 5, i.e. probability valve <0.05.

In order to compare the level and spatial distribution differences between levels of shipping in the Pelagos Sanctuary. Mypairs function from the Highstats library was used to plot and compute the correlation coefficient between the variables. When comparing the frequencies of the number of different boats within certain extents and temporal coverage, a Chi-squared test of independence was calculated. Differences in temporal analyses was conducted using Nested ANOVA on a random sample of 10 grid cells, to avoid violating independence assumption, located within the reduced extent. In order to test the model assumptions the data was fitted to a mixed linear model with the nested factor as a random factor fitted with a REML method to obtain the model residuals for validation. If the residuals did not validate the use of response variable transformations were conducted and in one instance the mean or sum on the nested variables were used if no successful transformation could be found.

Temporal analysis and some other analyses were conducted at a reduced extent that relates to perfect AIS receiver reception. Preliminary analysis and the scientific and technical literature has shown that terrestrial AIS receiver reception is roughly restricted to 55kms line of sight. So to ensure that no bias occurs through the confounding factor of reception, comparisons on the level of shipping were conducted at a reduced extent. The reduced extent, from here on in is referred to as the Genoa Canyon as it effectively covers the entire canyon system. The reduced extent was limited to 55kms from the position of the AIS receiver and hill shade from Cape Noli and Cape Mele were taken into account (Figure 22).

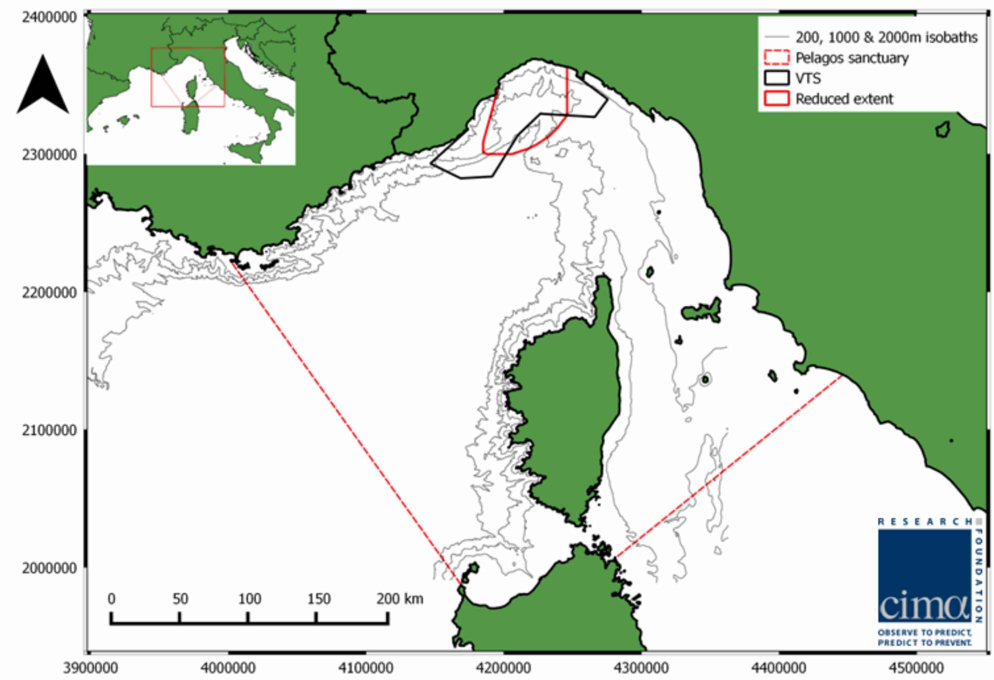


Figure 22. The reduced extent where the AIS reception is perfect displays with the Genoa VTS (Vessel Traffic Service) and the Pelagos Sanctuary. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

Due to technical difficulties with the Savona AIS receivers temporal reception a reduced temporal sub-sample of data was created. This was done in order to reduce any confounding factors that may be caused by missing data caused by the receivers reception. So as to have a robust dataset that would allow for greater number of monthly temporal comparisons. The sub-sample was created by selecting a time frame that contains the most uninterrupted temporal coverage for each month. Six days were chosen from the 23rd to the 29th of each month of 2013 and 2014 (of the 18 months with data). This allowed for a greater number of months to be compared. The temporal subset was also reduced spatially to the reduced extent.

5.4. Results about the total received AIS messages

The dataset analysed for the project is obtained with data collection of 18 months of raw AIS messages. Compared to the other studies made to describe the marine traffic, this study is unique for the following reasons.

1- Cost: AIS data are collected without direct cost. The only relative cost is for maintenance of the system (for hardware, data server and internet connection) while the other available AIS data are not free especially for long period (for instance Marine Traffic).

2- Quality of data: AIS data analysed for the project is collected in raw format and then archive. Doing so, CIMA Foundation developed its own selection of information (between the AIS raw messages), it own filtration procedures (to eliminate no data values or errors) and its own data management. It is well known (Harati-Mokhtari et al.

2007) that raw AIS data need to be verified on different levels so working on the raw data, CIMA Foundation sets the better procedure to manage the AIS data accordingly to its objectives. In the case of bought AIS dataset, it is impossible to know or change the procedures of AIS data filtration.

3- Quantity of data: This project analyses the exhaustive verified AIS data available for the 18 months; the total amount of data is very high. During this 18 months, the reception of AIS signal has been interrupted creating some minor temporal gaps into the dataset. These interruptions were due to the electricity or internet networks. However, the project analyses the complete dataset archived at CIMA Foundation during the 18 months without sub-sampling the dataset to reduce the amount of data. The few sub-sampling made, were done only to conduct statistic tests.

Starting from the 3rd of May 2013 to the 31st of October 2014, a total of 42,354,450 AIS messages were collected and parsed into the CIMA Foundation's database. The vast majority of these messages were of dynamic message types (79%). This included all dynamic information from Class A and B transponders as well as dynamic information from Search and Rescue (SAR) aircraft. After the preliminary removal of SAR PRCs and messages with longitude/latitude flagged as "not available" 31,638,514 PRCs remained (95%), displaying that only a very small proportion of the dynamic data was unusable. The Voyage and Static Related Message types were only a small proportion (5%) of all the message types and were used to collate an AIS vessel information database. A total of 5,821 unique vessels were recorded during 2013 to 2014 period.

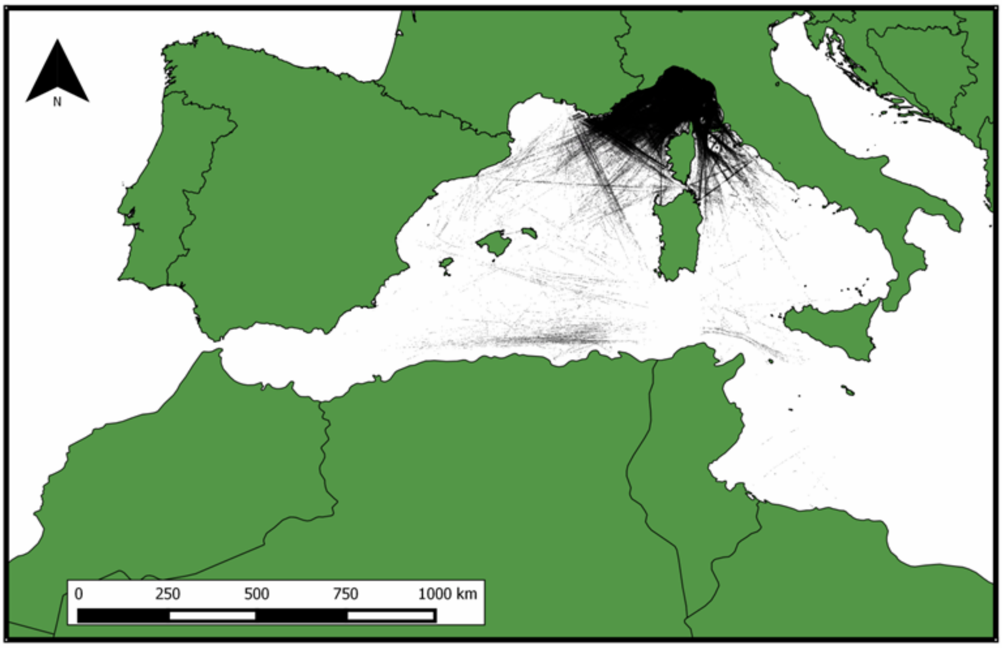


Figure 23. The distribution of the PRCs, after the cleaning procedure collected during the time frame of the CIMA Foundations AIS receiver information collection and parsing.

After the raw parsed AIS data was cleaned roughly 2/3rds of the dynamic PRCs were removed leaving 10,358,139 reliable PRCs of moving vessels with accurate positional and dynamic data from the Western Mediterranean basin at the 1knt filtration level (Figure 23). These related to 4,531 unique vessels with 88,346 transects of total length 3,849,328km with a mean of 43.6±63.1km and a median of 17.3km. The AIS receiver, due to technical difficulties was not always operational and there were a few temporal gaps.

Table 1. The temporal gaps in AIS reception with start, end and duration times for the entire temporal coverage.

Gap Start	Gap End	Gap length (hh:mm:ss)
2013-05-01 00:00:00	2013-05-03 16:16:13	64:16:13
2013-05-11 08:39:29	2013-05-11 11:11:51	2:32:22
2013-07-09 11:25:00	2013-07-18 11:50:00	216:25:00
2013-09-15 00:47:48	2013-09-15 01:48:37	1:00:49
2013-10-03 09:58:00	2013-10-19 00:57:03	374:59:03
2013-10-20 19:48:54	2013-12-17 05:04:07	1377:15:13
2014-01-09 15:40:43	2014-01-10 16:03:33	24:22:50
2014-03-14 11:10:08	2014-04-17 15:36:42	820:26:34
2014-07-08 09:38:28	2014-08-06 09:44:03	696:05:35
2014-08-06 12:52:44	2014-08-08 10:47:33	45:54:49
2014-08-09 17:42:44	2014-08-11 11:13:16	41:30:32
2014-08-14 07:50:18	2014-08-19 11:38:14	123:47:56
2014-08-29 17:42:12	2014-09-12 09:38:14	327:56:02
2014-09-13 17:53:29	2014-09-17 10:13:13	88:19:44
2014-09-17 10:18:04	2014-09-22 13:16:10	122:58:06
2014-10-10 14:04:07	2014-10-13 10:32:40	68:28:33

A gap was considered when the receiver was non-operational i.e. no data was being received for over 30 minutes. There were a total of 16 receiver temporal gaps of this classification, including the first few days of May 2013. The temporal gaps ranged from just over 1h to just over 1377h (Table 1) with a total accumulated missing reception time of just under 4400h, nearly 1/3rd of the total operational time of the AIS receiver. These temporal gaps resulted in incomplete temporal coverage for 12 of the 17 months.

5.5. Results about the analysis from the vessel list table

5.5.1. Vessel types

The created AIS vessel database has information relating to 5,821 recorded from 2013 to 2014. The following analyses and comparisons were conducted solely on the parsed AIS data within the CIMA Foundations' server. After the AIS cleaning procedure a total of 4,531 unique vessels with associated dynamic data remained, of which 4,205 were found solely in the Pelagos Sanctuary and 2,513 within the Genoa canyon extent.

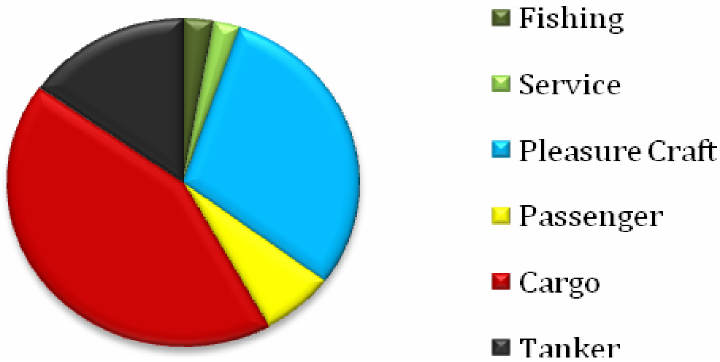


Figure 24. The types of vessels recorded within the AIS receivers operational time in the Pelagos Sanctuary.

All of the unique vessels from the cleaned dataset were classifiable to vessel type. The two most predominant vessel types were cargo (41.8%) and pleasure craft (31.8%) each contributing around one third of the total number of unique vessels. However, the combined commercial vessels (passenger, cargo and tanker) are well over half (62.9%) of the unique vessels recorded (Figure 24). Comparing the quantities by types at different scales, the proportions by types were independent between the total area and the Pelagos Sanctuary (χ^2=4.3, d.f.=5, p=0.506). However, the proportions for all types are shown to be dependent between the Pelagos Sanctuary and the Genoa canyon (χ^2=70.4, d.f.=5, p>0.001). Moreover, the proportions of only the passenger and cargo were shown to be independent (χ^2=3.0, d.f.2, p=0.226), suggesting that the Genoa canyon has a higher proportion of tankers, and lower portion of fishing, service and pleasure vessels (Table 2) compared to the rest of the Pelagos Sanctuary. Indicating that, many, if not all of the cargo and passenger craft in the Pelagos Sanctuary are entering and departing from either the port of Genoa or Savona.

Table 2. The recorded quantities and proportions of the different vessel type classifications, between the three coverage areas of this project where *Total* is the full received AIS signal without any geographical filtration, *Pelagos* corresponds to data inside the Sanctuary and *Genoa* corresponds to data within the full reception range of the antennae (reduced extent).

	Total		***Pelagos***		***Genoa***	
	Quantità	**Prop.**	Quantity	**Prop.**	Quantity	**Prop.**
Fishing	124	**2.7**	116	**2.8**	26	**1.0**
Service	111	**2.4**	105	**2.5**	35	**1.4**
Pleasure	1,361	**30.0**	1,338	**31.8**	675	**26.9**
Passenger	305	**6.7**	289	**6.9**	158	**6.3**
Cargo	1,941	**42.8**	1,759	**41.8**	1,152	**45.8**
Tanker	688	**15.2**	597	**14.2**	467	**18.6**

5.5.2. Flag states

Within the cleaned vessel database there were a total of 4,427 vessels that were classified to a state flag, and there were vessels from 93 different flag states. The top 5 countries with the most vessels under their flag were, in order Italy, Cayman Islands, Malta, United Kingdom and Panama. It is quite clear that the vessels in the total area came from a variety of flag countries but the majority are represent by only a few (Figure 25). Within the Pelagos Sanctuary, there were a total of 4,105 vessels that were classified to a countries flag and they were comprised of the flags from 90 different countries. The top 5 countries were the same as in the total area.

The classification to member state indicates that from the unique vessels in the Sanctuary the majority (74.1%) were represented by states countries outside of the Mediterranean bordering states. Vessels under the state control of one of the Pelagos states (France, Italy or Monaco) represented 19.2% of the total unique vessels in the Sanctuary. Just over half (51.6%) of the vessels recorded in the Pelagos Sanctuary were found to be navigating under a FOC. Within the Genoa Canyon 2,458 vessels were classified to a flag and related to 76 different countries.

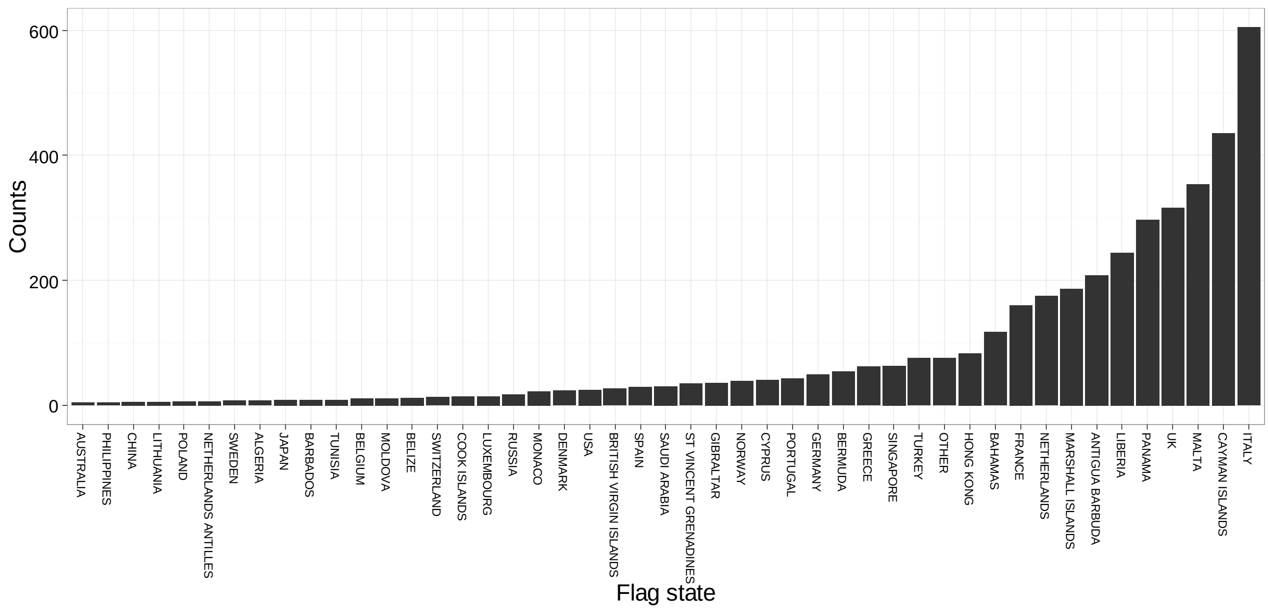


Figure 25. The frequencies of the vessel flags of the recorded vessels in 2013 and 2014 from the Pelagos Sanctuary, only countries with a frequency greater than or equal to 5 are presented here those with less have been cumulated into the class "OTHER".

The distribution of state flags is dependent on a vessels type with each vessel type displaying a distinctly different distribution (Figure 26), with trends becoming more pronounced when compared between member state groupings (Figure 27), a trend that is statistically significant (χ^2=1231, d.f.=10, p-value<0.0001).

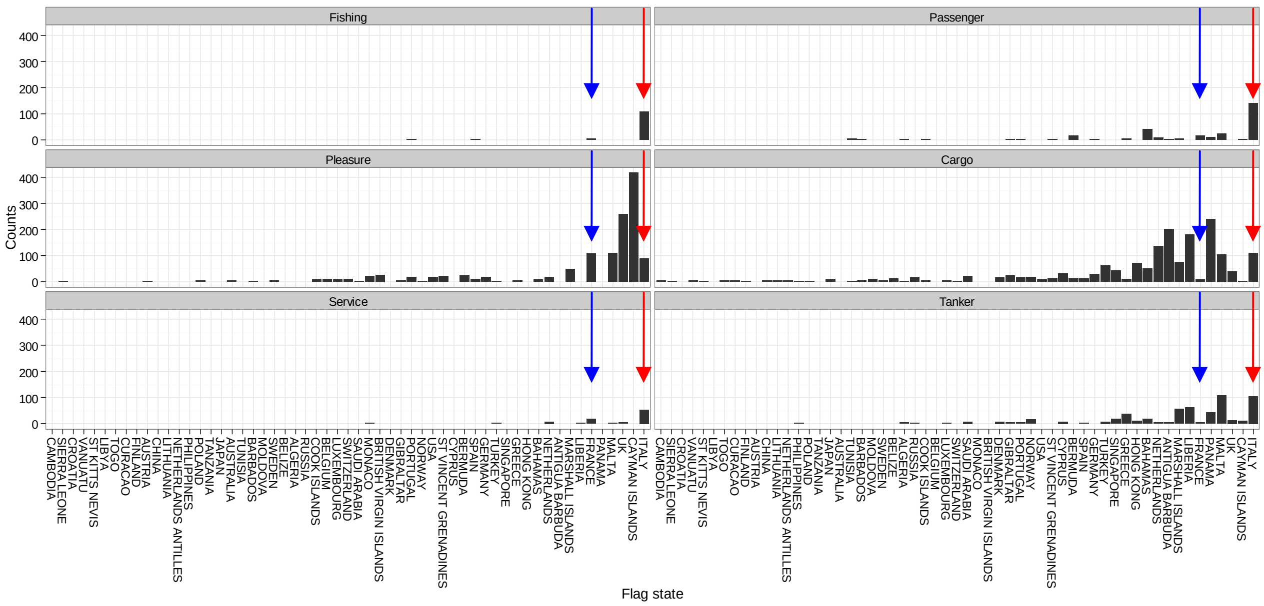


Figure 26. The country state flags divided by vessel type displaying that the different vessel classifications have significant differences on the distribution of flag states.

Moreover, one distinction is that Italy (red arrows) is not the most predominant flag state in all vessel types, despite this it is still present in reasonable proportions in all vessel type classes. The vessel types of fishing and service, that can be considered as "residential" (i.e. vessels that can be assumed to habitually be found functioning in the area) and to some extent also passenger vessels, it can be seen that Italy (red arrows) is clearly the most predominant flag state followed closely by France (blu arrows). These countries are member states of the Pelagos agreement and as such within the vessel type classification of fishing, service and passenger the flag state grouping with the most number of vessels is the Pelagos states, where other flag countries have limited numbers of vessel or are almost entirely excluded.

The other three vessel types, the commercial cargo and tanker vessels plus the pleasure crafts display a distinctly different pattern, with a high number and frequency of different flag states. A fact that is further supported by the state grouping that displays that the majority of vessels in these three classes are from non-Mediterranean states (Figure 27). The pleasure crafts display a distribution of counts that most fits the overall distribution of all vessels found in the Pelagos Sanctuary combined, not a surprising statement as being the most frequently recorded vessel type in the area it is most likely to affect the overall distribution.

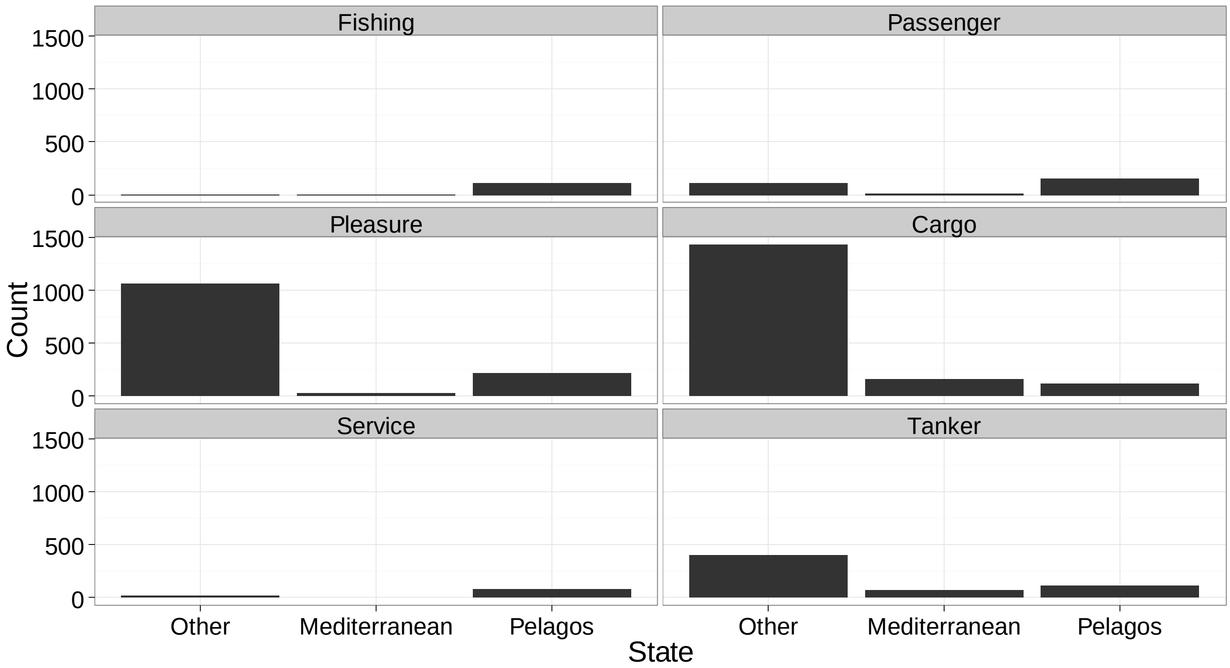


Figure 27. The quantities of boats per member state group as a function of vessel type recorded within the Pelagos Sanctuary.

The frequency of the different states is dependent on the scale (χ^2=27.4, d.f.=2, p-value<0.001). Genoa canyon has a lower proportion of Pelagos member state vessels and higher EU and other states when compared to the entire Pelagos Sanctuary (Table 3). There was no difference in frequencies of member states between the total recorded area and the Pelagos Sanctuary (χ^2=0.4, d.f.=2, p-value=0.8).

Table 3. The frequency and proportion of the different states between the Genoa canyon and Pelagos Sanctuary.

	Pelagos		**Genoa**	
	Quantity	**Prop.**	Quantity	**Prop.**
EU	1,197	29.2	746	30.4
OTHER	2,119	51.6	1,363	55.4
PELAGOS	789	19.2	349	14.2

5.5.2. Destination countries

The number of destination ports recorded were 361 with a destination to 61 different countries (Table 4). All Mediterranean countries were represented except Bosnia (and perhaps Palestine) and were amongst the most frequented destination countries.

Table 4. Top 22 destination countries with the proportion of transits by vessel type. The proportions in bold are the vessel type class with the highest proportion for that destination country.

Destination Country	Fishing	Pleasure	Service	Passenger	Cargo	Tanker	Total
ISRAEL	0.000	0.000	0.000	0.000	**0.909**	0.091	11
MONTENEGRO	0.000	**0.750**	0.000	0.000	0.250	0.000	12
UKRAINE	0.000	0.000	0.000	0.000	**0.750**	0.250	12
NETHERLANDS	0.000	0.053	0.263	0.000	0.211	**0.474**	19
DOMINICAN REBUBLIC	0.000	0.000	0.000	0.000	**1.000**	0.000	21
RUSSIA	0.000	0.000	0.103	0.000	0.034	**0.862**	29
USA	0.000	0.273	0.000	0.000	**0.485**	0.242	33
PORTUGAL	0.000	0.000	0.000	0.000	**0.842**	0.158	38
UK	0.000	0.014	0.000	0.000	**0.971**	0.014	69
MOROCCO	0.000	0.000	0.000	0.014	**0.986**	0.000	71
MALTA	0.000	0.074	0.000	0.025	0.284	**0.617**	81
GIBRALTAR	0.000	0.156	0.000	0.055	**0.606**	0.183	109
ALGERIA	0.000	0.000	0.000	0.016	**0.637**	0.347	124
TURKEY	0.000	0.025	0.019	0.013	**0.742**	0.201	159
LIBYA	0.000	0.000	0.000	0.000	**0.889**	0.111	171
GREECE	0.000	0.029	0.000	0.185	**0.682**	0.104	173
EGYPT	0.000	0.000	0.000	0.000	**0.913**	0.087	312
TUNISIA	0.000	0.028	0.003	**0.593**	0.308	0.068	354
MONACO	0.000	0.814*	0.002	0.184	0.000	0.000	451
SPAIN	0.000	0.026	0.000	0.162	0.688*	0.124	1475
FRANCE	0.000	0.212	0.002	0.496*	0.240	0.049	3358
ITALY	0.007	0.058	0.079	0.280	0.411*	0.166	21811

The three Pelagos member states and Spain were the most frequented countries, Italy disproportionately so, probably due to the frequent Passenger vessels.

5.5.3. Vessel ages

Within the cleaned vessel database there was a total of 3,349 vessels that had information relating to the year in which they were built. Of these vessels the build date of vessels ranged from 1896 to 2014 with a modal value of 2008 (Figure 28). Within the extent of the Pelagos Sanctuary, there was 3,069 vessels classified to year with the same range and mode as the total extent.

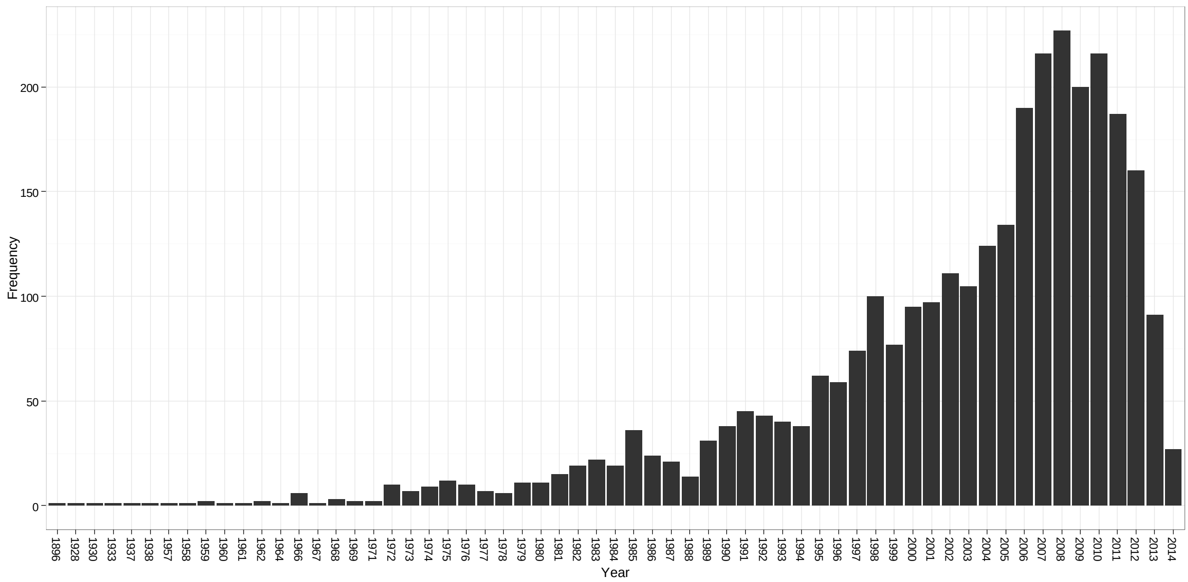


Figure 28. The quantities of boats per age, as year built of the recorded vessels in the Pelagos Sanctuary.

The majority of the all the vessels in the Pelagos Sanctuary appears to have been built in the last 15 years (2000+). This trend is most apparent in the tankers, despite having a lower modal age (2008) compared with cargo (2010), the majority of tankers (89.8%) were built in the last 15 years, compared to 59.0% and 68.9% for passenger and cargo respectively (Figure 29). However, the passenger and cargo vessels have a reasonably large frequency of older vessels. Passengers and service vessels have respective modes of 2001 and 2005 but a more uniform distribution of age when compared with the other vessels.

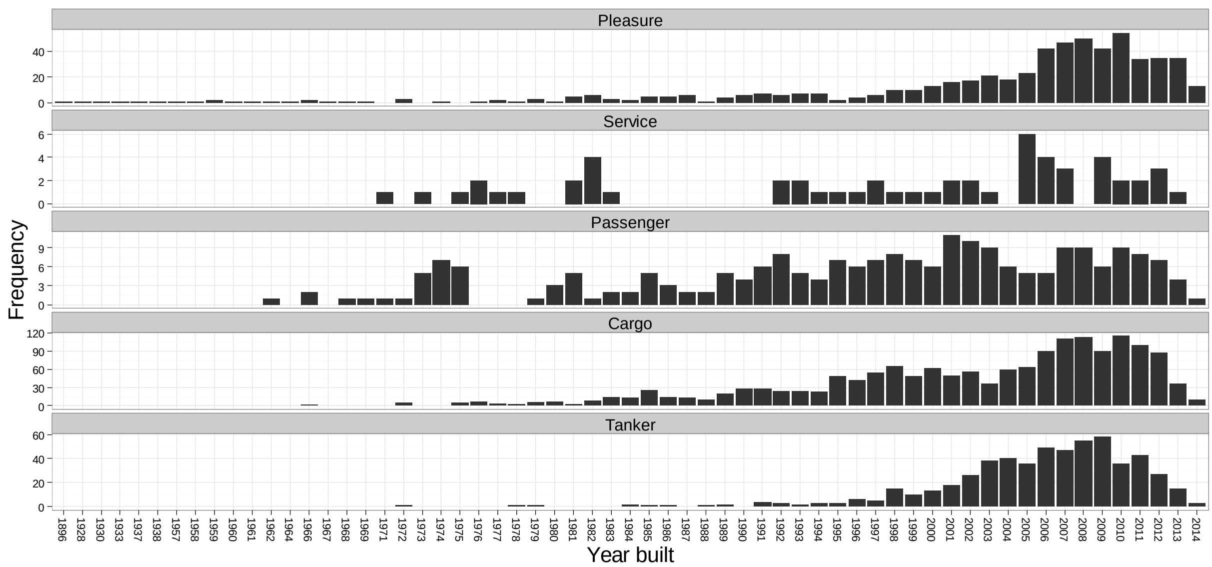


Figure 29. The quantities of boats per age, as year built of the recorded vessels in the Pelagos Sanctuary, separated into vessel types (excluding fishing vessel types, due to very limited data).

A chi squared goodness of fit indicates that both have a continuous probability distribution (□2=41.7, d.f.=44, p-value=0.6 and □2=22.7, d.f.=28, p-value=0.7). So generally pleasure, cargo and tanker vessels have a higher proportion of younger vessels, highlighted by a later build year skew. However, pleasure crafts have the largest range of ages with a long tail.

5.5.4. Vessel dimensions

There were a total of 4,375 vessels in the cleaned vessel data base that had reliable records of length and width. 3,362, 3,435 and 3,168 had reliable data relating to maximum draft, Gross Tonnage and Dead Weight respectively. The largest vessel recorded outside of the Pelagos Sanctuary was 397m in length and 57m wide. Within the extent of the Pelagos Sanctuary there were 4,063 vessels with reliable length and width records, 3,317 with reliable draught, 3,155 with Gross Tonnage and 2,894 with Dead Weight. Draught was excluded from the comparisons as it would, especially for the commercial vessels change between voyages and as such the current vessel database information is not adequate enough for comparisons.

There is a clear differentiation between a vessels dimension and its vessel type classification. The commercial vessel types of passenger, cargo and tanker are obviously larger in every dimension compared with the fishing, service and pleasure vessels. Moreover, there also exists differences between the commercial vessels themselves. On average cargo vessels are larger in dimension than the other commercial vessels in the Pelagos Sanctuary. However, by Gross Tonnage, passenger vessels carry more weight and tankers are heavier, all found to be significant at α=5. It is also apparent that each vessel type has a vide varieties of sizes, weight loading and weight (Figure 30).

Table 5. Information about all the vessels recorded in the Pelagos Sanctuary separated into vessel type classifications.

Type	**Length**		**Width**	
	mean ± s.d.	maximum	mean ± s.d.	maximum
Fishing	21.22 ± 05.67	50	5.36 ± 1.10	10
Pleasure	40.05 ± 21.14	200	8.21 ± 3.57	56
Service	37.02 ± 33.43	288	10.19 ± 6.03	48
Passenger	155.70 ± 92.66	339	22.38 ± 11.35	50
Cargo	174.06 ± 73.80	367	25.02 ± 9.45	74
Tanker	170.70 ± 58.68	334	28.32 ± 10.98	58

Type	**Gross Tonnage**		**Dead Weight**	
	mean ± s.d.	maximum	mean ± s.d.	maximum
Fishing	279 ± 129	388	45 ± 79	136
Pleasure	944 ± 2,588	60,131	208 ± 832	18,507
Service	2,908 ± 15,282	117,916	2,197 ± 9,924	73,736
Passenger	41,380 ± 38,538	155,873	5,139 ±3,680	15,000
Cargo	27,416 ± 28,954	153,115	29,858 ± 32,224	204,112
Tanker	28,100 ± 26,852	177,112	48,434 ± 50,018	309,498

When looking at the density distribution of the vessel frequencies by length, it is clear that the different vessels have different size distributions. Only information from length has been used in the comparisons between types as not surprisingly the length and width are highly correlated (r=0.957). For instance, the fishing vessels are all under 50m in length, where pleasure and service are predominantly under 100m in length. Cargo and tanker vessels tend to be between 90 to 200m in length with some much larger vessels being found, particularly in the 250 and 270m classes of tanker (Figure 30). Passenger has the widest distribution of vessel lengths, with a modal groupings between 30–50m and 170–240m length. Kruskal wallis tests found the length of all vessel groupings to be significantly different except for cargo vs tankers and tankers vs passengers.

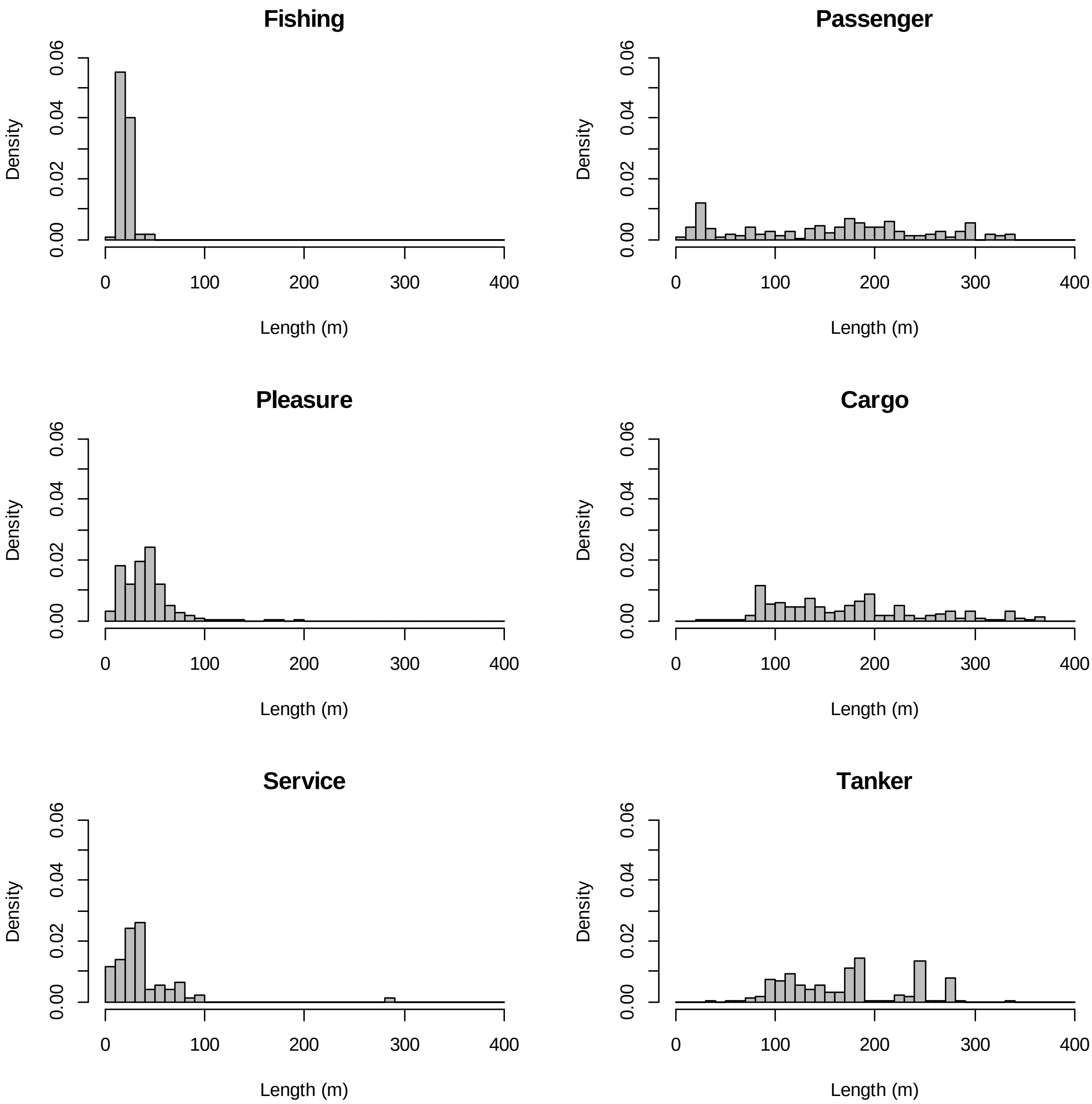


Figure 30. The vessel length dimensions according to vessel classifications.

5.5.6. Vessel speeds

For speed comparisons, it was decided to use the geometrically calculated speeds as these were deemed to be more reliable. The average speed was chosen for comparison as the modal and maximum speeds were both found to be highly correlated with an r values of r=0.908 and r = 0.848 respectively to the average speed. There is a clear difference between the speeds of the three commercial vessel types and the non-commercial vessels. Firstly the commercial vessel speeds are normally distributed (Figure 31), where the others are not.

The distributions clearly display that the mean speeds of the commercial vessels is highest in passenger and lowest in tanker with cargo in the middle (Figure 31), a difference that is statistically significant (F=168, d.f.=2, P-value<0.001) with a post Hoc Tukey HSD test displaying that cargo vessels are 4.3km and tankers are 6.8km on average slower than passenger vessels. Fishing and service vessels are much slower than commercial vessels with respective modal speeds of 6 and 9km/h. Fishing vessel speeds were found to be significantly slower than service (χ^2=6.0, d.f.=1, p-value=0.01). Pleasure vessels displayed a bimodal speed distribution with 4 and 22km/h modes, most likely caused by the grouping of the sailing and motor vessels into one category.

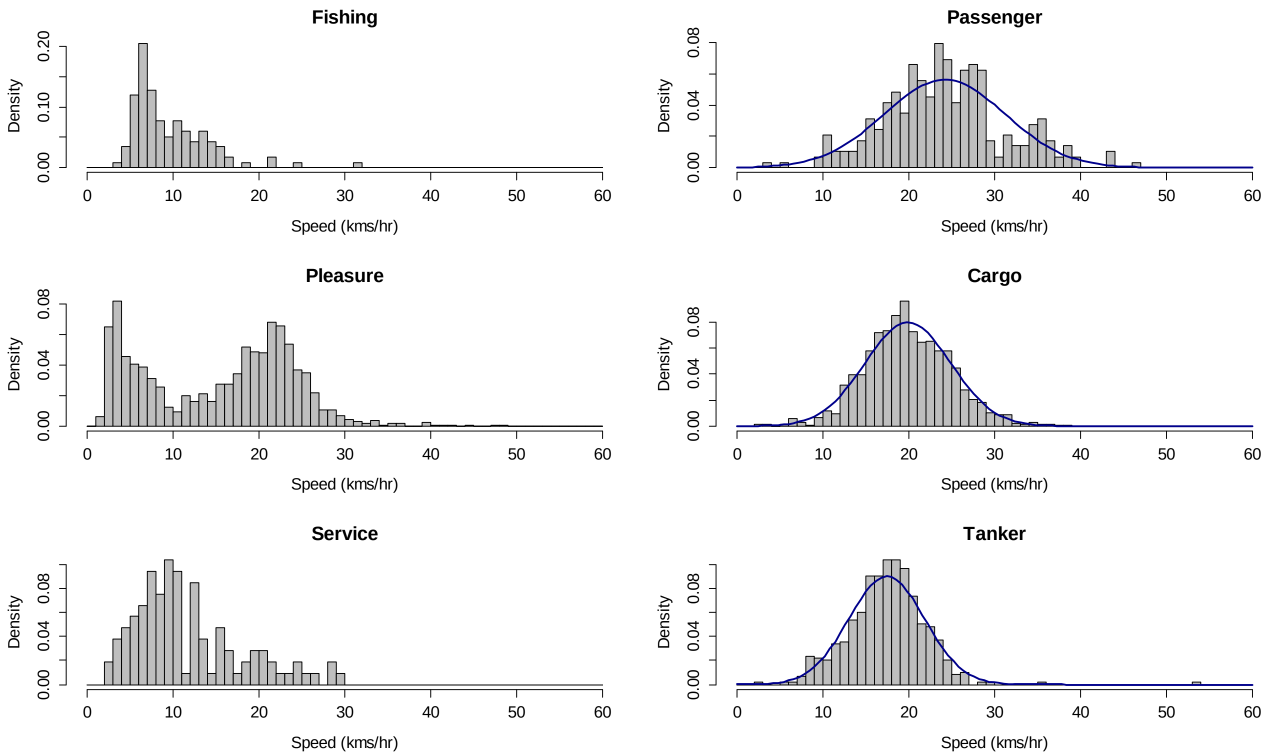


Figure 31. The modal calculated speed density distribution of the different vessel types within the Pelagos sanctuary. Density distribution with normal distributions have an added normal distribution line.

So in conclusion it can be seen that the number, type, size and speeds of vessels recorded within the Pelagos Sanctuary vary considerably. Most of these results are dependent to the vessel type grouping.

5.6. Results about the analysis about the transits

5.6.1. Number of transits per vessel type

The first step in calculating the amount of shipping in the Pelagos Sanctuary was successfully applied to create individual shipping transits for each unique vessel from the dynamic AIS data.

The filtration procedure worked well as shown by the preliminary results to keep all transits but successfully removing all erroneous points and moored or stationary vessels. A total of 88,346 transits were created with a combined length of 3,849,328km. However, only 82,831 of these transits were located in the Pelagos Sanctuary in its entirety. When the number of transits were divided into the vessel type classifications, it appears that cargo and passenger vessels are now the most prevalent vessel types in the Sanctuary (with respectively 26% and 30%, Figure 32).

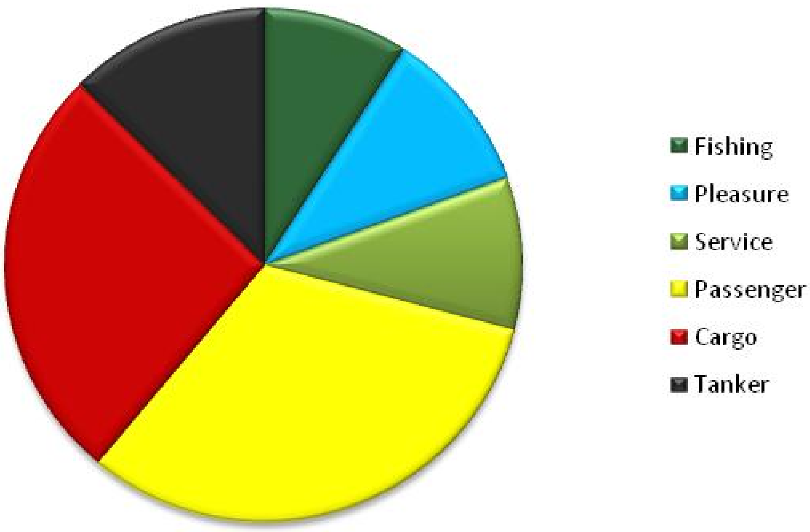


Figure 32. The percentage of all transits per vessel type, the summation of the transits of each unique vessel into type.

However, when comparing the mean number of transits of the unique vessels divided into type, it becomes apparent that although cargo has a large number of transiting vessels, each unique vessel transits on average far less frequently than passenger. In this respect, it can be seen that each unique fishing, service and passenger crafts transit the area more frequently (Figure 33).

Tanker, cargo and pleasure vessels tend towards fewer number of transits for each unique vessel. Moreover, within the unique vessels that had more than 200 transits recorded, 40 were passenger, 9 service, 6 tanker, 5 cargo and one fishing.

The number of transits made by each vessel is not evenly distributed between the vessel types. Particularly passenger, but also fishing and to some extent service clearly have more vessels that are transiting the Pelagos Sanctuary on multiple occasions.

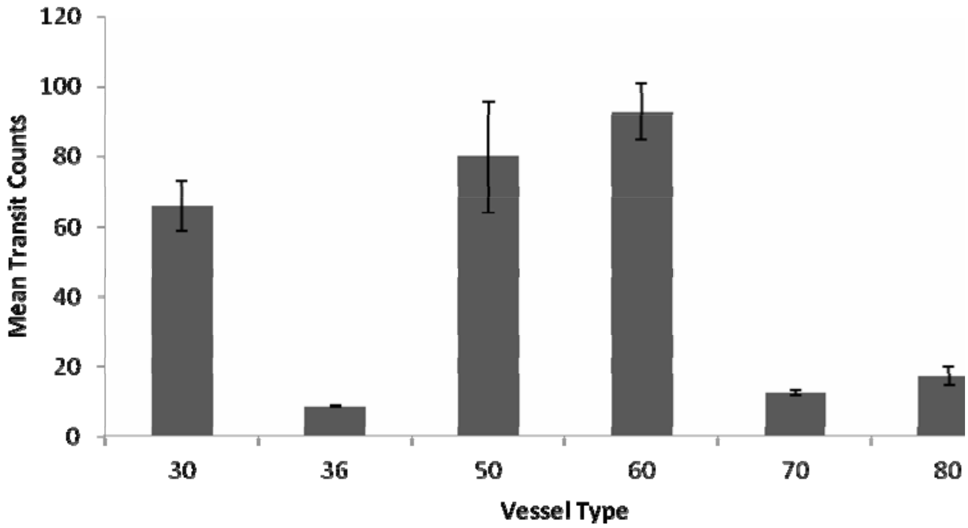


Figure 33. The mean number of transits per unique vessel type into the Pelagos sanctuary. Standard error bars area shown and the type categories are fishing (30), pleasure (36), service (50), passenger (60), cargo (70) and tanker (80).

5.6.2. Transit flags

Comparing the transit flags to vessel flags from the list of unique vessel, it is possible to highlight that the total number of transits of vessels operating under a FOC is now only 24.9% and vessels operating under a Pelagos state flag are now the majority with 60.2% of all transits. The difference stands most likely by the large number of Italian passenger crafts with many multiple navigations per day, compared with the other state flag operating cargo vessels.

5.6.3. Transit speeds

The transit speeds (the transit speed is the average speed recorded along the transit and differs to vessel speed that is the instantaneous speed of a vessel, calculated at each position) of different vessel types belong to distinct speed distributions (Figure 34). Distributions that are significantly different (F=12,621, d.f=5, p-value>0.0001) between types and post hoc Tukey HSD test indicates that the difference is significant between all types. Transits speeds in order of descending looks to be passenger, cargo, pleasure, tanker, service and fishing.

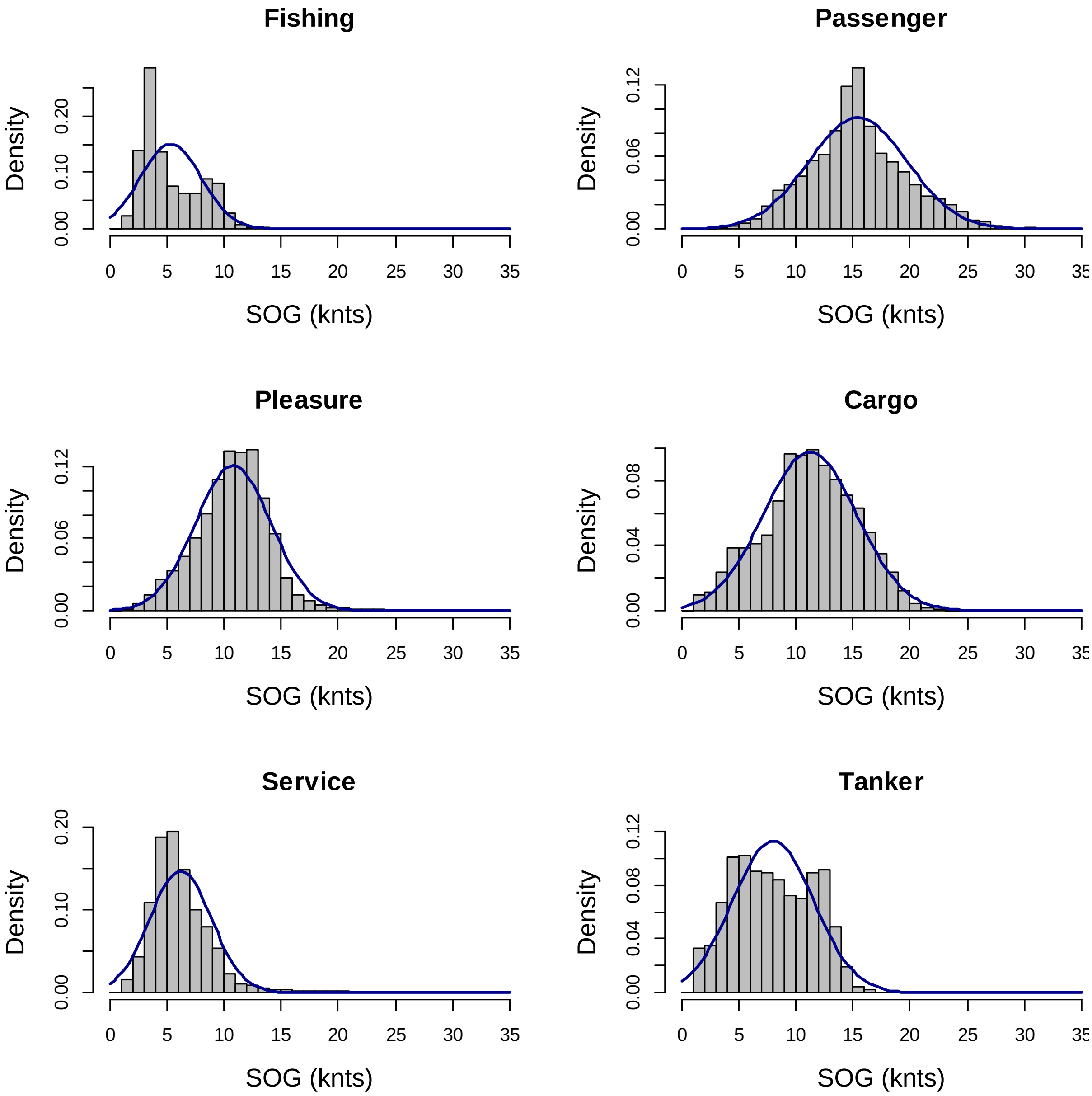


Figure 34. The distribution of the mean speed (calculated SOG using the dynamic data) of the vessel transits by type. All showing a very normal distribution and clear distributional differences.

5.6.4. Polygon composites of the total amount of shipping

Within the Pelagos Sanctuary, a total of 3,757,587km of shipping traffic of all types (passenger, cargo, tanker, pleasure, fishing and service vessels) of 82,831 transits were calculated from the PRCs collected by the Savona AIS receiver. However, this number is merely an indication to the shipping level and is seriously under biased, due to:

- pleasure crafts and fishing vessels under 300GT not obligated to be fitted with AIS transponders,
- the problems associated with receiver reception beyond a given distance,

- the temporal gaps.

The cell of 1km resolution with the highest recorded kilometers of shipping transects was 12,100km and located near the port of Genoa. The spatial distribution of which is not uniform (Figure 35) with obvious areas of high and low shipping, many of which displayed clearly visible routes or shipping lane passages.

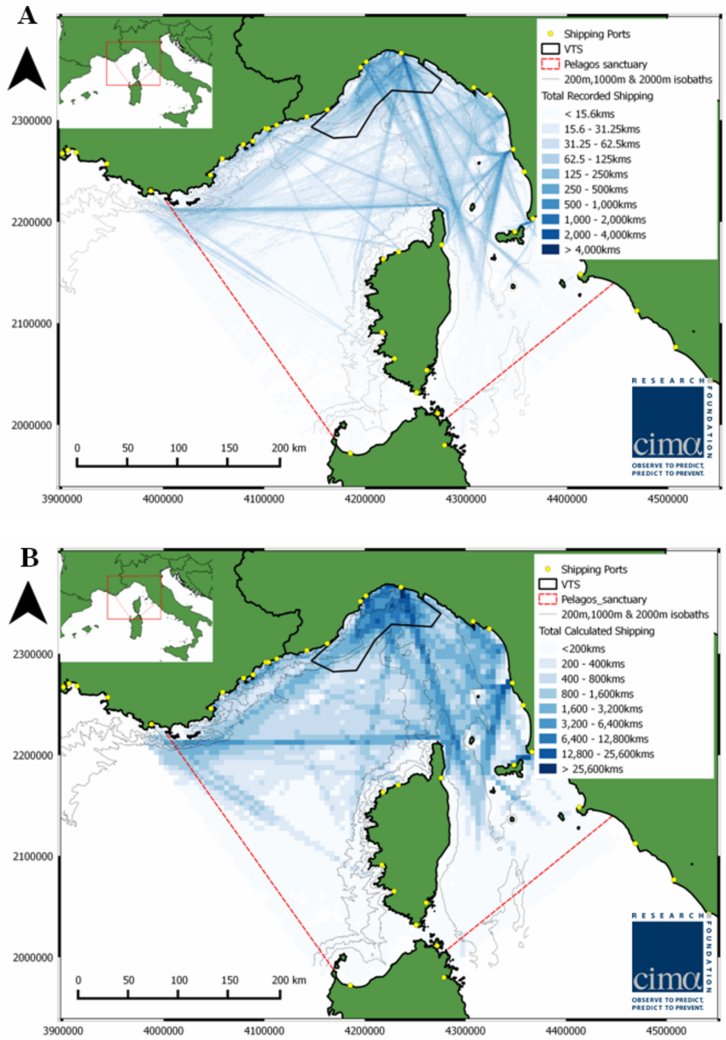


Figure 35. The spatial distribution of the total combined shipping in the Pelagos Sanctuary recorded by the Savona AIS receiver as the total of kilometres of shipping transits within the 1km (A) and 5km grid cells (B). Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

5.6.5. Shipping lanes from the total amount of shipping

The shipping lanes in the Pelagos Sanctuary were successfully created using the methodology described in section 5.3.4. Identification of shipping lanes). A total of 7385km of shipping lanes were found to exist in the Pelagos Sanctuary (Figure 36), even though this may be an underestimation. No record for the number of shipping routes can be stated, as many merge into one and shared the same localities and thus could not be reliably classified as individual lanes. For this reason, naming of routes (i.e. departure and destination port) was not possible.

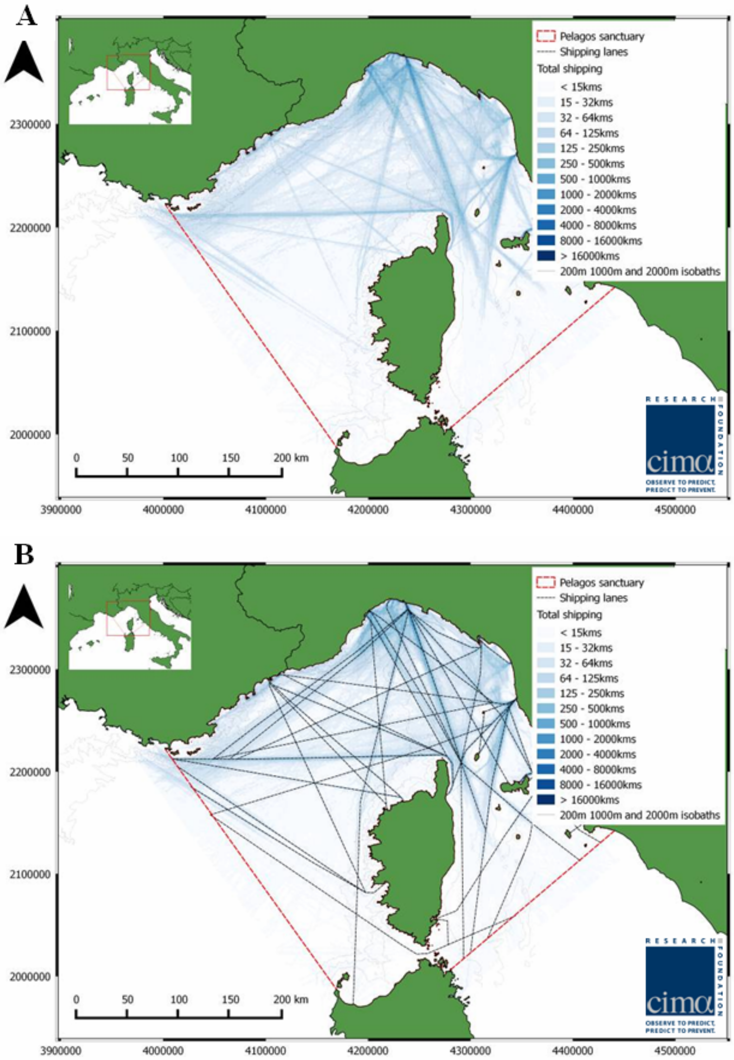


Figure 36. The shipping lanes (B) created using the 1km grid of the total shipping density (A) collected during the Savona AIS receiver. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

Within the Pelagos Sanctuary, the ship lanes crisscrossed the entire area and the maximum possible distance from a shipping lane is 50km (Figure 37). The mean distance from a shipping lane was 7km and over 2/3rds (68.2%) of the entire Sanctuary was within this distance from a created shipping lane. The percentage of the whole area that was even closer to a shipping lane was also very high with 47.5% and 14.4% within 5km and 1km respectively.

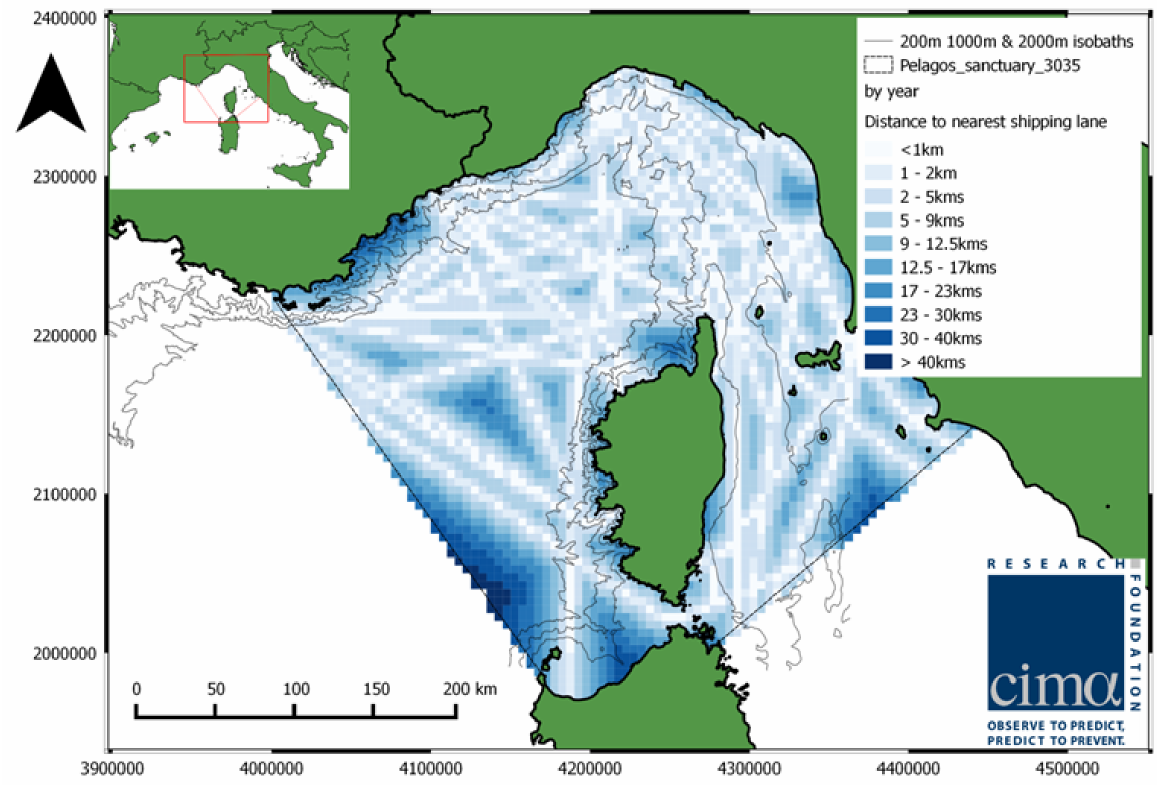


Figure 37. The distance of each 5km grid cell to the closest shipping lane, calculated using geometry ST_distance in PGadmin and displayed in kilometres. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

5.6.6. Total amount of shipping by vessel classification type

5.6.6.1. Maps of the total amount of shipping by vessel classification type

The maps of the total amount of shipping by vessel classification type highlight the differences of shipping density for each type. The cargo, passenger and tanker vessels are clearly the shipping vessel that impact more on the environment (Figure 38).

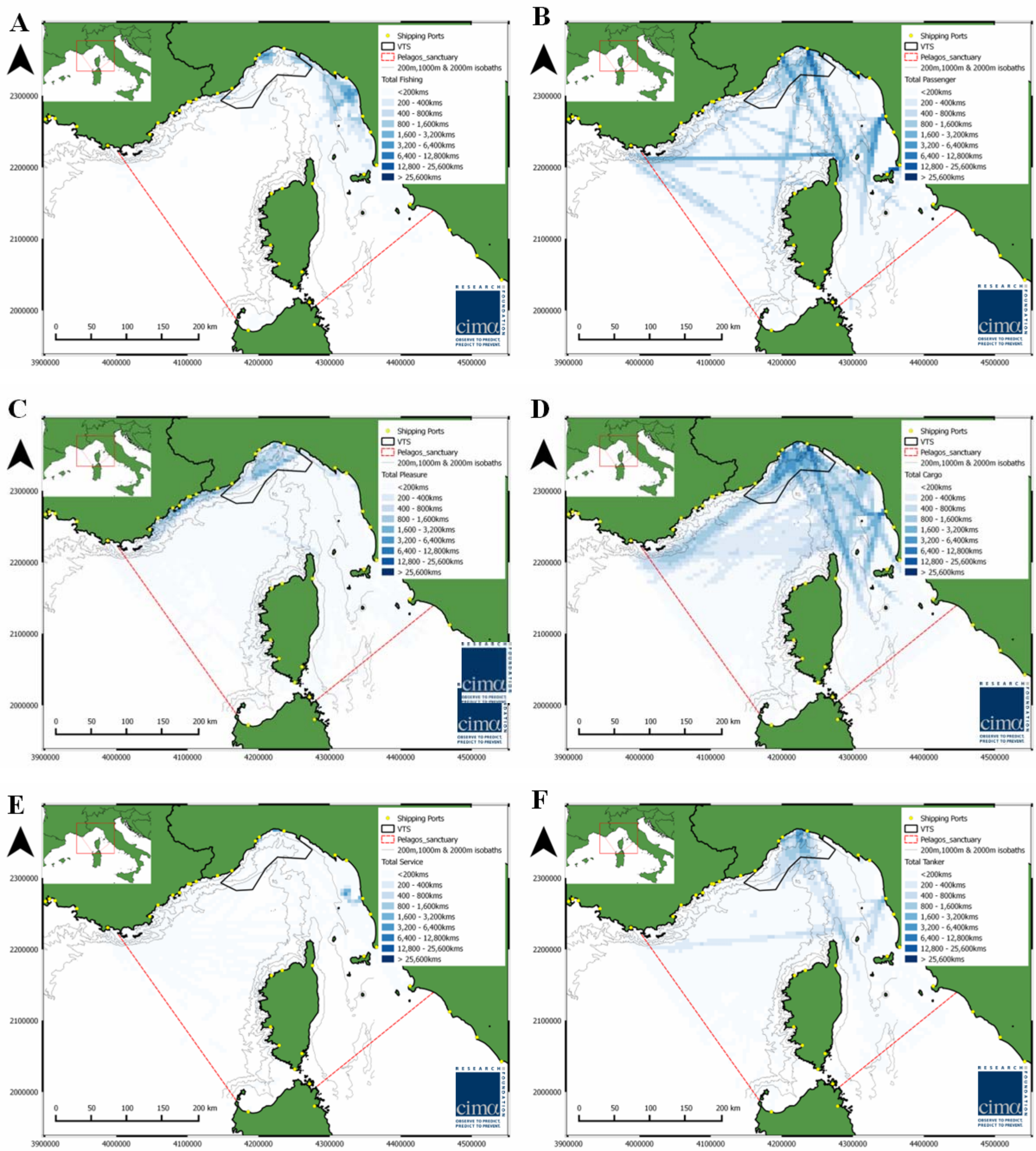


Figure 38. The spatial distribution of the level of shipping by type of vessel (A) fishing, (B) passenger, (C) pleasure crafts (sailing vessels and motor yachts), (D) cargo, (E) service crafts and (F) tanker. All maps are presented in ESPG:3035 and displayed at the same scale for comparison.

5.6.6.2. Statistical analysis to compare the total amount of shipping by type

Given the literature and the findings, for statistical analysis, it was decided to work at a reduced extent and on 1km grid resolution to reduce the down bias caused by receiver reception (5.3.5. Statistics). The reduced extent is an area that is located around the ports of Savona and Genoa and covers an area of 3,106.891km^2. It equates to 3.5% of the entire Pelagos Sanctuary.

Table 6. Total level of shipping by vessel type from all the AIS data collected within the Pelagos Sanctuary (A) and within the reduced extent of the Genoa canyon (B), calculated from 1km resolution.

A.

Vessel Type	total km	maximum	mean	sd	median
Fishing	212,858	920	2.0	14.5	0.0
Pleasure	289,006	527	2.8	12.2	0.0
Service	73,716	3,202	0.7	20.8	0.0
Passenger	1,385,361	6,363	13.5	65.6	1.6
Cargo	1,427,618	4,773	13.9	53.0	2.0
Tanker	369,026	1,741	3.6	17.5	0.0
Total	**3,757,587**	**12,100**	**36.7**	**133.3**	**7.422**

B.

Vessel Type	total km	maximum	mean	Sd
Fishing	32,472	920	10.1	40.3
Pleasure	80,933	386	25.3	31.6
Service	31,390	3,202	9.8	108.6
Passenger	295,199	6,363	92.2	265.5
Cargo	412,878	4,773	129.0	231.8
Tanker	136,284	1,741	42.6	83.4
Total	**989,156**	**12,100**	**309.0**	**570.8**

Comparisons were made of the level of shipping in the Genoa canyon between the different AIS vessel type classifications. There is a clear indication (Figure 38 and Table 6) that the spatial distribution and level of shipping is different for the separate vessel classifications. The commercial vessel types (passenger, cargo and tanker) have a distinctly higher level of total vessel traffic in the area compared with the service, pleasure and fishing (Table 6). It is these vessel types particularly cargo and passenger that are most responsible for the total shipping level (Figure 39). However, a comparison between these types indicates that the passenger and cargo vessel traffic is similar in level and distribution (Figure 39), despite passenger vessels appearing to be more spatially localized than cargo (Figure 38). Moreover, the shipping routes that these two vessel types frequent (10 in total) are superficially the same, except for the cargo taking the three routes departing from Genoa Pra and the passenger taking the Genoa–Corsica route. Tanker vessels appear to predominantly use the 3 particular shipping routes departing from Genoa Pra over the others. There also seems to be quite a distinct transit for tankers between the ports of Genoa and Savona (Figure 38).

The predominant transit of pleasure crafts in the area is a South eastern-North western transit from and to the western Mediterranean to the touristic port of Portofino. However, there also exists transits into and out of the port of Genoa, but not to such a high degree.

Fishing vessels in the area seem to be localised around the South East of Savona between the 1,000m isobaths and the coast (Table 6 and Figure 38). Service vessels are even more extremely localized, high mean and high total recorded kilometers (Table 6) around the ports of Genoa and Savona.

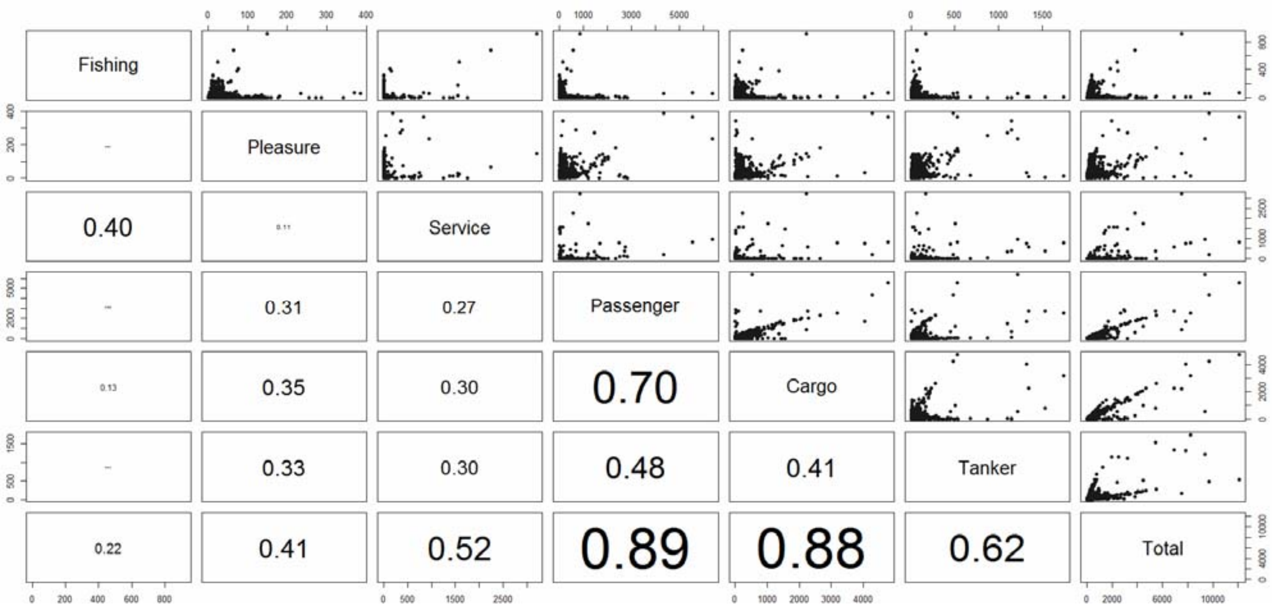


Figure 39. The spatial distribution correlation by type of vessel within the Genoa Canyon using Mypairs from the highstats library, displaying that the cargo and passenger crafts follow the same spatial distribution and are the two vessel types that explain most the overall shipping distribution. The other types utilise the area differently.

5.6.6.3. Vessel with hazardous materials

From the 82,831 transits, 33,367 could be classified to type by using the Voyage Related Data methodology. However, of the transits classified, 2,278 were classified as unknown and 60 had nonsense classifications, leaving only 31,029 transits with reliably type classifications. Roughly around one third of the cargo and tanker transits of known class were found to be carrying hazardous materials; passenger vessels on the other hand had very few transits classified as hazardous (Figure 40).

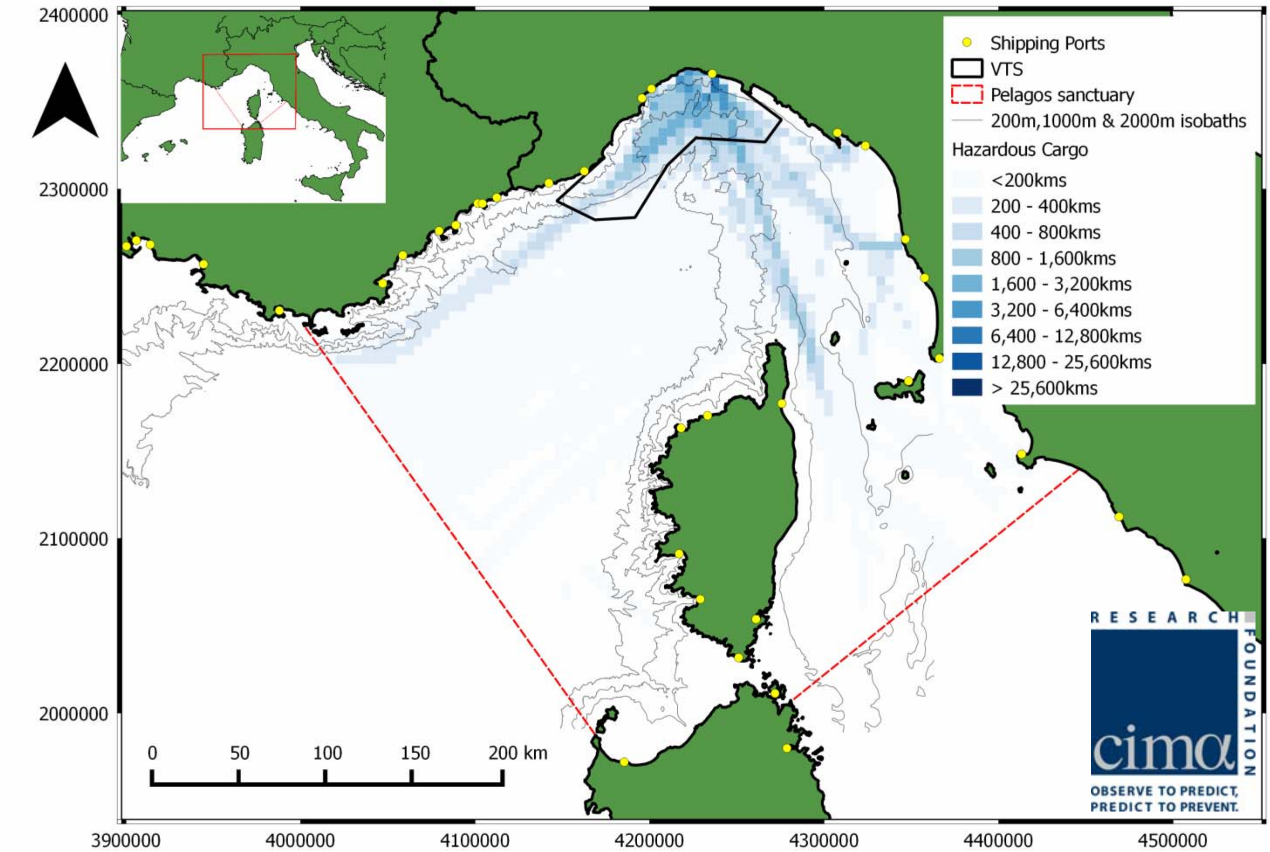


Figure 40. The spatial distribution of the combined vessel transits recorded to carrying hazardous materials, as the kilometres of transits in 5km grid cells. Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

5.6.6.4.Total shipping stratified by speed

A speed filtering procedure was applied to understand the spatial distribution of the faster travelling vessels transiting the Pelagos Sanctuary. Once the filtration speed procedure was done, the transits were drawn again in order to describe the total amount of shipping. Speed is an important factor when considering both risk and potential injury caused by vessel during vessel-whale collisions and also in relation to vessels emitted underwater noise pollution. There is also an IWC document stating that knowledge of shipping stratified by speed is important (IWC, 2011).

The results display in Figure 41 indicate the spatial distribution of shipping according to the four classes of speed filtration. For the first two levels, the shipping distributions look similar but for the other tow higher levels, it appears that the shipping is more localised and becomes along the shipping lanes (Figure 41). The main lanes with the higher speed level (more than 20knt) are two lanes from Genoa going southwards, a horizontal lane passing just at North of Corsica, the lane from Nice going on the Eastern part of Corsica and the lane from Leghorn going Southward and passing on the West of Elba Island.

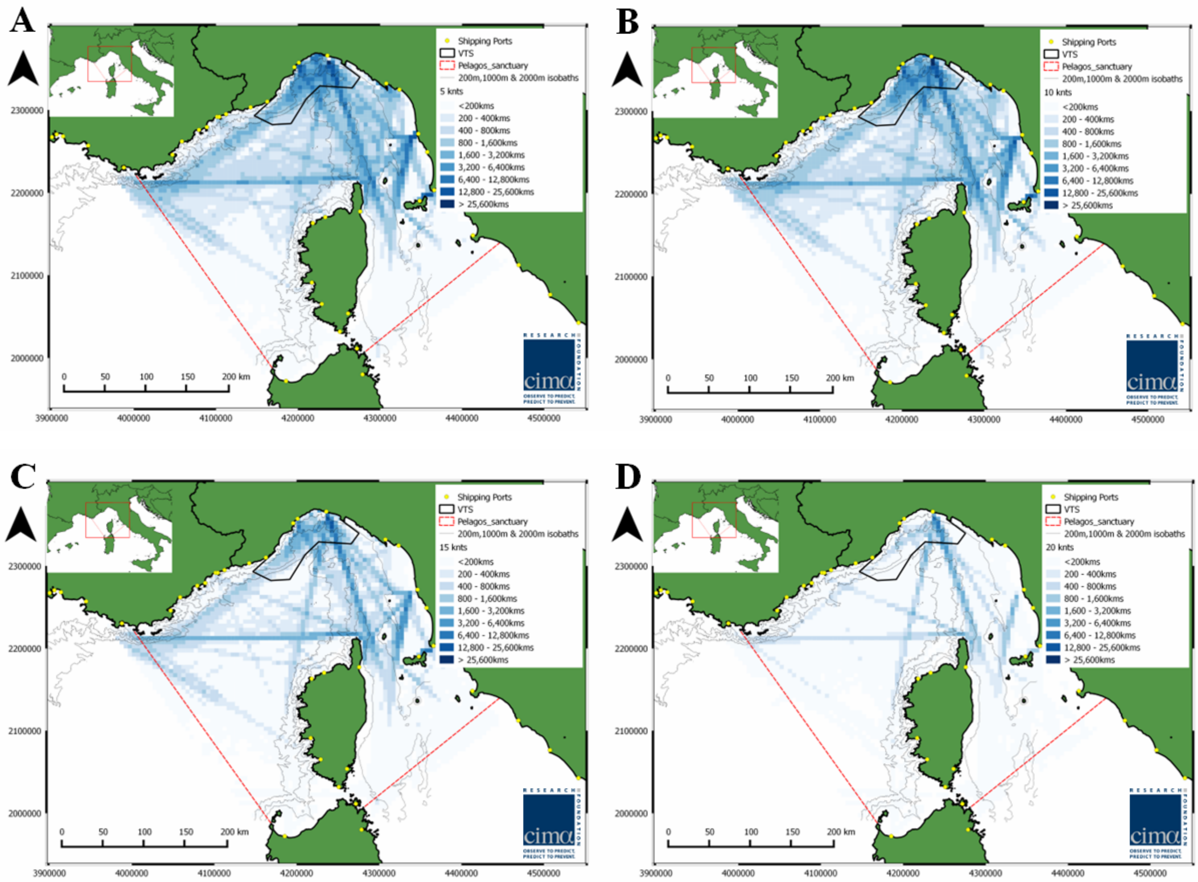


Figure 41. The four speed filtered maps as 5 (A), 10 (B), 15 (C) and 20kn (D). Map presented in a ETRS89 Lambert Azimuthal Equal Area (EPSG: 3035).

Before any speed filtration, the total number of vessel was 2455. The Figure 42 states that most of the vessels travel at less than 15 knots. Moreover, the filtration seems to affects evenly all types of vessels at less than 15 knots.

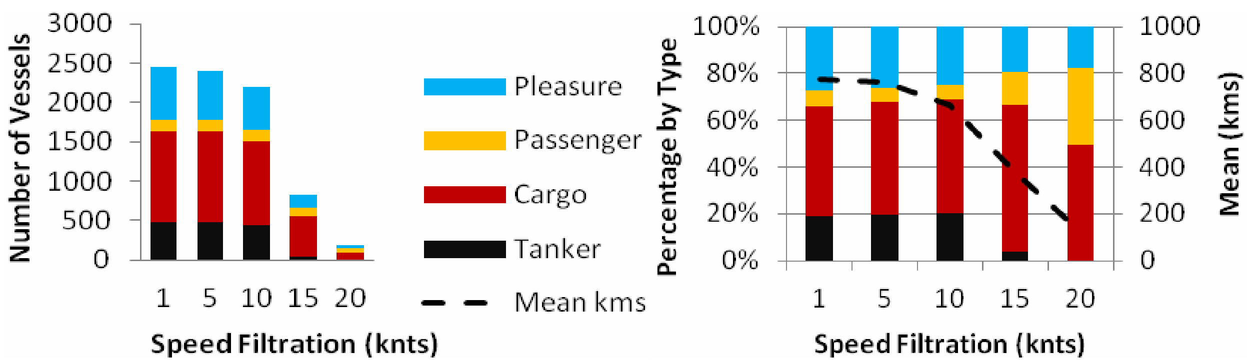


Figure 42. The number of vessels by type and the percentage of vessels by type for each level of speed filtration.

Looking at the results of the filtration over 15 knots, there are not much vessel travelling at fast speed: 821 vessels travel at more than 15knt and 176 travel at more than 20knt. The percentage of type clearly demonstrates that passenger and cargo vessels are the fast vessels.

5.6.6.5.Temporal variations of shipping

Comparing the 4 months with the complete data from both years on the temporal subset (from 23rd to the 29th), the inter-annual trend appears to be similar (Figure 43). However, May and June appear to resemble each other very closely and August and September are lower but appear to follow the same seasonal pattern. No significant difference was found between the years using an ANOVA with a nested factor of month (F=0.091, d.f.=1, p-value=0.764) tested on a subsample from the 5km grid at the reduced extent and with a 6 day sub sample.

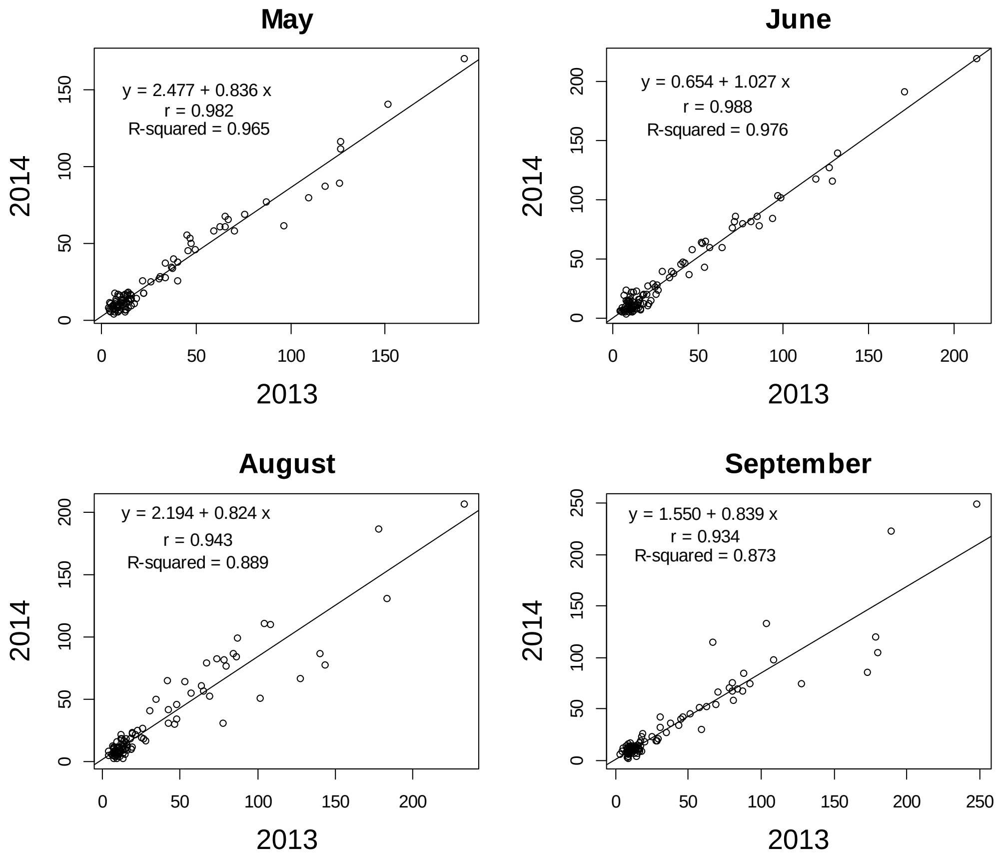


Figure 43. The spatial autocorrelation between the four available months from both years.

To display the variation of shipping by type of vessel during a year, it has been assumed that there was no significant difference between the two years of study (see results of Figure 43). The monthly total sum of kilometers for each vessel type classification have been calculated on the reduced extent and only for months without time gaps (on the temporal subset). In case of double sampling (both in 2013 and 2014), the value is the average obtained for the 2 years.

The Figure 44 displays how cargo and passenger vessels are their dominancy on the shipping density all year round. However, as it has been explained before, the pleasure and fishing craft activity are obviously underestimated, using AIS data.

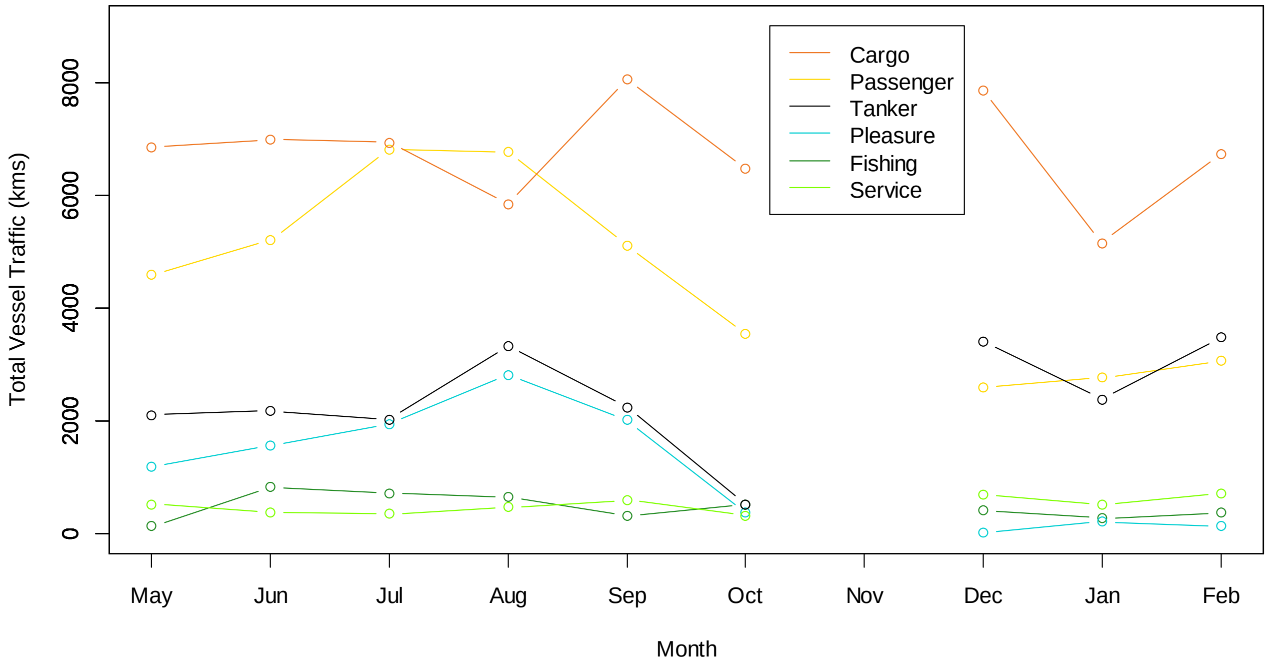


Figure 44. The monthly total sum of kilometres during the temporal subset in the Genoa Canyon (reduced extent with complete coverage) for each vessel type classification. The month value is averaged between 2013 and 2014 when both year values are available and no data for both years was available at November.

6. Objective 3, noise impact estimation within the Pelagos Sanctuary

6.1. Task presentation

This section presents the work realized for the Objective 3 by CHRISAR. To do so, CHRISAR has involved:

- a team of experts in bio-acoustic, signal processing, sound propagation and simulation;
- the softwares of acoustic synthesis (CHRISAR SIM), prediction range (ACSRAY) and noise propagation (SOUND MAP), proprieties of CHRISAR;
- the equipment for development and simulation by CHRISAR, including two HPC computing servers allowing the generation of noise maps.

The Objective 3 focuses on modeling and quantitative assessment of contribution of anthropogenic noise related to marine traffic, using a set of AIS data used as an input of the model in the Objective 2.

The analysis and integration of the maps of indicators, based on the descriptors of marine traffic obtained by Objective 2, has allowed the definition of:

- acoustic classification of anthropogenic noisemakers based on vessel categories;
- noise weighting depending on density of traffic in the various maritime transport corridors identified.

These data have been correlated with the aim of assigning to the main corridors of marine traffic, a model of anthropogenic noise for each acoustic class. The modeling of acoustic classes is based on the mechanical drive train and the size of the vessels, each class has then been simulated in the software for synthesis and acoustic simulation ChrisarSIM.

These simulations were used to extract the frequency distribution of noise for:

- different port areas based on site activity;
- each acoustic class of vessels.

A map of bathymetric and bathy-celemetric data, based on different acoustic sites identified in Pelagos area, has been realized. This data allowed to map the anthropogenic noise using the software suite for prediction range and noise propagation ACSRAY. A series of seasonal static maps of anthropogenic noise, realized taking into account the areas of port activities and the maritime corridors in the Pelagos area, has been generated and compiled as the output of the model of the Objective 3.

The output data from Objective 3 are then transmitted to Objective 5 as input data in order to build the risk maps and address the issue about anthropogenic impacts linked to maritime traffic.

6.2. Context

6.2.1. Focus on noise "pollution" caused by maritime traffic

The development of human activities affecting the marine sector (eg. marine traffic, offshore, seismic,…) obviously have a major influence on the surrounding environment (close and far) and particularly in terms of noise pollution. Therefore, the impact of anthropogenic noise introduced by man (marine traffic, seismic exploration, active sonar,..) on marine mammals can affect (Richardson et al., 1995):

- their detection capacities: *the increase of level of noise in the environment within the bandwidth of the audiogram of cetaceans can hide and make it impossible to detect other acoustic signals which could be important for marine mammals;*
- their behaviour: *their reaction to anthropogenic noise can range from a brief interruption of their normal activities (feeding, rest or social interaction) to a migration for short or longer periods from the noisy area;*
- their hearing sensitivity (physiology): *the exposure of marine mammals to intense acoustic signal for a period T with a given frequency f can lead to a temporary (TTS = Temporary Threshold Shift) or permanent (PTS = Permanent Threshold Shift) loss of hearing sensitivity.*

To fully understand the impact of anthropogenic noise on odontocetes, and in particular for this project on Cuvier's beaked whale and sperm whale, it is important to know "at best" the hearing abilities of the different species (audiogram, dynamic TTS/PTS) in order to best determine thresholds of potential risk. As the state of current research does not allow to perfectly characterize the hearing abilities of these two species, it is very important to adopt the maximum precaution in the thresholds in case of uncertainty or unknown parameter occurs. Nowadays, the hearing abilities are known only for few species on a small number of individuals and the experiments on sperm whales remain too isolated (Richardson et al., 1995).

It is important to underline that, within the specifications required by the task 3, the aim is not to integrate bio-acoustic criteria related to the two considered species to determine the potential acoustic risk, but to provide to the task 5 a series of maps of the estimated sound fields generated by marine traffic in the Pelagos Sanctuary.

Therefore, the adopted approach for the task 3 was to not limit the analysis to lower frequencies recommended for characterization of ambient noise, nor to limit to bandwidths of audiograms known for the two considered species in order to provide as much information as it is possible for the task 5 for the global analysis of correlated risks (marine traffic intensity, see Figure 45, noise and chemical pollution generated by shipping) related with the distribution of sperm whale and Cuvier's beaked whale.

Figure 45. Activities related with marine traffic.

6.2.2. Perception of anthropogenic noise by different species (influence zones)

Detection abilities of cetaceans are strongly related to levels and types of background noise present in the area. The possible sources contributing to the increase of ambient noise are illustrated in Figure 46. They are:

- environmental sources:
    - weather conditions (Knudsen et al., 1948, Ross, 1976) as sea state, wave height, wind speed, rainfall,…
- seismic activity (Wenz, 1962);
- biological activity (Myrberg, 1978; Dahleim, 1987);
- thermal noise (Mellen 1952): molecular agitation;
- remote human activities:
    - marine traffic, offshore activities, oceanographic and military activities,…

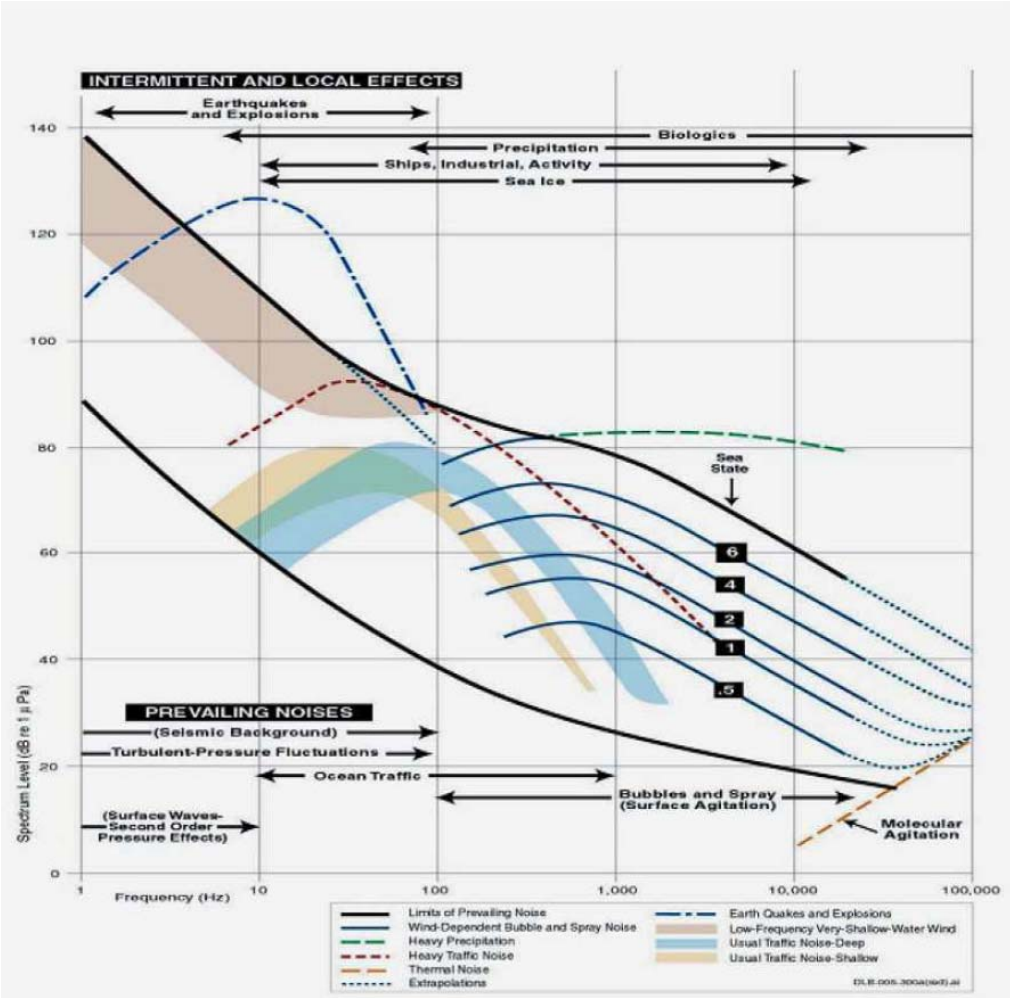


Figure 46. Spectrum of submarine isotropic noise (from Wenz, 1962).

The impact of anthropogenic noise on marine mammals can affect:

- their detection capacities to detect (hiding);
- their behaviour;
- their hearing sensitivity (physiology).

The influence of anthropogenic noise can be defined according to four influence zones:

- detection zone,
- hiding zone,
- behavioural zone,
- physiologic zone:
    - o TTS: Temporary Threshold Shift (temporary loss of hearing),
    - o PTS: Permanent Threshold Shift (irreversible damage).

The influence zones (illustrated in **Figure 47**) are defined by:

- acoustic characteristics of the anthropogenic noise sources (including spectral),
- the distance between the anthropogenic noise source and the cetacean (including the propagation)[2],
- the audiometry of cetaceans (frequency and dynamic sensitivity).

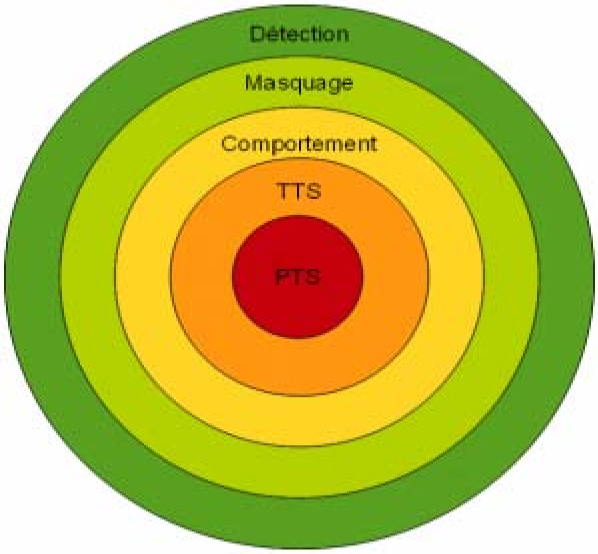


Figure 47. Zone of influence of theoretical noise (Richardson et al., 1995 ; Erbe, 2010)

6.3. Methods

This section presents the methodology implemented for the task 3 to generate, as outputs of the model, a set of seasonal quantitative maps, representing the spatial distribution of the sound field related to the underwater propagation of the radiated noise caused by marine traffic for the area of the Pelagos sanctuary.

The analyzing process constituting the algorithm of the model of anthropogenic noise incorporates the following steps:

- analysis, standardization (formatting, filtering) and integration of AIS data given as input by the task 2;
- re-sampling and temporal interpolation of all discrete occurrences of ship positions at a given time in order to obtain synchronous events and generate a position table called "Location table". This time table shows, for each re-sampling step, a collection of AIS positions of vessels together with a cinematic context and an identification number MMSI;

[2] The quantified acoustic levels do not directly correspond to the sound perception of marine mammals. Indeed, it is essential to apply an appropriate frequency weight adapted to the species based on which the thresholds of the physiological and behavioral sensitivity (audiogram, TTS & PTS ...).

- synthesis and classification of stationary acoustic signatures generated by a type of vessel and linked to the electro-mechanical and kinematic characteristics. This step creates the acoustic table of vessels "Acoustic Ship table" which allows to attach to each type of vessel a template of frequency noise depending from cinematic context. This model is interfaced with the software of sound synthesis "CHRISAR SIM".
- computation of acoustic and environmental models based on the associations of tables (joins) for creating other tables representative of the spatial distribution of sound field:
    - o the table "Radiated Noise table" representing the radiated noise at 1m from a ship for a given context. This table is generated from acoustic models of noise radiated from ships "Acoustic ship model", the environmental noise ("Ambient noise model") and the table "Location table".
    - o the table "Kernel propagation loss table" representing the loss due to propagation, computed from the "Environment table" and the "Location table". The range prediction model interfaces with the acoustic propagation software "ACSRAY".
- spatial integration, at each timestamp, of levels of acoustic pressure (for each considered bandwidth) of all occurrences of radiated noise. This integration is spatially delimited by:
    - o the GIS framework, limited to the Pelagos Sanctuary area,
    - o the coverage of AIS data produced by the task 2.
- temporal integration based on the selection of adequate time range and chosen quantitative acoustic indicator ($L_{\%}$, L_{max}).

In order to validate and increase the performances of the anthropogenic noise mapping model among all the preliminary phases of the project, an iterative and incremental development was implemented on a sample dataset (June 2013 Cargo) before launching computations on all the Pelagos area for all occurrences of the AIS database. After this step, the algorithms have been deployed on two HPC remote servers dedicated solely to the generation of acoustic maps from the proprietary software "SOUND MAP" interfaced with the QGIS platform.

6.4. Presentation of the software "SoundMap" bridge

In order to enable the management and automatic generation of anthropogenic noise mapping, CHRISAR has developed a specific bridge allowing to interface its own softwares of synthesis and acoustic propagation (including CHRISAR SIM and ACSRAY), with the platform QGIS and the database model of AIS data provided by task 2.

The combination of the "SoundMap" bridge with the software CHRISAR allows a predictive and analytical approach in the evaluation process of human pressures.

The "SoundMap" bridge can be used as a plug-in QGIS via a graphical user interface (HMI), or directly independently from command line (Figure 48).

Moreover, "SoundMap" allows to export the noise maps as georeferenced raster in GeoTIFF format, associated with a QML file incorporating the palette of colors of sound levels used in the GeoTIFF. Indeed, this software allows to generate acoustic maps of ambient noise suitable for the study area including:

- acoustic modeling leading to the characterization of the radiated noise emitted by various human noise sources (type of vessel) according to their context (kinematic, functional status);
- the simulation of the propagation of sound fields based on the quantification of the spatial, temporal and per frequency of the level of sound pressure of each source;
- the mapping of sound fields based on the selected acoustic indicator.

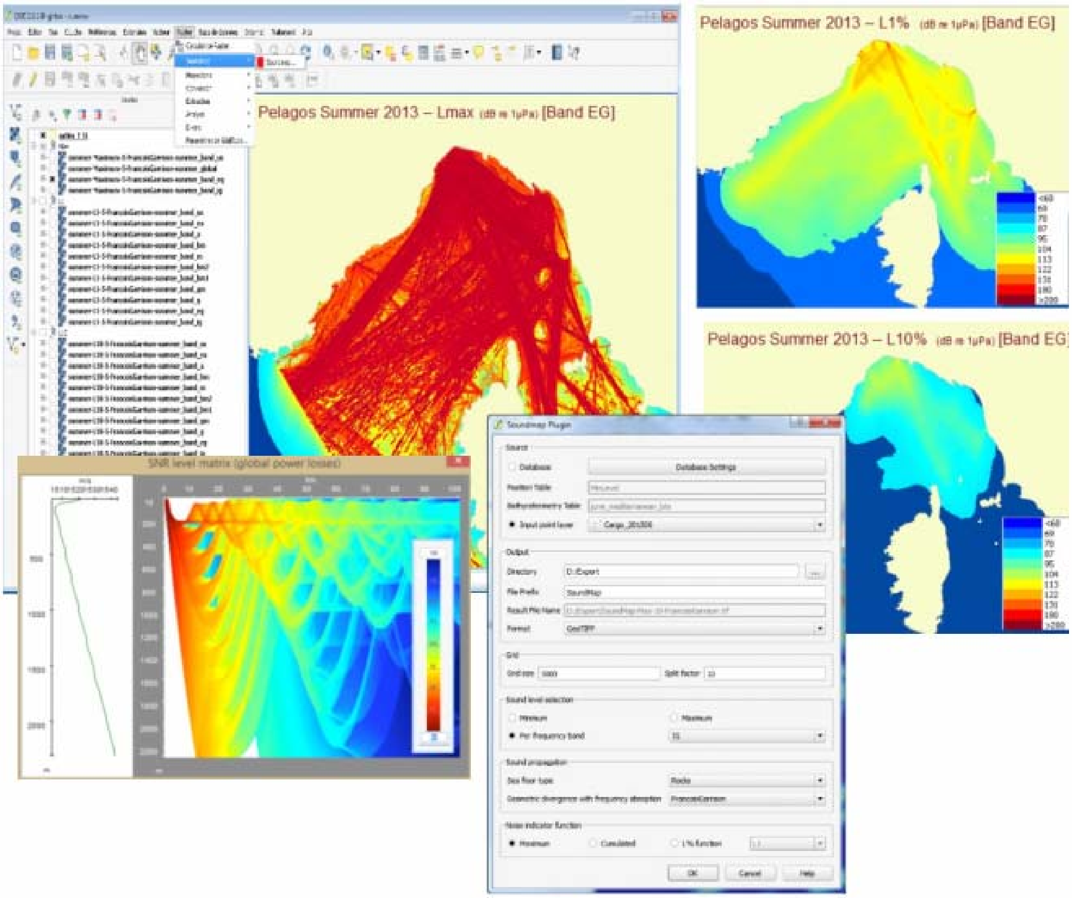


Figure 48. Graphic interface associated with the software "SoundMap".

6.5. Synopsis of the acoustic model of anthropogenic noise

The synopsis (Figure 49) shows the work flow implement for data processing and the interaction between different algorithmic bricks entering into the numerical modeling of noise generated from maritime traffic starting from the AIS data provided by the task 2.

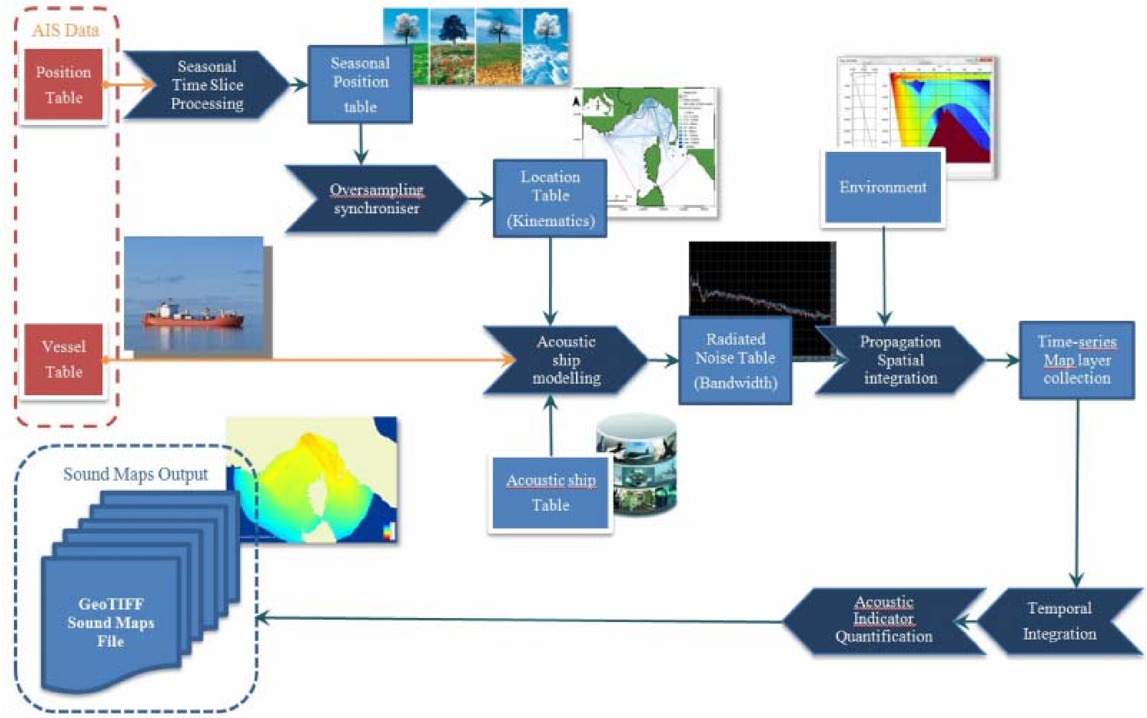


Figure 49. Work flow implement for data processing.

6.6. Details of the modelling process of anthropogenic noise related to marine traffic

6.6.1. Presentation of AIS input data

The input data for the anthropogenic noise mapping model developed in the task 3 includes:

- the elements necessary for the characterization of different levels of sounds, representing the frequency distribution of the submarine sound pressure level transmitted at 1m from the source, associated to each point source. Each source of noise is defined in the AIS database (see task 2) by vessel type, characterized by:
    - o type,
    - o dimension,
    - o identification number,
    - o localization,
    - o cinematic,
- the GIS framework of the study area incorporating seasonal bathycelemetrics associated to the study area (or temperature profile, salinity, bathymetry, bottom type);
- the boundaries of the output data processed by the model used for the task 3 is directly linked to the AIS data inputted by task 2 (Figure 50), namely:
    - o coverage: Pelagos Sanctuary
    - o period: from 03/05/2013 to 31/10/2014
    - o number of messages to be processed : 42milions
    - o 7000 identified vessels (MMSI)

- 88000 routes (totalizing 3'757'587 km).

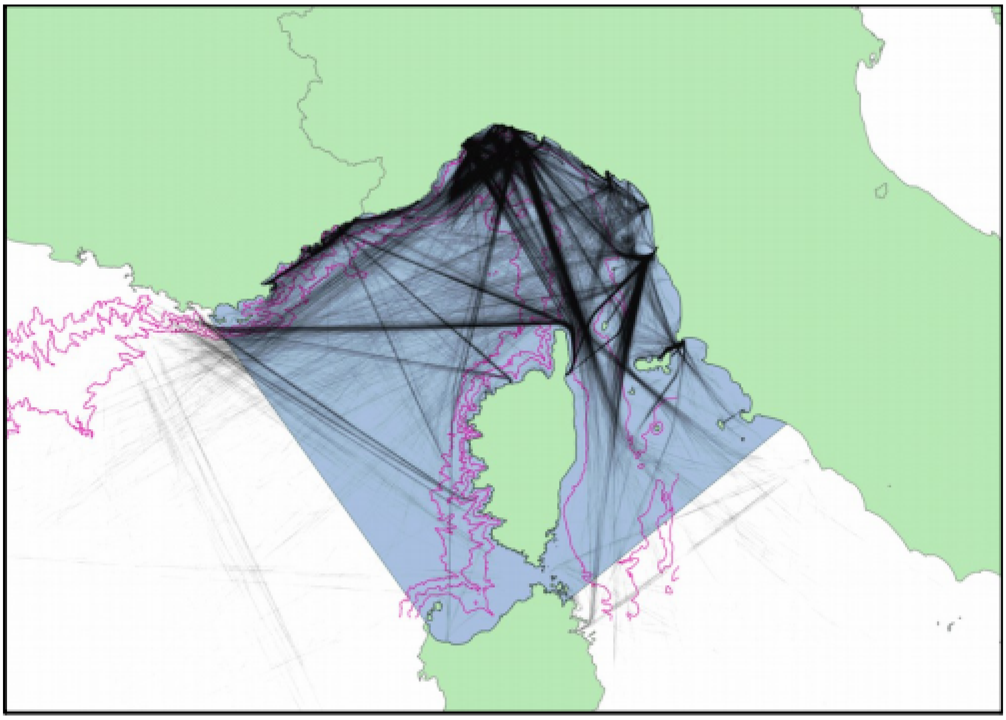


Figure 50. Summer map of vessel traffic lines [CIMA]

- different categories of vessel identified (Figure 51).

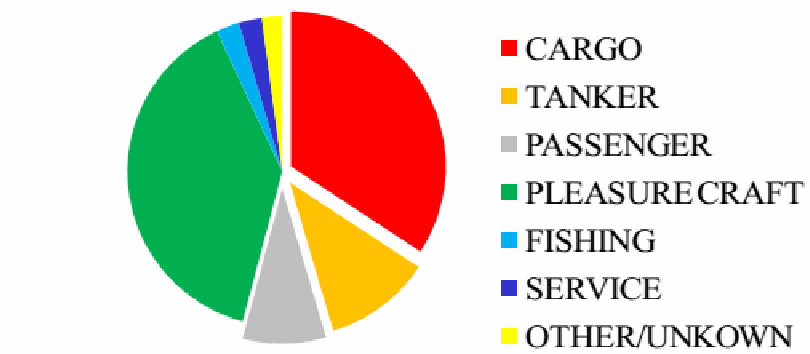


Figure 51. Categories of vessels identified in the AIS data

6.6.2. Modelling the spatial noise radiated by shipping

The first step of the modeling is to associate for each vessel a series of noise templates depending on the context. The modeling of noise radiated by a ship regards the assessment of the spreading of the energy of vibro-mechanical signals transmitted in water by acoustic radiation of a vessel. It is important to underline that this model focuses on the noise radiated by a vessel at 1m and does not apply to electro-acoustic pulse emission of active sonar. Indeed, this model focuses on the integration of vibro-acoustic class of a vessel (size, type of drives) with a given kinematics context (speed, state).

The model of each acoustic class is a synthesis of acoustic simulation of Chrisar correlating real and simulated data (additive synthesis of the propulsion chain, and Ross model). The traffic noise is then calculated by spatially integrating all boats present at every time (representative of the density of maritime traffic).

- The model "acoustic ship model" can generate the noise template "radiated noise ship template" which allows the setting of the sound pressure level (SPL - dB re 1µPa@1m) radiated from a ship to a reference distance of 1m. This template represents the frequency distribution of the overall sound of the resulting additive synthesis of the sources of internal noise (auxiliaries, propulsion chain,...) and external sources (vibration transmitted through the hull, cavitations,...) from the electro-mechanical characteristics of a ship (Figure 52) at a given speed. Indeed, each ship can be identified at a given time (age of the vessel) and for a given context (speed, state machines) by its "acoustic fingerprint" (or acoustic template, Figure 53). This acoustic template incorporates a set of acoustic signatures (or classification key) especially dependent on its propulsion system, auxiliary, mechanical failure, dimensions,...

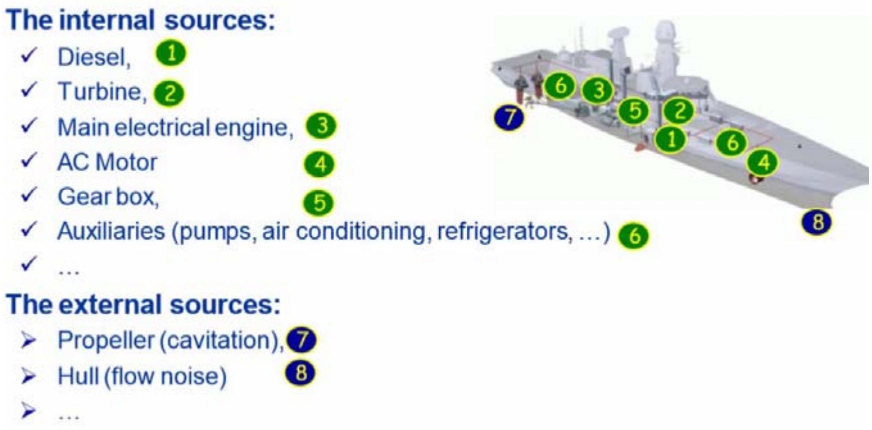


Figure 52. Vessel noise sources (interns or externs).

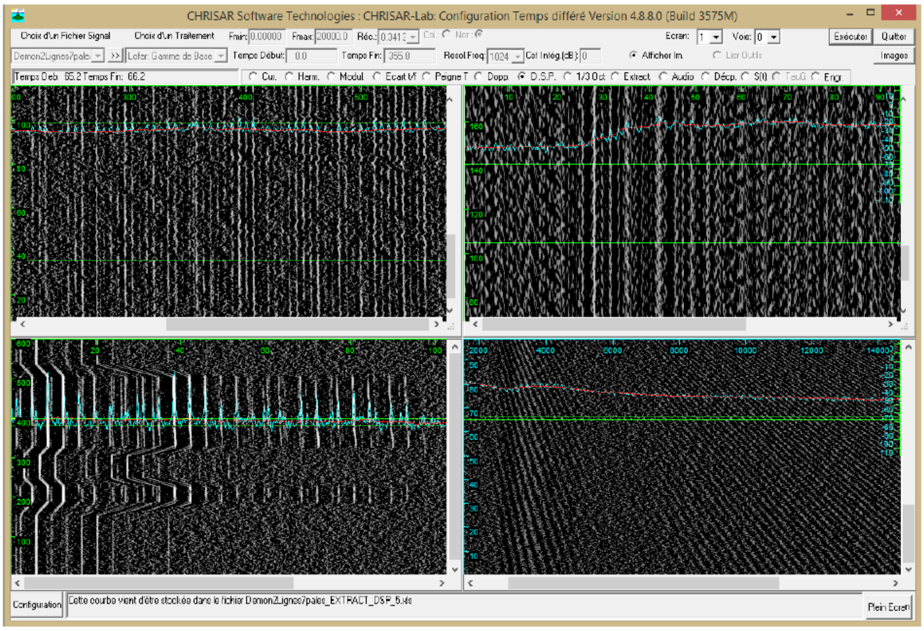


Figure 53. Example of synthesis of additive radiation acoustic of a ship according to different context (spectral representation of LofarGramme to help Chrisar lab).

- The "Acoustic ship" table is joined to the table "Vessel table" provided by the AIS dataset in order to assess the maximum source level associated to each type of ship at a particular speed, for each following frequency bands (Table 7).

Table 7. Pattern of noise per band with according to ship type.

Classe acoustique du navire	Cinématique (kts)	N° Bande	Nom Bande	Freq. Min (Hz)	Freq. Max (Hz)
Type de navire	0 - 5	n°1	Infra-grave (IG)	5	40
		n°2	Extrême-grave (EG)	40	80
		n°3	Grave (G)	80	160
		n°4	Grave-medium (GM)	160	320
		n°5	Bas-medium (BM1)	320	640
		n°6	Bas-Medium (BM2)	640	1280
		n°7	Medium (M)	1280	2560
		n°8	Haut-medium (HM)	2560	5120
		n°9	Aigu (A)	5120	10240
		n°10	Extrême aigu (EA)	10240	20480
		n°11	Ultra-son (US)	20480	40960
	5 - 10	n°1	Infra-grave (IG)	5	40
		...	...	...	...
		n°11	Ultra-son (US)	20480	40960
	10-15	n°1	Infra-grave (IG)	5	40
		...	...	...	...
		n°11	Ultra-son (US)	20480	40960
	15 - 20	n°1	Infra-grave (IG)	5	40
		...	...	...	...
		n°11	Ultra-son (US)	20480	40960
	20 - 25	n°1	Infra-grave (IG)	5	40
		...	...	...	...
		n°11	Ultra-son (US)	20480	40960
	>25	n°1	Infra-grave (IG)	5	40
		...	...	...	...
		n°11	Ultra-son (US)	20480	40960

- A propagation model is applied for each occurrence positions in order to compute the corresponding kernel losses at each time-step and for each frequency band. Then, a spatial integration in amplitude of the level integration of acoustic pressures is processed to generate a global noise map by time-step for all the occurrences (Figure 54). Each loss of each ship is integrated to an specific instant t for each time-step in order to obtain for each cell the spatial ambient noise corresponding to the total of noise propagated and proper noise of the acoustic class of the ships occurring on the cell. The acoustic waves transmitted into the sea water suffer during their propagation a loss linked to:
  - o the geometrical effect of divergence depending on the distance;
  - o the absorption of the acoustic energy by the medium in function of the emitted frequency.

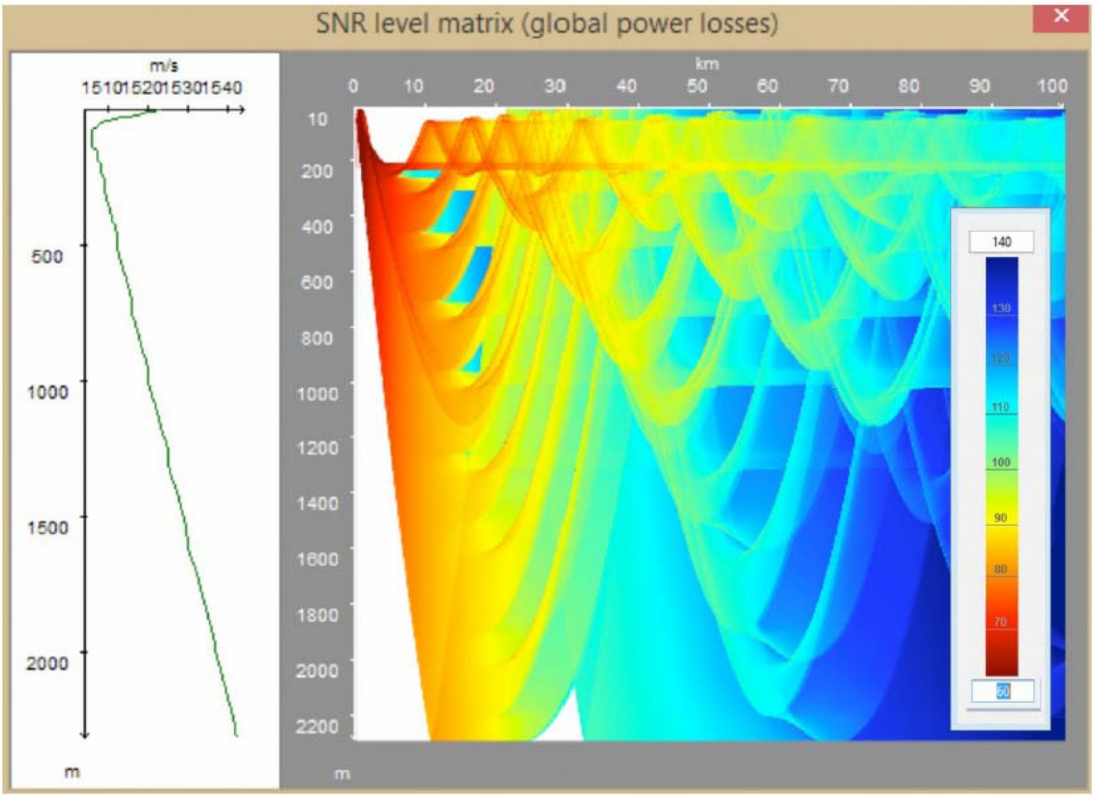


Figure 54. Example of matrix of global loss by ACSRAY (June 2013 La Ciotat).

- Finally, a series of acoustic indicators are used to evaluate the noise level contribution on time frame via time integration.

6.6.3. Output data

The output data of the "SoundMap" corresponds to 144 acoustic maps assessment the maritime traffic covering the Pelagos Sanctuary from spring 2013 to winter 2014.

All of these maps are organized with the following method (Figure 55):

- Prioritizing data:
  - Seasons> acoustic indicators> Bandwidth

  with (4x) seasons, (3x) sound indicators, (11x) frequency bands and (1x) global band.
- Standard of sound maps:
  - raster georeferenced GeoTIFF images associated with a QML file for the scale use colors (colormap)
  - additional formats:
    - Project QGS for the use in QGIS,
    - PNG images to facilitate integration to the report,
    - Example of animated GIFs to support the task 5 in the interpretation of variability (spatial, seasonal, sound level).

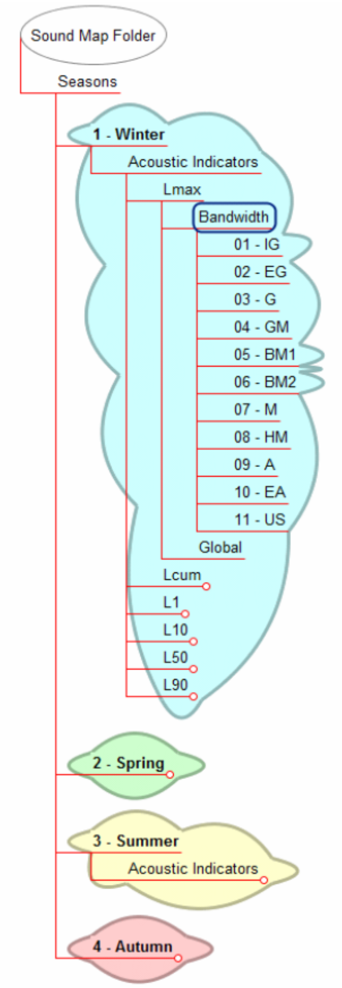


Figure 55. Prioritization of seasonal static maps of anthropogenic noise.

6.6.4. Acoustic level indicator

Most environments are affected by anthropogenic noise which continuously varies, largely as a result of maritime traffic density. Anthropogenic noise contribution can differ, significantly among time at a particular point. The fluctuation of anthropogenic noise level, for a particular point on the map, depends on the range to shipping routes (propagation loss), the shipping density, the ship type (electro-mechanical characteristic), the power-speed characteristic of a ship class.

The level of the percentile acoustic indicator $L_{N\%}$ indicates when the noise level that has been exceeded for N% of the time and allows to highlight the quantification of anthropogenic noise. The acoustic levels of each cell of the grid are distributed on the seasonal period using the of the cumulated frequency histogram (Figure 56).

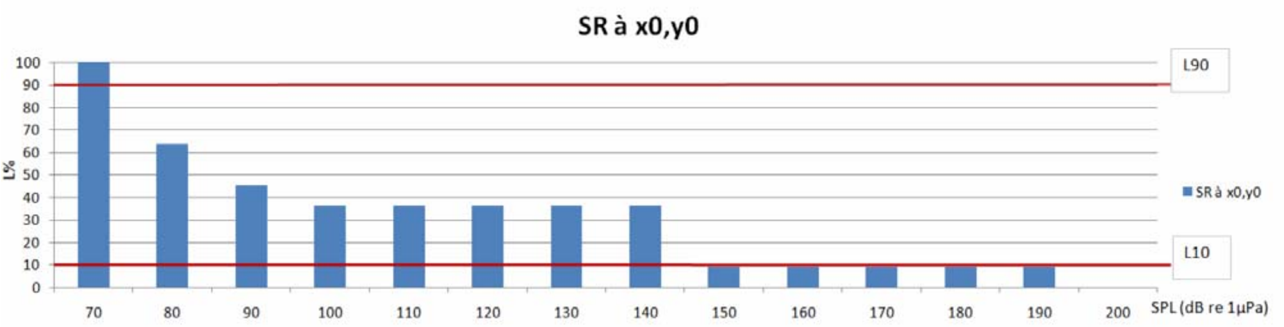


Figure 56. Example of an acoustic level histogram of a position over the period of analysis.

- Maximum Noise Level (L_{max}): the maximum noise level over a sample period is the maximum level, measured on fast response, during the sample period;
- Indicator Percentile ($L_{N\%}$): the level passed during N% du temps and with the 100-N% remains on to the inferior level during the temporal analysing window (Figure 57).

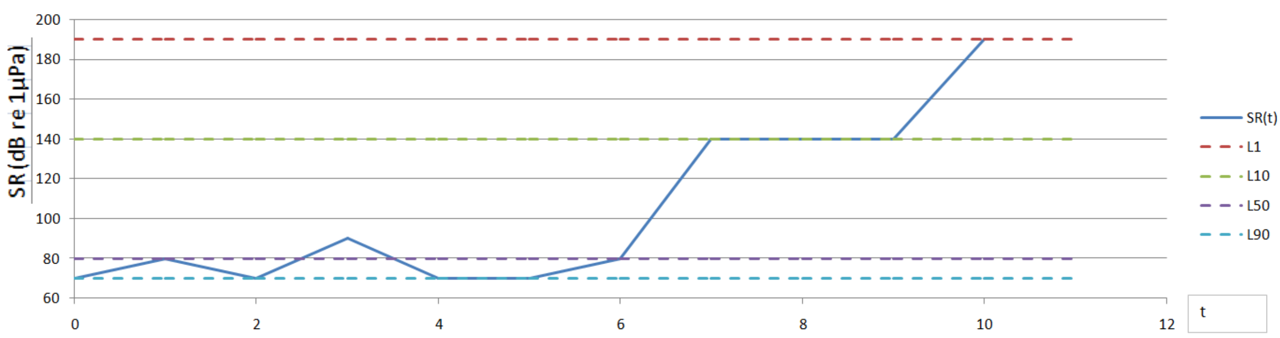


Figure 57. Example of percentile level in function of the time.

6.6.5. Assessment parameters

As indicated in the section 6.5.2. (Output data), a series of maps of the sound field are realized accordingly to three levels of analysis:

- in the frequency distribution (Figure 58);
- to the seasonal trends (Figure 59);
- acoustic indicators (Figure 60).

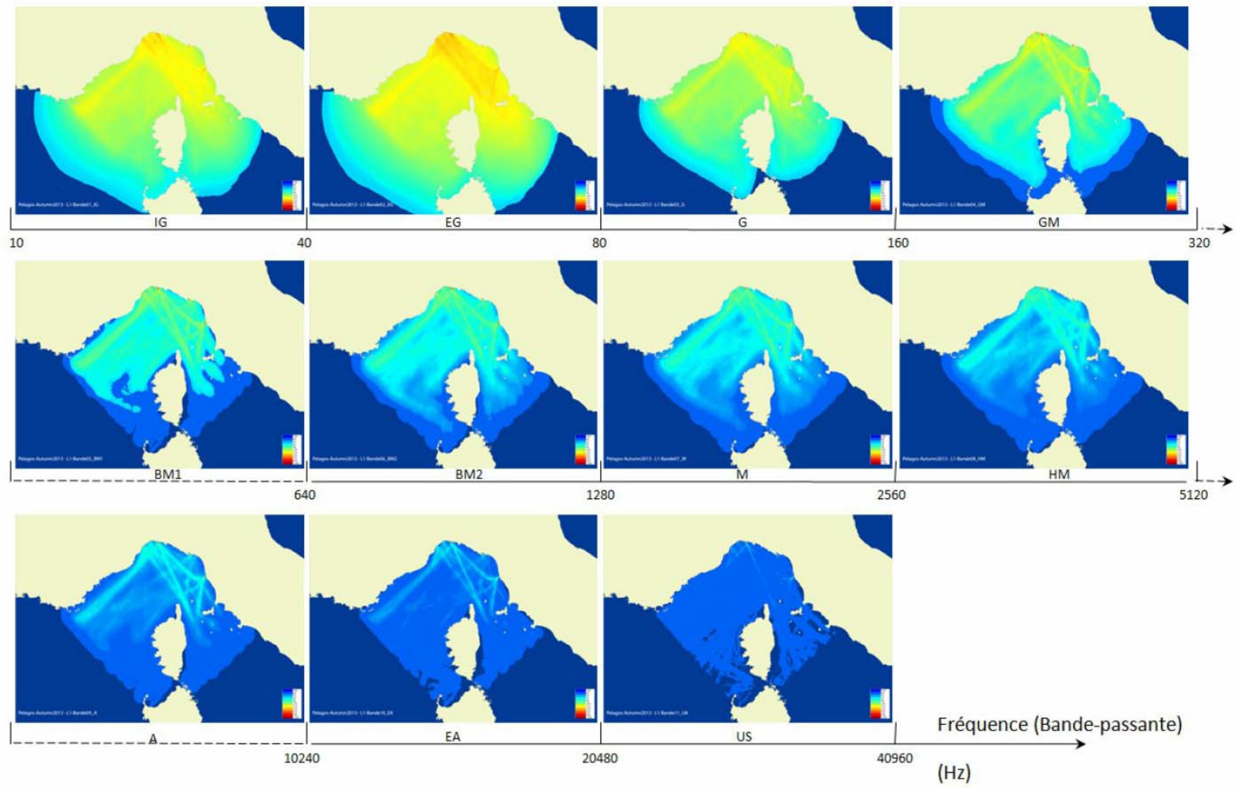


Figure 58. Effect of the bandwidth on noise map obtained for Autumn 2013 with L1%.

The commercial traffic seems to be more abundant during autumn and winter and shows seasonal variability linked to ferries and fishing vessels.

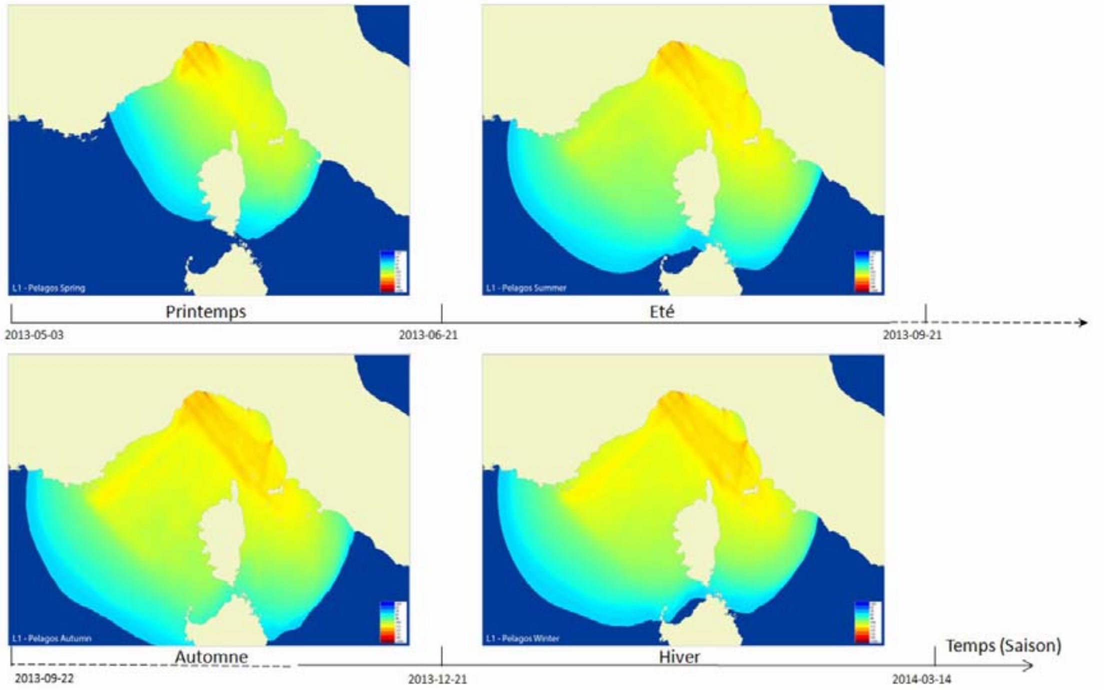


Figure 59. Seasonal effect on noise map with L1% and the global bandwidth.

The maps of the different indicators highlights the quantity of energy present in the Pelagos Sanctuary during the study period.

- L_{max} (dB re 1µPa): the maximum noise level over a sample period is the maximum level measured on fast response, during the sample period;
- L_1 (dB re 1µPa): the noise level which is exceeded for 1% of the sample period;
- L_{10} (dB re 1µPa): the noise level which is exceeded for 10% of the sample period.

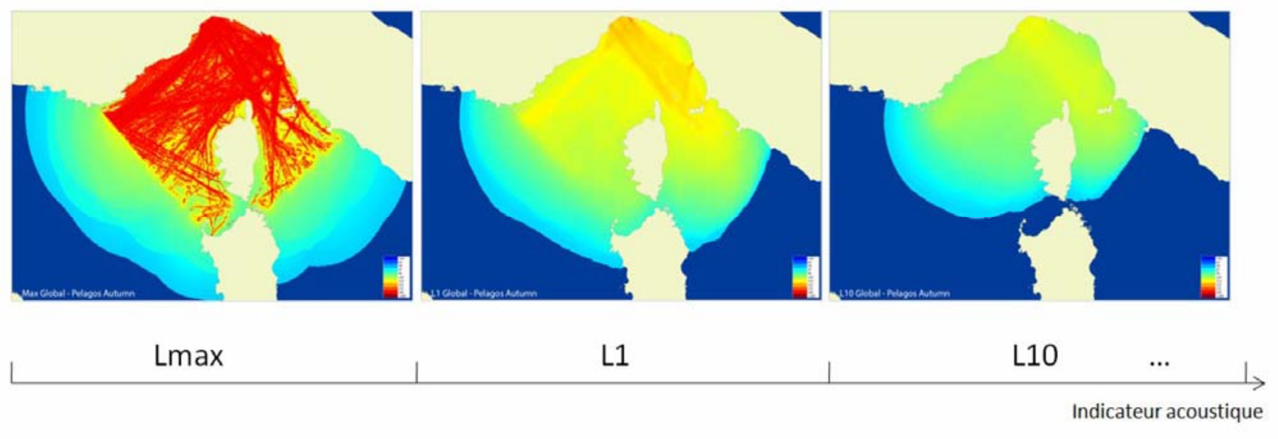


Figure 60. Effect of the type of indicator on the map noise for Autumn 2013 with the global bandwidth.

7. Objective 4, habitat modelling as support for the impact estimates

7.1. Correlations with environmental variability

Sperm whale and Cuvier's beaked whale sightings have been analysed in order to evaluate possible impacts due to naval traffic. In order to rule out any potential implication of the environmental variability in the observed distribution patterns a correlation analysis was performed between the two species encounter rates and the annual average statistics of Sea Surface Temperature (SST, Figure 61), and chlorophyll-a (Chl-a, Figure 62). Chlorophyll and SST monthly data were obtained from the following remote sensing sensors:

- SST , AVHRR sensor (time series: 1990- 2014);
- Chl-a, SeaWiFS sensor Ocean Color (time series: 1998-2007);
- Chl-a, MODIS-Aqua (time series: 2008-2014);

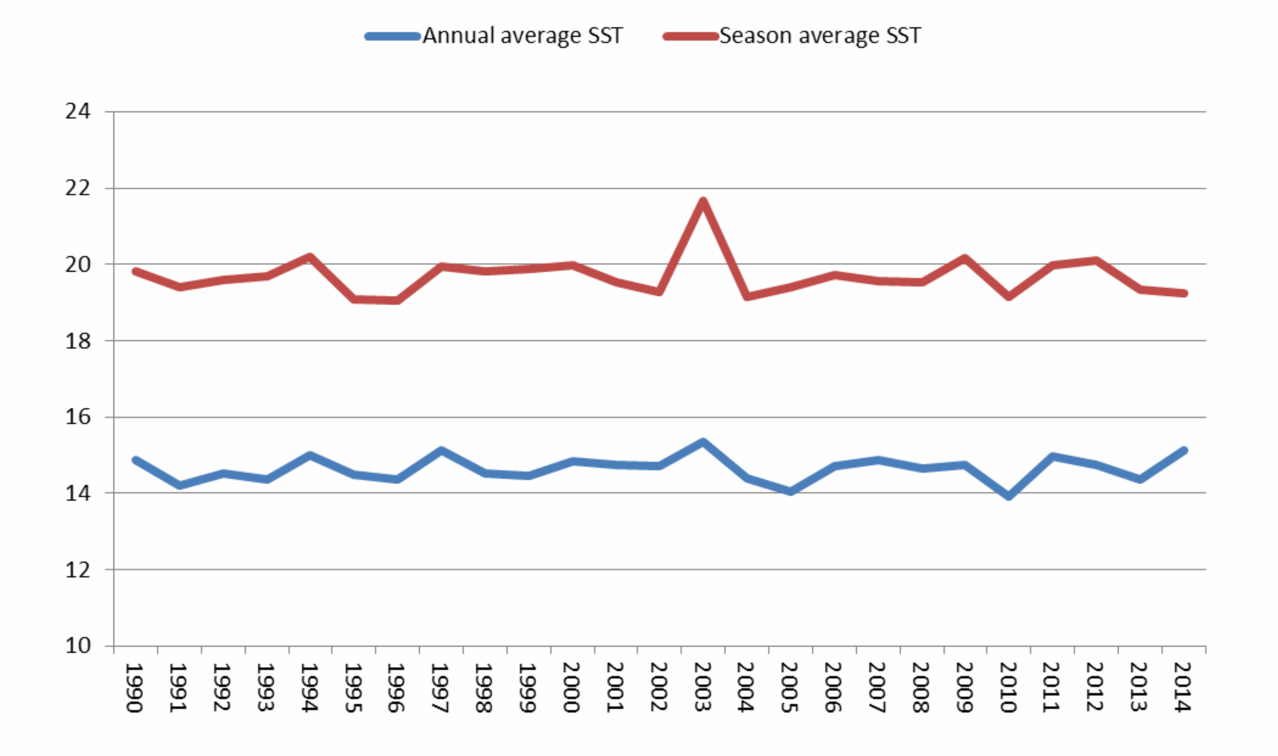


Figure 61. SST annual trend and summer season trend.

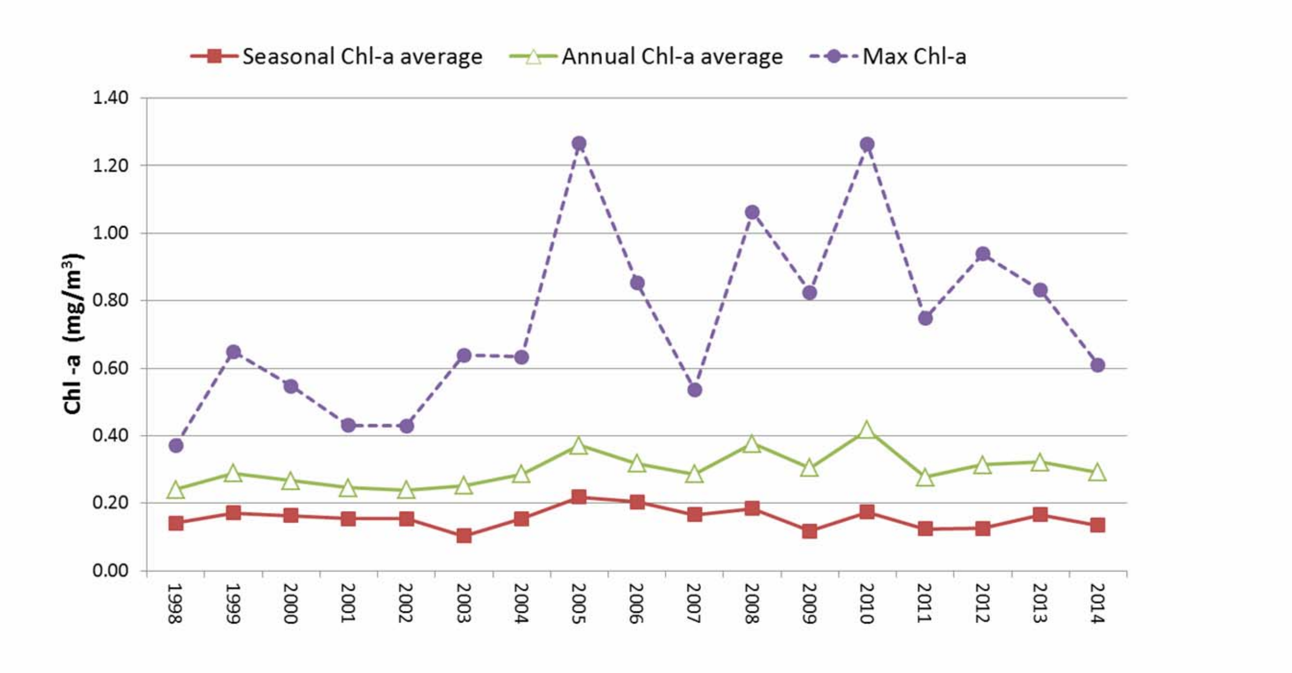


Figure 62. Chlorophyll-a annual, summer season average and maximum trend.

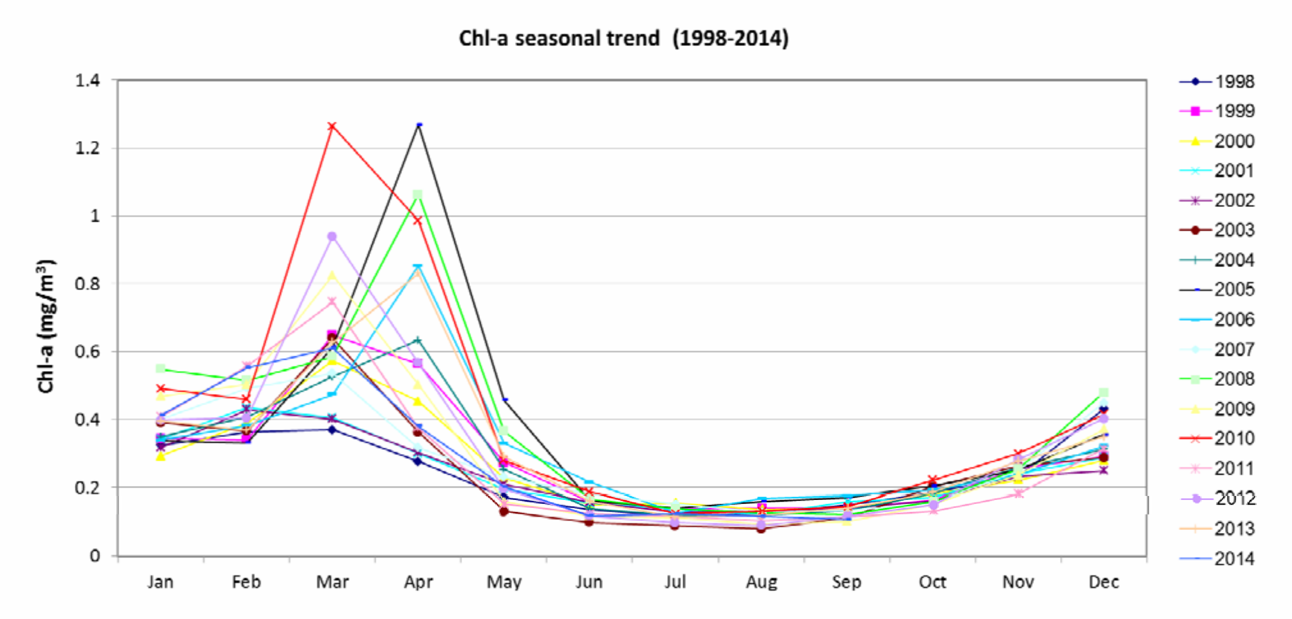


Figure 63. Chlorophyll-a seasonal trend.

Although no obvious annual trends can be seen for both SST and Chl-a, the Chl-a seasonal pattern reveals that there is a marked variability in the timing of the seasonal peak which may occur in March or April (Figure 63). Table 8 shows the correlation analysis performed. It can be observed that both species show an annual increasing trend in their encounter rates whereas no significant trend can be observed for SST while Chl-a shows a significant decreasing trend.

Moreover, it is worthwhile to remark that both the species show a correlation with Chl-a figures. Sperm whale encounter rate is in fact inversely correlated with Chl-a but this correlation reflects the effect of concurrent increasing trend of sperm whale occurrence and the

Chl-a decreasing trend. On the other hand, Cuvier’s beaked whale is directly correlated with the monthly Chl-a peak, being higher for seasons where the Chl-a peak occurred later in the year.

Table 8. Correlation analysis of sperm whale and Cuvier’s beaked whale encounter rates with the year, the research effort and the SST and Chl-a annual and seasonal patterns.

Correlations

		effort	encounter rate_Pm	encounter rate_Zc	year	chl_a	SST	Chl-a peak month	Chl-a max
effort	Pearson Correlation	1	.067	.788	.473	.132	.059	.678	.423
	Sig. (2-tailed)		.752	.000	.017	.615	.780	.003	.090
	N	25	25	25	25	17	25	17	17
encounter rate_Pm	Pearson Correlation	.067	1	.295	.837	-.514	-.150	-.062	.337
	Sig. (2-tailed)	.752		.152	.000	.035	.476	.813	.186
	N	25	25	25	25	17	25	17	17
encounter rate_Zc	Pearson Correlation	.788	.295	1	.600	-.271	.147	.599	.342
	Sig. (2-tailed)	.000	.152		.002	.293	.482	.011	.179
	N	25	25	25	25	17	25	17	17
year	Pearson Correlation	.473	.837	.600	1	-.522	-.123	.292	.372
	Sig. (2-tailed)	.017	.000	.002		.032	.558	.256	.141
	N	25	25	25	25	17	25	17	17
chl_a	Pearson Correlation	.132	-.514	-.271	-.522	1	-.419	.067	-.056
	Sig. (2-tailed)	.615	.035	.293	.032		.094	.798	.832
	N	17	17	17	17	17	17	17	17
SST	Pearson Correlation	.059	-.150	.147	-.123	-.419	1	.194	.380
	Sig. (2-tailed)	.780	.476	.482	.558	.094		.456	.132
	N	25	25	25	25	17	25	17	17
Chl-a peak month	Pearson Correlation	.678	-.062	.599	.292	.067	.194	1	.564
	Sig. (2-tailed)	.003	.813	.011	.256	.798	.456		.018
	N	17	17	17	17	17	17	17	17
Chl-a max	Pearson Correlation	.423	.337	.342	.372	-.056	.380	.564	1
	Sig. (2-tailed)	.090	.186	.179	.141	.832	.132	.018	
	N	17	17	17	17	17	17	17	17

This analysis confirms the relevance of environmental drivers of change in shaping the distribution of sperm whales and Cuvier’s beaked whales although this changes are mostly related to Chl-a and they are apparently the direct or indirect effect of the decreasing trend of the primary productivity in the study area. For this reason the temporal predictor (i.e. the year) can be considered equivalent for modelling purposes to the Chl-a predictor.

7.2. Effects of the anthropogenic pressures

The scope of this project is to determine the potential implications of naval traffic, both in terms of the traffic itself and in terms of generated noise. Although, noise is the main focus of the study, its relative relevance has to be evaluated with respect to other potential impacts associated to naval traffic.

Binary logistic regression analysis (Afifi and Clark, 1996; Guisan and Zimmermann, 2000) has been used to correlate presence/absence data of the species to naval traffic density and noise indicators. In order to better undermine potential correlations with naval traffic and noise a K-means Cluster Analysis (CA) was used to analyze the similarities among the traffic density profiles and composition within the study area. So the total number of ships and the number by ship type were evaluated for every cell unit of the working grid and the Euclidean Distance was used as distance metric (Equation 1).

$$d_2(\mathbf{x}_i, \mathbf{x}_j) = \sqrt[2]{\sum_{k=1}^{q} (\mathbf{x}_{ik} - \mathbf{x}_{jk})^2} \qquad \text{Equation 1}$$

7.3. Cluster Analysis

Cluster Analysis was run twice, the first run based on randomly extracted initial centers and the second run based on the final centers derived from the first run. A four clusters solution was obtained, the characteristics of these clusters been showed in Figure 64 As the bar chart shows there are clear differences in the traffic profiles of the clusters, particularly cluster 1 and 4 have similar characteristics although cluster 1 is characterized by almost homogeneous presence of ship types whereas cluster 4 shows a lower percentage of Fishing and Service ships. Cluster 2 and 3 are more coastal and both present a much higher percentage of Pleasure ships and Passenger. Tankers are mostly absent in these last two clusters.

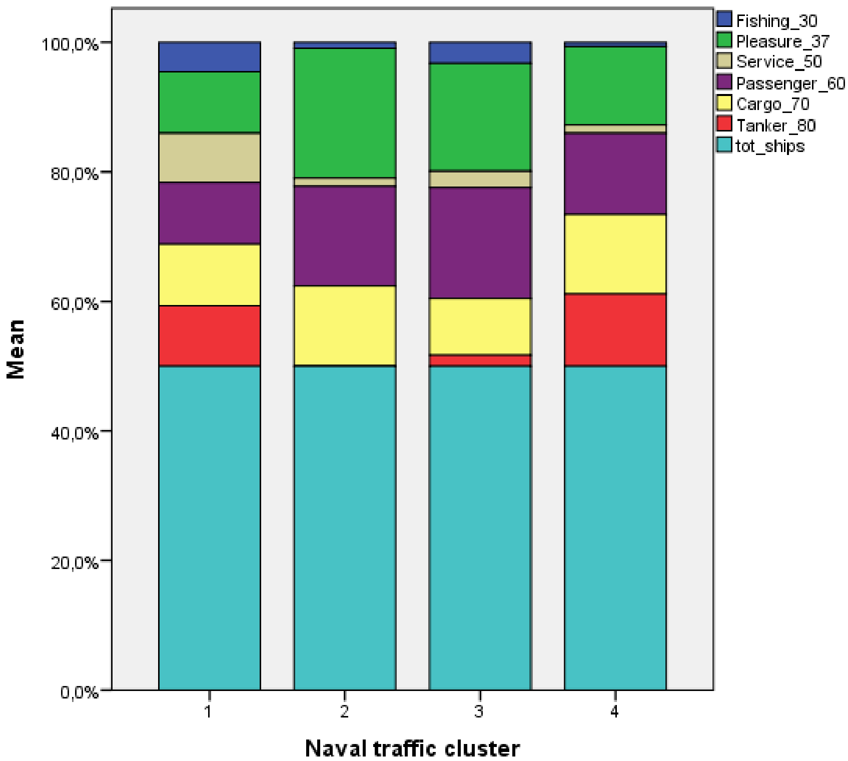


Figure 64. Naval traffic cluster characteristics.

These clusters have been used as reference for zoning the traffic and to evaluate the cell differential traffic value for every ship type (i.e. the difference between the cell traffic statistics and the zone average: e.g. diff_tot_km_ship = cell total ship km – zone average ship km).

7.4. Logistic Regression Analysis

Binary logistic regression analysis (Afifi and Clark, 1996; Guisan and Zimmermann, 2000) has been used to correlate presence/absence data of the species to the differential traffic value and noise indicators. As the presence/absence dataset is zero-inflated, the number of absence cells was balanced to the number of presence cells, according to the "two stage sampling design", described by Breslow and Cain (1988). The extraction of the subset of absence cells was obtained through the Mersenne Twister random number generator (Matsumoto and Nishimura, 1998).

Logistic regression results are shown respectively in Table 9 concerning sperm whale and in concerning Cuvier's beaked whale.

Table 9. Summary statistics of the logistic regression analysis concerning sperm whale (upper) presence/absence and Cuvier's beaked whale (lower).

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 3	Diff_Tanker	0,662	0,333	3,943	1	0,047	1,938	1,009	3,726
	Year	0,125	0,013	97,680	1	0,000	1,134	1,106	1,162
	Effort_class	0,216	0,061	12,793	1	0,000	1,242	1,103	1,398
	Constant	-252,204	25,461	98,118	1	0,000	0,000		

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 4[d]	Diff_Fishing	-1,029	0,305	11,407	1	0,001	0,357	0,197	0,649
	Diff_Service	-1,698	0,333	25,948	1	0,000	0,183	0,095	0,352
	Year	0,091	0,020	20,783	1	0,000	1,095	1,053	1,139
	Effort_class	0,981	0,094	109,458	1	0,000	2,666	2,219	3,204
	Constant	-185,718	40,119	21,429	1	0,000	0,000		

d. Variable(s) entered on step 4: diffFish30.

where

B are the unstandardised regression coefficients with their relative standard errors (S.E.), Wald is the stastistic on which is based the hypothesis testing on coefficients with relative degree of freedom (df) and significance level (Sig.) and Exp(B) is the exponential transformation of the unstandaridsed coefficient B which corresponds to the odds ratio, a proxy for the relative risk associated with a one-unit increase in the exposure (see Afifi and Clark, 1996 for reference), for which a 95% Confidence Interval (95% C.I.) is also provided.

The two models outline the different characteristics of the habitat of the two species, identifying higher sperm whale presence probability in the area whereTanker passage is higher and outlining for Cuvier's beaked whale the preference for a more pelagic habitat and therefore characterized by a lower presence of Fishing and Service ships. It is also worthwhile to observe that the Year is a significant covariate for both the species outlining the importance of the environmental variability as it was already shown in the paragraph discussing the correlations with chlorophyll-a and Sea Surface Temperature.

7.5. Optimal habitat correlation analysis

In order to better understand the effect of the traffic on the use of the habitat for these two species, the analysis was restricted to the optimal habitat. Presence/absence habitat models, using physiographic predictors as covariates, were used to estimate the presence probability of the two species. The physiographic predictors for the study area have been obtained through the GEBCO One minute Digital Atlas. Sea bed slope was calculated according to Burrough (1986). However, on the behalf of the following analysis, models developed on independent dataset were used to predict the optimal habitat, whereas present study sightings were instead used to investigate the correlations with naval traffic and noise within the optimal habitat. Particularly, sperm whale model was derived based on Azzellino et al., 2012, while Cuvier's beaked whale model was instead derived from Azzellino et al., 2011. Figure 65 shows the presence probability of the two species obtained by means of the habitat models.

Probability predictions were produced for every cell unit and, depending on the model, different threshold probability values which identify the higher species presence (i.e. the optimal habitat see Figure 66) were selected. Concerning sperm whale, having the model a lower accuracy (i.e. 69.7% see Azzellino et al., 2012) a 50% threshold was assumed as high probability threshold. On the other hand, considering that Cuvier's beaked whale model had a much higher accuracy (i.e. 87.2% see Azzellino et al., 2011), as high probability threshold was chosen the 70%.

The optimal habitat predictions obtained from the two models "external to this study" were tested versus the encounter rates of the two species. A Mann-Whitney test was applied to compare the encounter rate of the two species between the optimal habitat and the unsuitable habitat conditions. The encounter rates were found significantly higher for both species in the optimal habitat cell units ($P<0.001$).

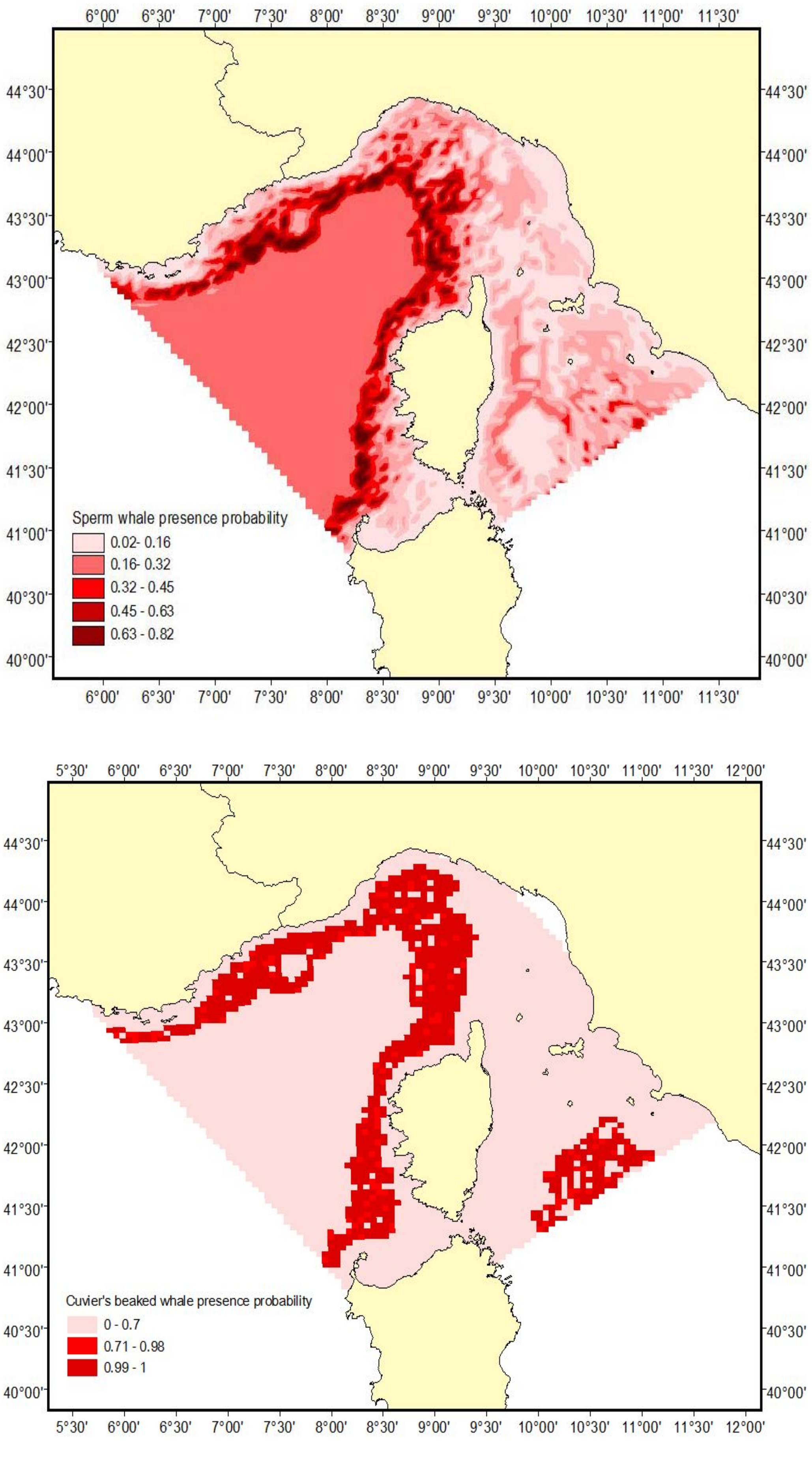


Figure 65. Presence probability of sperm whale (upper) and Cuvier's beaked whale (lower).

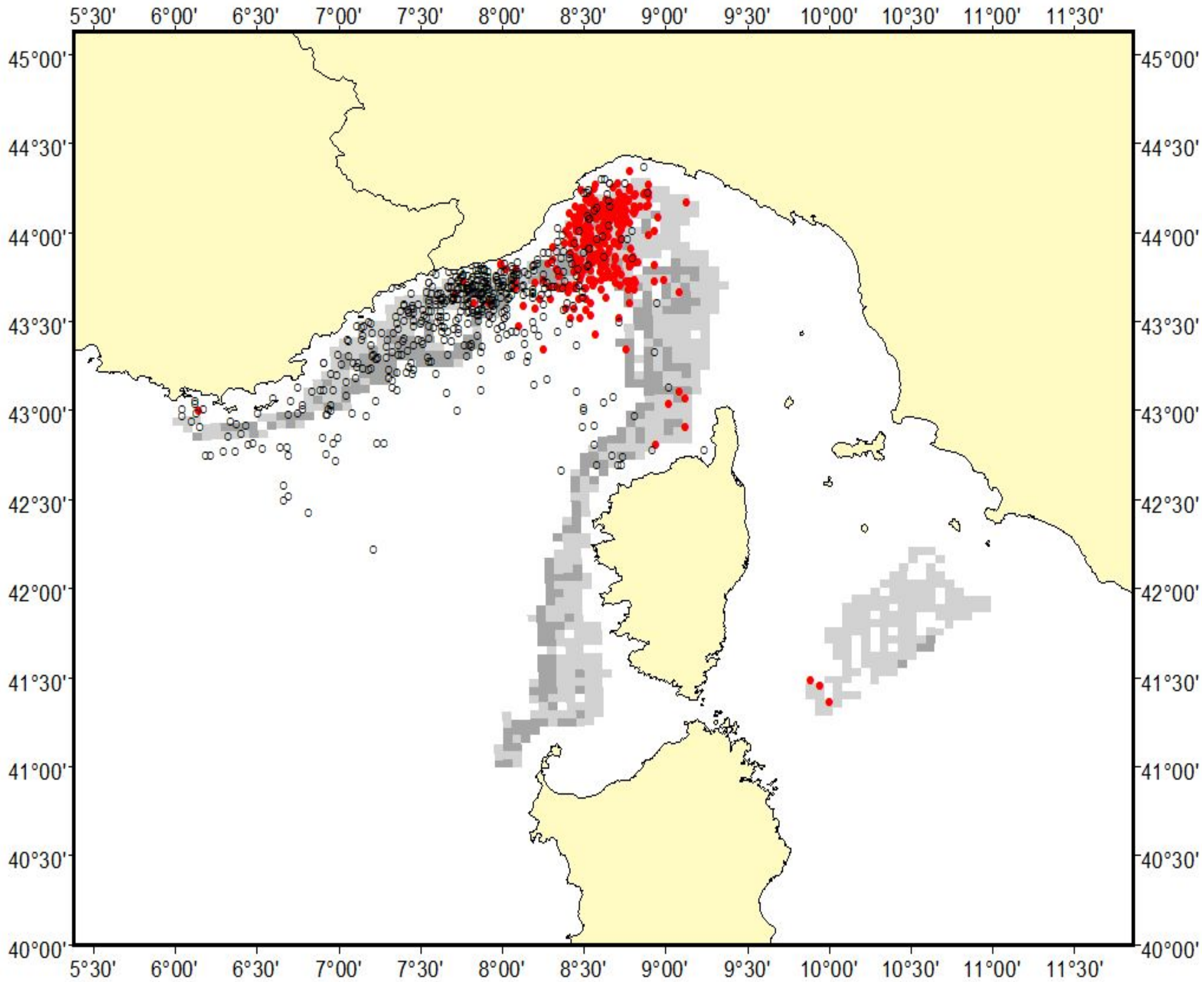


Figure 66. Sightings of sperm whale (empty circles) and Cuvier's beaked whale (red dots) and optimal habitat delineation for sperm whale (dark gray) and Cuvier's beaked whale (light gray).

At this point, an additional logistic regression analysis was performed to correlate the presence/absence of the two species within the identified optimal habitat with both the traffic and noise indicators. Both Traffic and Noise indicators were evaluated as predictors either considering their absolute cell values and also considering their relative values with respect to the traffic-noise cluster zoning (e.g. the difference between the cell traffic statistics and the zone average: e.g. diff_tot_km_ship=cell total ship km–zone average ship km; Diff_Su_L10_global=cell Su_L10_global-zone average Su_L10_global).

The results of this second logistic regression analysis are shown in Table 10.

Table 10. Summary statistics of the Logistic regression analysis applied to sperm whale (upper) and Cuvier's beaked whale (lower) presence/absence data restricted to the optimal habitat area.

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 4[d]	Effort_sum	0,031	0,007	18,324	1	0,000	1,032	1,017	1,047
	Su_L10_global	0,038	0,023	2,738	1	0,098	1,039	0,993	1,087
	Su_L01_global	-0,140	0,043	10,468	1	0,001	0,869	0,799	0,946
	Number ship/km tracks	-18,620	5,598	11,063	1	0,001	0,000	0,000	0,000
	Constant	11,429	3,171	12,992	1	0,000	91936,765		

d. Variable(s) entered on step 4: sul10global.

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
								Lower	Upper
Step 5[e]	Effort_sum	0,082	0,011	60,176	1	0,000	1,086	1,063	1,108
	Year	0,131	0,030	19,000	1	0,000	1,140	1,075	1,209
	Diff_km_tot ships	-0,002	0,000	20,412	1	0,000	0,998	0,997	0,999
	Diff_Su_L10_global	-0,047	0,012	15,233	1	0,000	0,954	0,931	0,977
	Diff_Su_L01_global	0,434	0,053	65,809	1	0,000	1,543	1,390	1,714
	Constant	-263,761	60,213	19,188	1	0,000	0,000		

e, Variable(s) entered on step 5: diff_kmships,

where

B are the unstandardised regression coefficients with their relative standard errors (S.E.), Wald is the stastistic on which is based the hypothesis testing on coefficients with relative degree of freedom (df) and significance level (Sig.) and Exp(B) is the exponential transformation of the unstandaridsed coefficient B which corresponds to the odds ratio, a proxy for the relative risk associated with a one-unit increase in the exposure (see Afifi and Clark, 1996 for reference), for which a 95% Confidence Interval (95% C.I.) is also provided.

It could be observed an inverse correlation with naval traffic figures in both species. A lower sperm whale presence probability was in fact found correlated with a higher Number ship/km tracks ratio; Whereas a lower Cuvier's beaked whale presence probability was found associated with a ship track length higher than the zone average (i.e.diff_km_tot ships). The noise indicators were also selected as significant predictors for the two models although showing both direct (i,e, Su_L10_global concerning sperm whale and diff_Su_L01_global concerning Cuvier's beaked whale) and inverse (i,e, sul01global concerning sperm whale and diffsul10global concerning Cuvier's beaked whale) relationships probably due to the collinearity of these two modeled parameters (Su_L10_globaland diff_Su_L01_global).

8. Objective 5, risk estimation map

Grounding on the results previously described, risk maps were developed for both species considering their presence probability as "species exposure" and the naval traffic density as the magnitude of the impact. Figure 67 shows the layers of species exposure and the naval traffic density. The produced risk maps will outline the zones where collisions and all the other traffic-related impacts are higher for the two species.

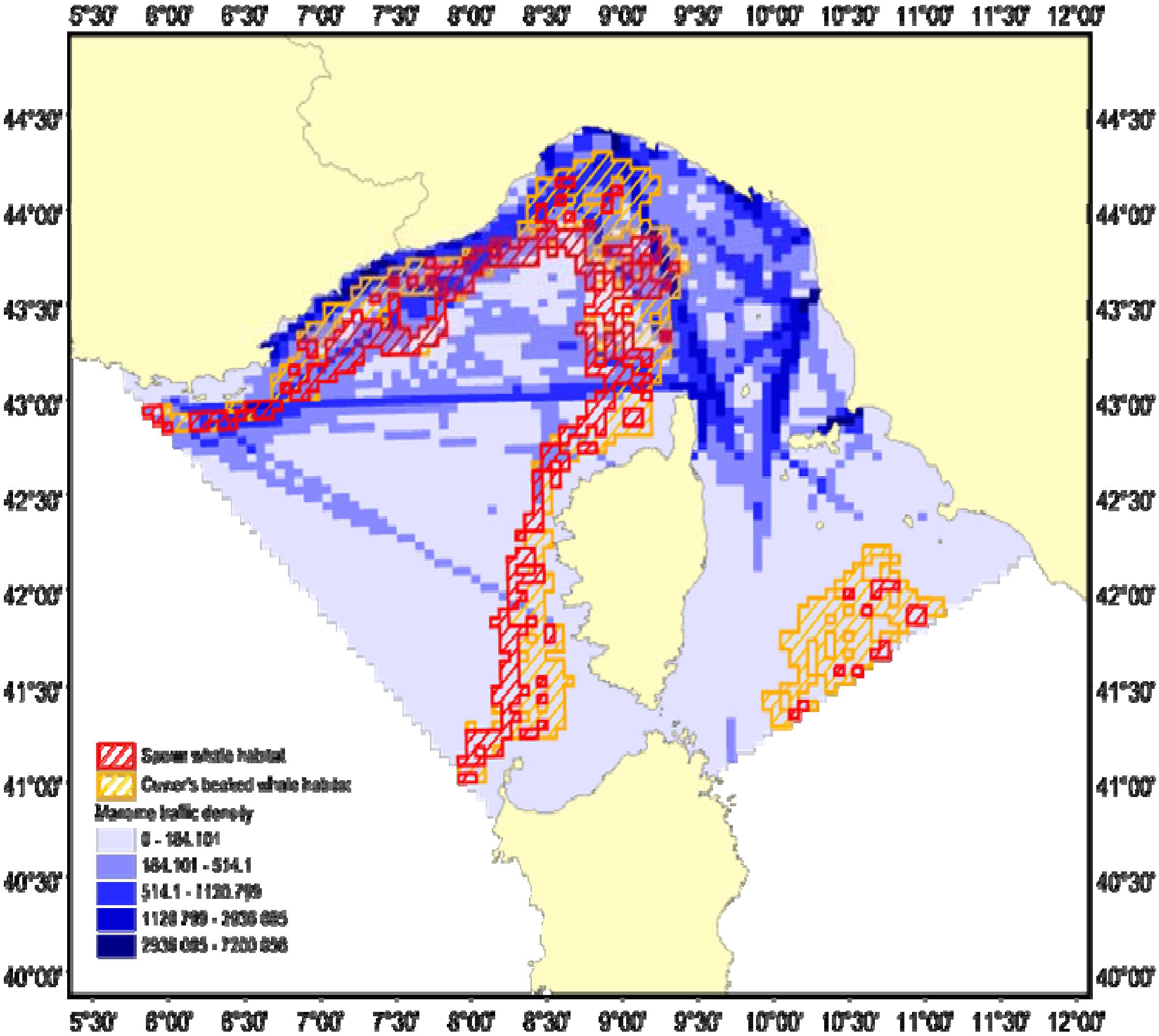


Figure 67. Optimal habitat delineation and naval traffic density.

Finally, two different risk maps were produced to identify area with higher risk of maritime traffic exposure for these two species in the Pelagos Sanctuary. The risk was evaluated by multiplying the normalized species presence probability with the normalized ship traffic density and normalized again to the unitary scale. Figure 68 and Figure 69 show the risk map concerning sperm whale and Cuvier's beaked whale.

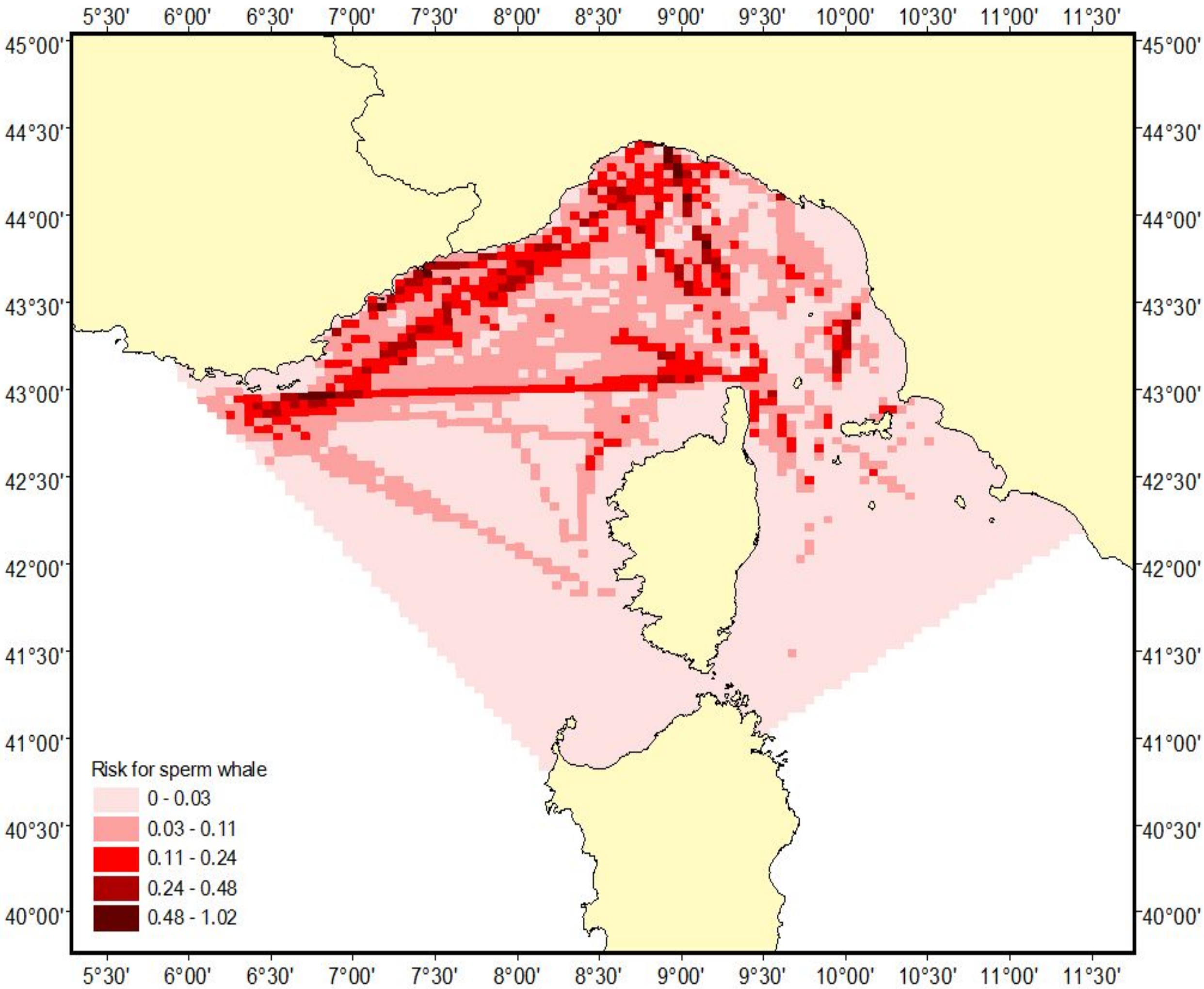


Figure 68. Risk map concerning sperm whale.

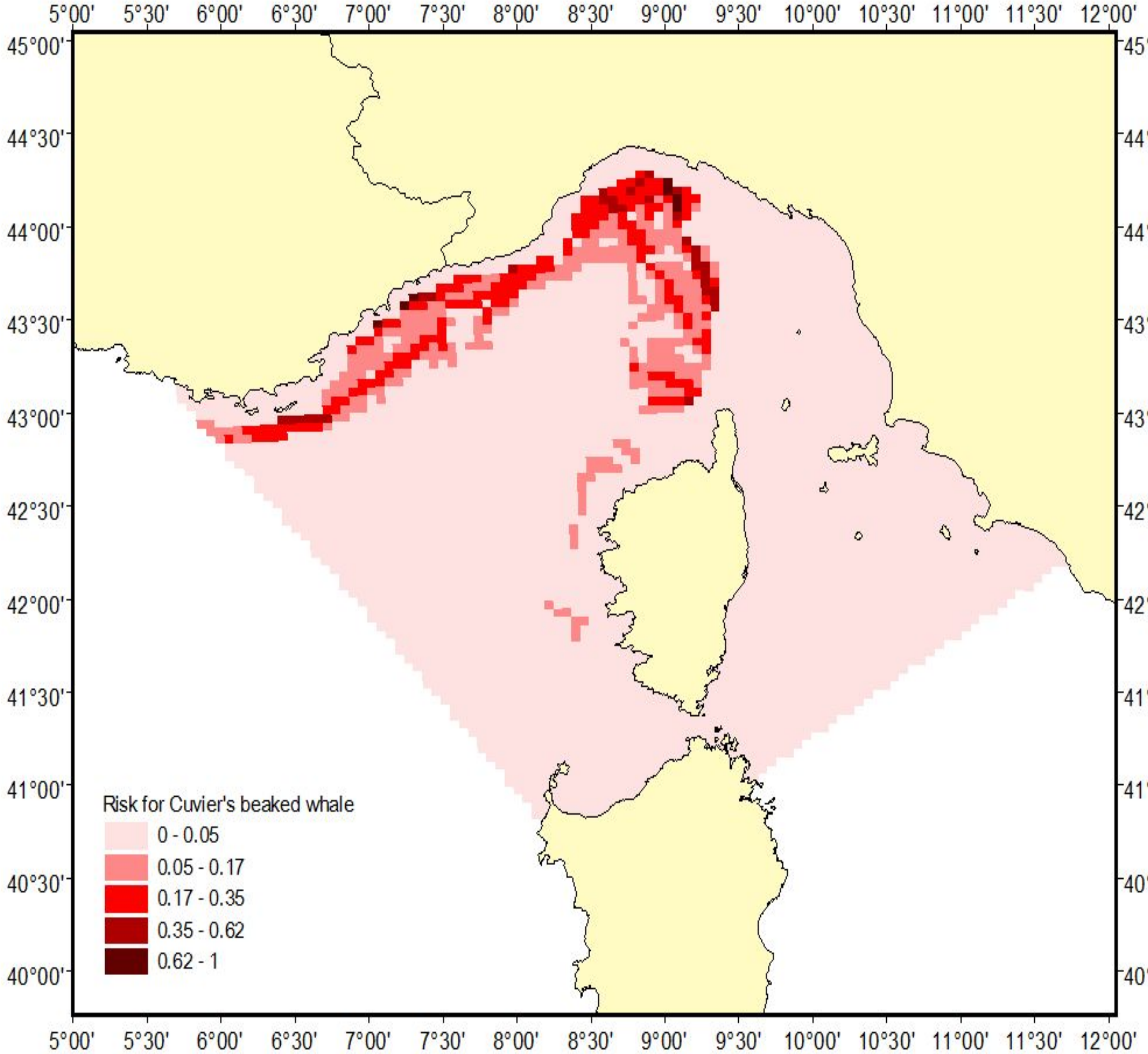


Figure 69. Risk map concerning Cuvier's beaked whale.

The two obtained maps outline the zones where collisions and all the other traffic-related impacts are higher for the two species. It can be observed that the continental slope areas are areas of significant risk for both the species whereas concerning sperm whale there is also a significant risk associated with the open basin.

9. Objective 6, dissemination to scientific community and at large

9.1. Strategy of dissemination

In October 2015, the project completed the task 5 so, at this point, it was possible to use the materials produced by the research to organize and plan the actions dedicated to disseminate the results and the experiences of the project. Based on the indications proposed into the convention with the Permanent Secretary of the Pelagos Sanctuary, this section describes the audience, the media and the state of execution of the actions scheduled.

9.1.1. Settings of the actions for public at large

The goal of the dissemination at large is to raise awareness about:

- the presence of the two studied species into the Pelagos Sanctuary (one being emblematic and the other being totally unknown);
- the anthropogenic threats of the two species;
- the role of Pelagos Sanctuary for cetacean protections in the Mediterranean Sea;
- the intensity of marine traffic and its associated human-made underwater noise;
- the needs to limit the degradation of the species habitat.

Media were selected in function of their supposed audience.

<u>For an audience of all ages</u>

Two types of events have been planned on the Pelagos territories:

- the temporary exhibition in the Oceanographic Museum (in Monaco);
- the science events (in France and in Italy).

The temporary exhibition is aimed to raise awareness about the two studied species through a photographic exhibition. Other supports (video and sounds) will be used to raise concerns about human-made underwater noise. The exposed pictures will be commented in French and in English in order to enlarge the target audience. Visitors are both local residents and tourists from Monaco, France, Italy and other countries.

Three science events have been planned:

- in Savona (Italy): Notte bianca dei ricercatori 2016 (30 September);
- in Nice (France): Festival de la Science 2016 (8-16 October);
- in Genoa (Italy): Festival della Scienza 2016 (27 October - 6 November).

The science events are aimed to raise awareness about all notions listed in the section 6.1.1. They will be in the native language.

For 18-50 year old audience

Internet is a very used support to reach the 18-45 year old audience. Using social networks and websites, it is easier to disseminate at large scientific information.

In Facebook, the project has its own page managed by CIMA Foundation. The goal of the posts are to disseminate the notions listed in § 9.1.1. They are mainly in English and can be written by all partners of the project. An average of a post per week will be published. Indeed, the success of the dissemination depends on the quantity of updates and their regularity in time, the quality and attractively of the messages. Messages are supposed to be short and as most as possible attached to pictures or other supports.

The project page is host by CIMA Foundation site (available in Italian and English). In this case, the objective is to describe in detail the project. This page is mainly static and will have very few updates.

For sea users

The project planned into its proposal to submit an article to the French Pelagos' newsletter "Bulletin de liaison Pelagos". The journal is dedicated to share experiences between research institutions working on Pelagos themes and all sea users (associations, municipalities, authorities, partners, professionals).

9.1.2. Settings of the dissemination actions for the scientific community

The goal is to diffuse the know-how acquired during the project to scientific community. The main aspects of the dissemination are about:

- the quantity of sightings of the two studied species and their spatio-temporal distribution into the Pelagos Sanctuary obtained pooling together the datasets of the partners;
- the spatial and temporal gaps of the dataset obtained;
- the description of the marine traffic and its associated noise into the Pelagos Sanctuary (with 9 specific datasets);
- the assessment Cuvier's beaked whale habitat degradation risk by marine traffic and its associated noise and sperm whale habitat degradation risk by marine traffic and its associated noise.

Different research supports were selected to communicate about the project findings: a social network, different scientific congress, at least a publication in peer-reviewed journal and some presentations during other meetings.

Peer-reviewed papers, scientific meetings

Publication of results in peer-reviewed journal is an integral and essential component of research. Publishing in high-quality peer-reviewed journals will enhance the reputation of the team that work on the paper and help get the work cited by others. Automatically, it has positive repercussions on the funding institution named in the acknowledgement. Moreover, open-access publishing helps the article to reach more people because it is a way of removing the subscription barrier.

On another hand, presentations during scientific meetings (conferences, workshops or other types of meetings) is complementary component of the publication into peer-reviewed journals. It allows to interact with the scientific community more directly.

In both case, the choice of the conference or the journal depends of the target audience. The project covers various topics: marine noise pollution, marine noise assessment and modelling, marine traffic, cetacean conservation, cetacean threats, cetacean acoustic, deep-divers ecology, ecological impact assessment, marine planning and policy, Marine Protected Area strategy.

The contributions are usually published in English excepted for national congress or national journals for which the contribution can be in the native language.

SEAWETRA

The web platforms allow to visualize data and maps, overlapping them eventually with your own geographic information (using WMS or WFS technologies), to an unlimited number of users that are anywhere at all times. Moreover, the current developments of the Geodata Infrastructure allow to plot on a same environment, different geographic resources from eventually different providers (at different scale or with different geographic system projections) in real-time, improving the use and re-use of on-line data (ensuring in this way, the use updated data).

Unlocking the data for use and re-use improves also the profits of the project. For the project, it is proposed to visualize some of layers created for the project on SEAWETRA, a web-platform designed for the Marine Spatial Planning for cetacean conservation (please consult the section 3 INSPIRE compliancy to see the detail).

<u>Social network</u>

ResearchGate (as for instance Academia.edu) is a social network dedicated to disseminate, communicate and measuring the impact of each contributor on scientific community. Its community is made of scientists from all countries. Each contributor has its own profile, can publish its scientific work (peer-reviewed papers, congress presentations, datasets) and is in contact with other scientists (followers).

For the project, ResearchGate is used to invite the scientific community to know about the aspects listed in § 9.1.2. The medium will be used permanently (as soon as a contribution is available) to publish the contribution linked to the project. Here again, the success of the dissemination depends on the quantity and the quality of updates and on the upload of the full-text contributions.

9.2. Materials available for dissemination

9.2.1. Project's logo

From the three initial logos created, one particular logo has been selected (the lower one on Figure 70).

Figure 70. The three logos initially created.

It has been then modified adding the shape of a sperm whale in order to make easier the understanding of the logo relatively to the project's aim. Two versions have been created and are presented on Figure 71. The definitive logo is the logo on the right.

Figure 71. Two other logos created with the definitive logo on the right.

9.2.2. The project's page on the CIMA Foundation website

The project's page (Figure 72) has been created in November 2015, using the layout and the type of information presented on the other pages describing other projects of CIMA Foundation.

The link is: http://www.cimafoundation.org/cima-foundation/pelagos-noise/

Figure 72. The page of the project hosted on the the CIMA Foundation website.

9.2.3. The project's Facebook page

The project's facebook page (Figure 73) has been launched on 11 January 2016 at the following link: https://www.facebook.com/Pelagos-Noise-1551598065166352

Since, 4 posts have been published on an average of one per week. To date, 69 persons "Like" the page, the coverage totalizes 774 consultations and 112 interactions with the posts. Looking the statistics of the last 28 days, the audience is made of a majority of women (55%). The main categories of age consulting more the page are the 25-34 (49%), the 18-24 (15%) and the 35-44 (20%). The countries most represented are Italy (in first position), France, Nederland, Spain, RU, Portugal, Germany, Denmark, Greece, Switzerland, USA and Canada.

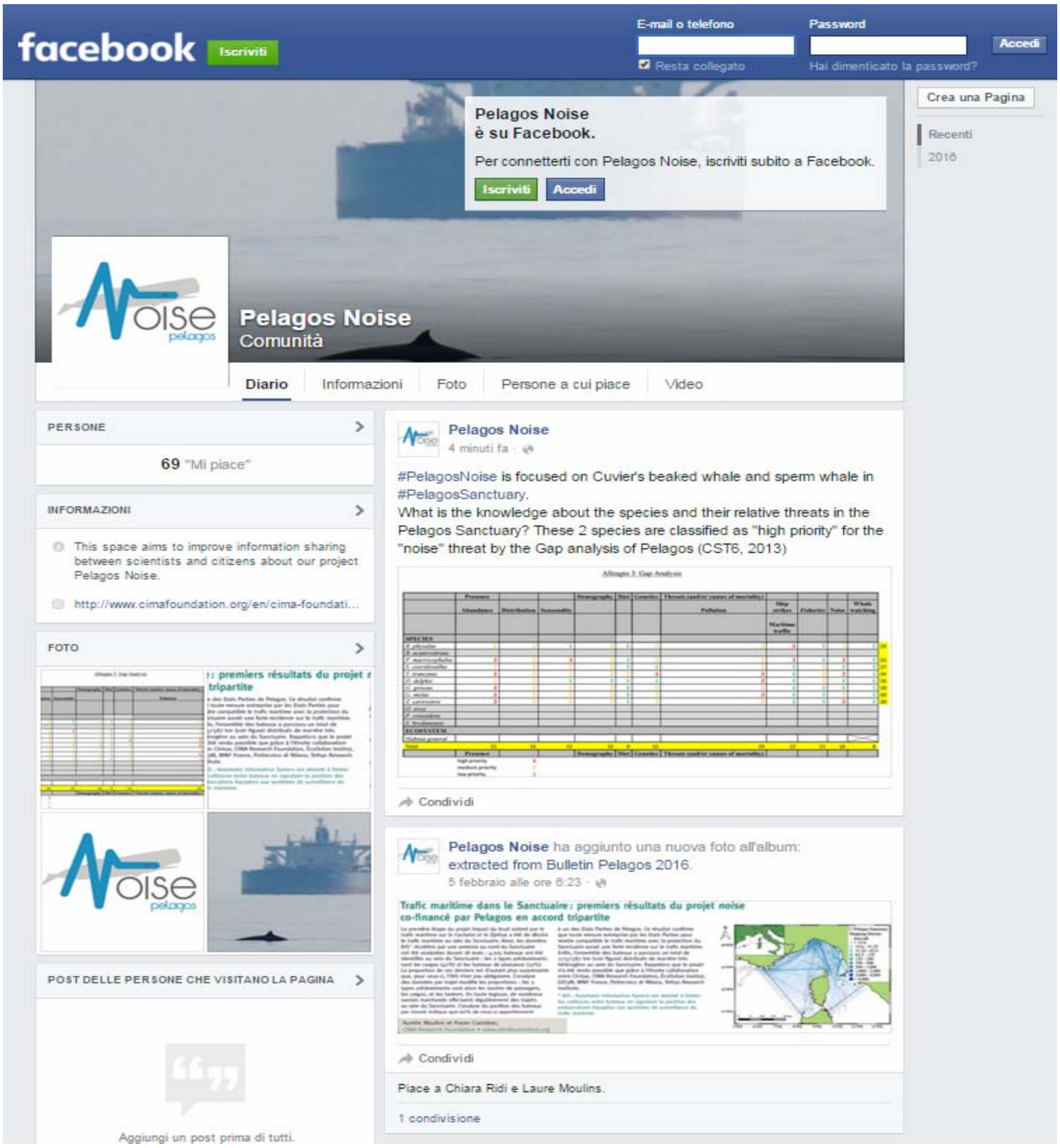


Figure 73. The page of the project on Facebook.

9.2.4. Shapefiles available on open-access

For this project, as it is explained into the section 3 INSPIRE compliancy, CIMA Foundation publishs 9 layers of the marine traffic data in open-access (Figure 74). The layers are published in SEAWETRA at the following link:
http://apps.cimafoundation.org/seawetra/app.html

They are stored in the folder named "TransportNetworks_MarineTraffic [NoisePmZcPELAGOSint]".

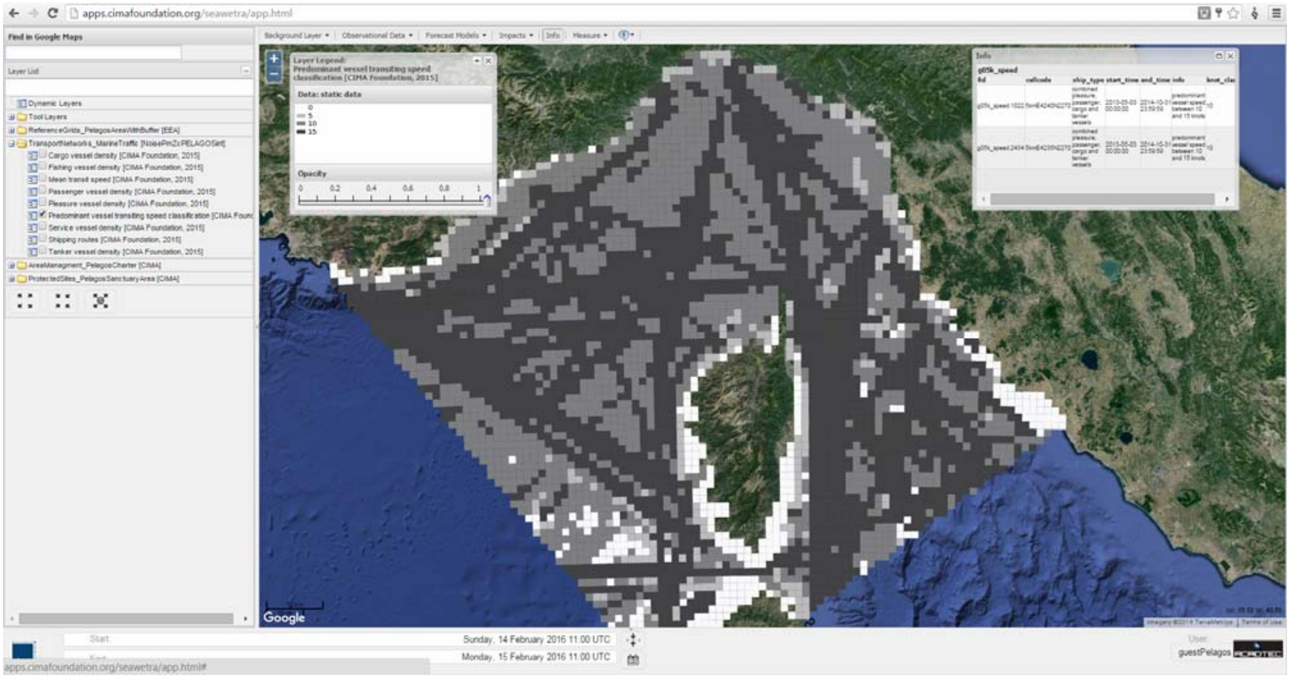


Figure 74. Example of shapefile produced for the project visualized on SEAWETRA, a web platform to consult geographic information.

9.2.5. Research Gate feedings with the produced materials

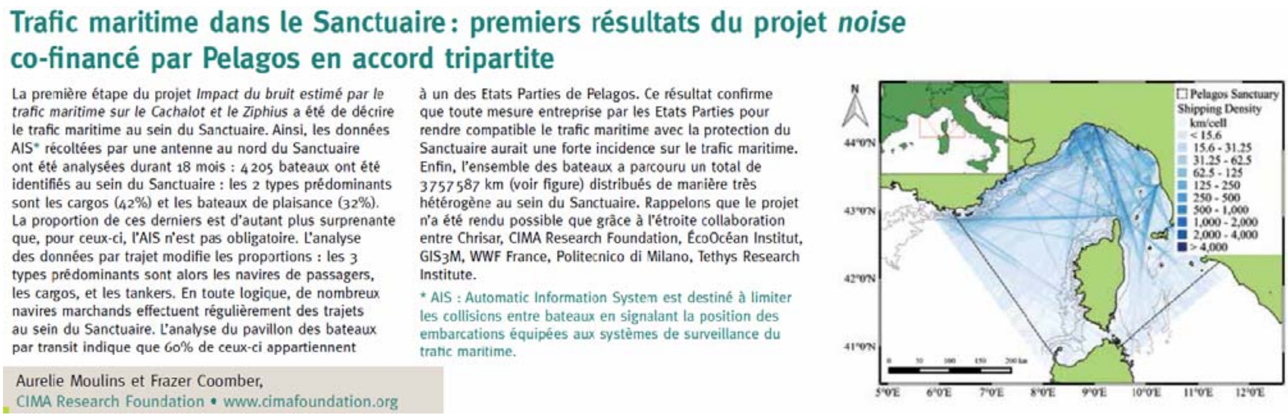
CIMA recommends to all researchers involved into the project to publish its own materials produced for the project (presentations for conferences, papers or datasets) on its profile. When possible, it is also recommend to use both logo and #PelagosNoise.

9.2.6. The article in Bulletin de liaison Pelagos 2016

The article "Trafic maritime dans le Sanctuaire : premiers résultats du projet noise co-financé par Pelagos en accord tripartite" was submitted the 1 October 2015. It is for divulgation at large, included some of the results of the project and is written in French. The 14 January 2016, we have been informed that the article was accepted. This issue will be printed in 2000 copies and distributed in digital copy at the following link:
http://www.sanctuaire-pelagos.org/fr/sensibilisation/bulletins-de-liaison-annuel

A translation in English and Italian is available on the CIMA Foundation's website.

The article has been then extracted and linked in the Facebook page of the project.



Trafic maritime dans le Sanctuaire : premiers résultats du projet *noise* co-financé par Pelagos en accord tripartite

La première étape du projet *Impact du bruit estimé par le trafic maritime sur le Cachalot et le Ziphius* a été de décrire le trafic maritime au sein du Sanctuaire. Ainsi, les données AIS* récoltées par une antenne au nord du Sanctuaire ont été analysées durant 18 mois : 4 205 bateaux ont été identifiés au sein du Sanctuaire : les 2 types prédominants sont les cargos (42%) et les bateaux de plaisance (32%). La proportion de ces derniers est d'autant plus surprenante que, pour ceux-ci, l'AIS n'est pas obligatoire. L'analyse des données par trajet modifie les proportions : les 3 types prédominants sont alors les navires de passagers, les cargos, et les tankers. En toute logique, de nombreux navires marchands effectuent régulièrement des trajets au sein du Sanctuaire. L'analyse du pavillon des bateaux par transit indique que 60% de ceux-ci appartiennent à un des Etats Parties de Pelagos. Ce résultat confirme que toute mesure entreprise par les Etats Parties pour rendre compatible le trafic maritime avec la protection du Sanctuaire aurait une forte incidence sur le trafic maritime. Enfin, l'ensemble des bateaux a parcouru un total de 3 757 587 km (voir figure) distribués de manière très hétérogène au sein du Sanctuaire. Rappelons que le projet n'a été rendu possible que grâce à l'étroite collaboration entre Chrisar, CIMA Research Foundation, ÉcoOcéan Institut, GIS3M, WWF France, Politecnico di Milano, Tethys Research Institute.

* AIS : Automatic Information System est destiné à limiter les collisions entre bateaux en signalant la position des embarcations équipées aux systèmes de surveillance du trafic maritime.

Aurelie Moulins et Frazer Coomber,
CIMA Research Foundation • www.cimafoundation.org

Figure 75. The article published in Bulletin de liaison Pelagos 2016.

9.2.7. The oral presentation during the Ocean Noise conference 2015

Considering the topic of the project, it has been decide to attend to the conference Ocean Noise 2016: Towards an Acoustically Sound Ocean, in Bacelona (Spain), 11-15 May 2015.

The short description of the website of the conference is:

"The growing scientific and societal concern about the effects of underwater sound on marine ecosystems has been recently recognized through the introduction of several international initiatives aiming at measuring the environmental impact of ocean noise at large spatial and temporal scales. OCEANOISE2015 will bring together international leading experts in noise measurement, modeling and mapping, physiological and behavioural effects as well as regulation and mitigation procedures. OCEANOISE2015 format aims at favouring a dynamic exchange of the latest findings in the field of ocean noise in order to assist in providing ocean users with the best scientific knowledge and technical solutions to address operational and environmental issues".

The work called "Measurements of the shipping levels in the Genoa Canyon system to address the impact on an acoustically sensitive cetacean species Ziphius cavirostris" has been submitted the 22 January 2015, and accepted as an oral in the session "Shipping".

The presentation (Figure 76) was realized the 11 May 2015.

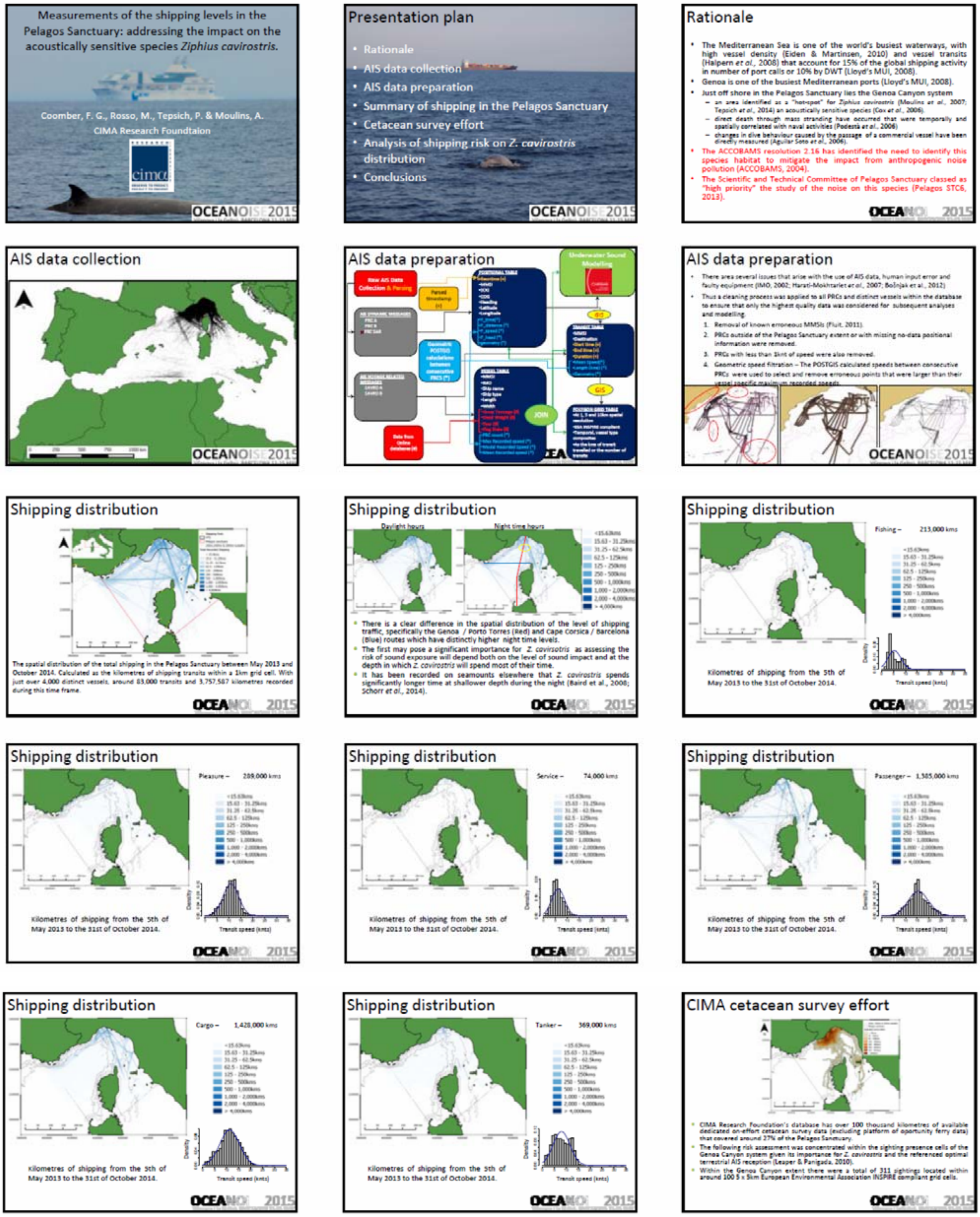


Figure 76. Oral presentation realized the 11 May 2015 at the conference Ocean Noise

(*continued on the next page*)

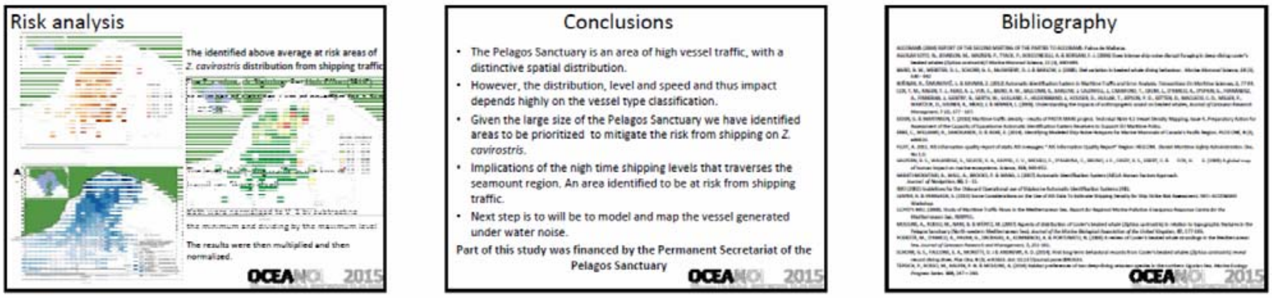


Figure 76. Oral presentation realized the 11 May 2015 at the conference Ocean Noise (continued).

9.2.8. The poster presentation during the Ocean Science Meeting 2016

The conference Ocean Sciences meeting was also selected considering that it covers all areas of ocean sciences. Moreover, a session is dedicated to "Advances in the Ecology, Behaviour, Physiology, or Conservation of Marine Top Predators". The session "focuses on studies of the ecology, behavior, and physiology of marine top predators that either advance our scientific understanding or support the conservation of these important taxa. Because Ocean Sciences provides a unique forum for marine ecologists, marine biologists, and oceanographers to interact, contributions from researchers studying a wide variety of taxa, including fish, squid, reptiles, seabirds, and marine mammals, from anywhere in the world's oceans are welcomed".

In 2016, the meeting is in New Orleans, LA, United States (21-26 February 2016). The work called "Description of the Marine Traffic inside the Pelagos Sanctuary for Mediterranean Marine Mammals: Key Information for Conservation Policy" has been submitted the 25 September 2015, and accepted as a poster presentation.

The presentation (Figure 77) will be realized the 22 February.

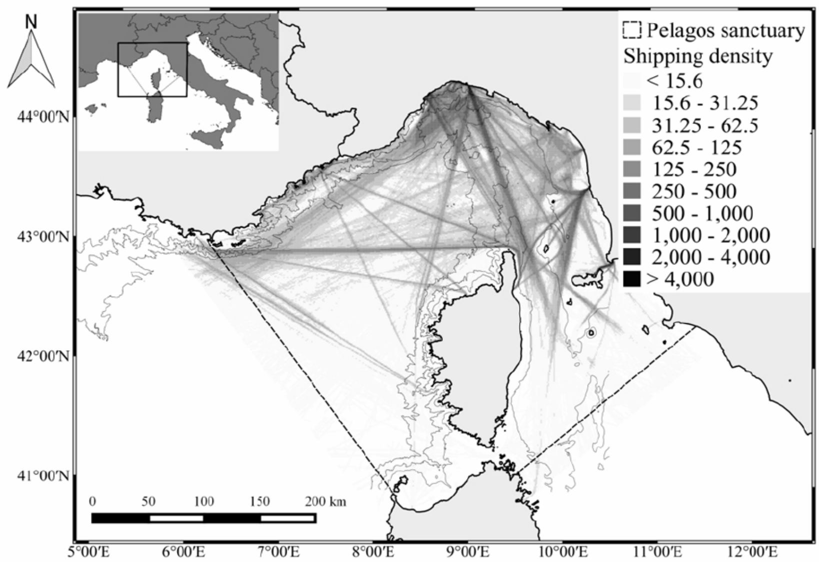
Description of the Marine Traffic inside the Pelagos Sanctuary for Mediterranean Marine Mammals: Key Information for Conservation Policy.

Aurelie Moulins, CIMA Research Foundation, Savona, Italy

Abstract Text:

The International Sanctuary for the Protection of Mediterranean Marine Mammals was established in order to improve conservation measures where cetaceans are abundant and highly impacted by human pressures. Shipping is one of the main human activity in the Sanctuary with many impacts on the ecosystem but still, it is not well known. This study presents the results of shipping collected during 18 consecutive months by an AIS (Automatic Information System) antenna. More than 3 millions of km were covered by the 6 types of ships: passenger, cargo, tanker, fishing, pleasure and service. The predominant types of the vessel list were cargo (41.8%) and pleasure vessels (31.8%) and over half (62.9%) were classed as commercial vessels (passenger, cargo, tanker). Considering the distance covered, passenger and cargo vessels were the most predominant (with 37% and 38% kilometers respectively) and the commercial vessels contribute with 85% of the total kilometers. Compared to the global scale, the study highlights the importance and predominance of intra-Mediterranean transits made especially by passenger crafts between the Italian and French mainland to the islands of Corsica and Sardinia. The spatial distribution was not uniform and the density was found to be vessel type dependent. Many high densities displayed distinct shipping routes and impacted on different jurisdictional boundaries: a third (32%) of the commercial traffic was recorded outside the territorial waters and on different ecological areas of the sanctuary: the main shipping corridors traverse all ecological regions. Overlapping the shipping density with the different cetacean species distributions, it was possible to evaluate spatial vulnerability of the different species and help to focus Pelagos protection measures on more restricted areas. The vessel speeds were found to be high and dependent on vessel type with specific spatial distributions. This work confirms that passenger vessels, and to some degree the other commercial vessels, travelled faster than other ships but had spatially localized higher speeds within distinct shipping corridors. Considering that ship-whale collision probability increases with vessel speed, this study points out areas of higher vulnerability and the more impacting types of vessels.

24/9/2015 Submission Completed



The spatial distribution of the total combined shipping in the Pelagos Sanctuary recorded by the Savona AIS receiver during the total sampling period as the summation of km of shipping transits within a 1km grid cell.

Figure 77. Abstract submitted to the conference Ocean Sciences meeting.

9.2.9. The poster presentation during the European Cetacean Society 2016

The Annual Conference of the European Cetacean Society aims to promote and advance the scientific studies and conservation efforts of marine mammals and to gather and disseminate information about cetaceans to members of the Society and the public at large. The 2016 edition will be at Funchal, Madeira the 14-16 March.

The work called "Assessing the ecological risk of anthropogenic noise pollution from maritime traffic on the Cuvier's beaked whale in the hotspot of Genoa Canyon" has been submitted the 23 October 2015, and accepted as an oral presentation.

30TH CONFERENCE OF THE
EUROPEAN CETACEAN SOCIETY
MADEIRA · 2016

Assessing the ecological risk of anthropogenic noise pollution from maritime traffic on the Cuvier's beaked whale in the hotspot of Genoa Canyon.

Coomber, Frazer Guy, Rosso, Massimiliano, Tepsich, Paola, Origné Laurent, Moulins, Aurelie

Previous studies have highlighted the behavioural disruption of anthropogenic noise pollution on Cuvier's beaked whale (CBW) and the coincidental mass strandings associated with the use of military Sonar. The aim of this work is to assess the ecological effect of the marine noise pollution on the CBW hotspot in the northwest Mediterranean Sea and determine if there are risk areas. An 11year cetacean survey dataset was used to fit a 5km descriptive Bernoulli Generalized Additive Model (GAM) and a 1km predictive logistic GAM using remotely sensed, bathymetric and impact (calculated transits and modelled noise using AIS data) predictor variables. A 1km normalized risk index map was then created using the predicted probable habitat and the maritime transit frequency and the associated modelled noise L1max. The total survey covers 3,524km^2 and contains 109 cells of 5km^2 and 391 cells of 1km^2 with respectively 66 and 195 CBW presence cells. The 5km impact model was successfully fitted with 6 significant predictors: eastward current ($p=0.018$), depth ($p=0.002$), northward current ($p=0.003$), chlorophyll ($p=0.042$), transit frequency ($p=0.067$) and aspect cosine ($p=0.140$). The model explained 51.6% of the deviance and had a moderate evaluation C-index value (0.753 ± 0.055). Results indicate a negative effect between the marine traffic and the CBW sighting probability. The 1km predictive habitat model found 61% of the Genoa Canyon was suitable CBW habitat. Of this habitat 3.7% and 70% were found to be at higher than average risk from shipping traffic and underwater noise pollution respectively. This work shows for the first time that maritime traffic and its correlated noise pollution ($r=0.794$) has a detrimental ecological effect on CBW. It also highlights several areas at risk from these impacts so this information should be integrated into future conservation management plans.

Figure 78. Abstract submitted to the conference of the European Cetacean Society.

9.3. Materials submitted for dissemination

9.3.1. Publication

It has been decided to present the more important results of the study about marine traffic to the journal "Marine Policy". Here is the description of the journal on its website:
"Marine Policy is the leading journal of ocean policy studies. It offers researchers, analysts and policy makers a unique combination of analyses in the principal social science disciplines relevant to the formulation of marine policy. Major articles are contributed by specialists in marine affairs, including marine economists and marine resource managers, political scientists, marine scientists, international lawyers, geographers and anthropologists. Drawing on their

expertise and research, the journal covers: international, regional and national marine policies; institutional arrangements for the management and regulation of marine activities, including fisheries and shipping; conflict resolution; marine pollution and environment; conservation and use of marine resources. Regular features of Marine Policy include research reports, conference reports and reports on current developments to keep readers up-to-date with the latest developments and research in ocean affairs".

The 8 December 2015, the paper called "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" has been submitted the to the journal. The 5 Febbruary 2016, the editor invites us to resubmit the paper accordingly to the minor revisions indicated by the reviews. The authors are working on the new version of the manuscript.

9.3.2. The event organized during the European Researchers' Night 2016

Polo di Ricerca e Innovazione Energia Sostenibile in collaboration with Università degli Studi di Genova, Centro di Servizio per il Polo Universitario di Savona have submitted the 13 Jannuary 2016 to the call H2020--MSCA-NIGHT -2016 "European Researchers' Night" different events including 3 organized by CIMA Foundation and in particular, one event called "Living into the ocean: how the noise of human activities can disturb the life of our deep-divers".

9.3.3. #whalegames, the learning laboratory organized during the Festival della Scienza 2016

The propoasal, written in Italian, has been submitted on 15 Febbruary 2016 (Figure 79). The learning laboratory called #whalegames is designed for school (6-13 year old) and community groups (maximum capacity is 40). 60-minute sessions will guide students through recreative card game designed and developed prototype solutions to cetacean conservation challenges.

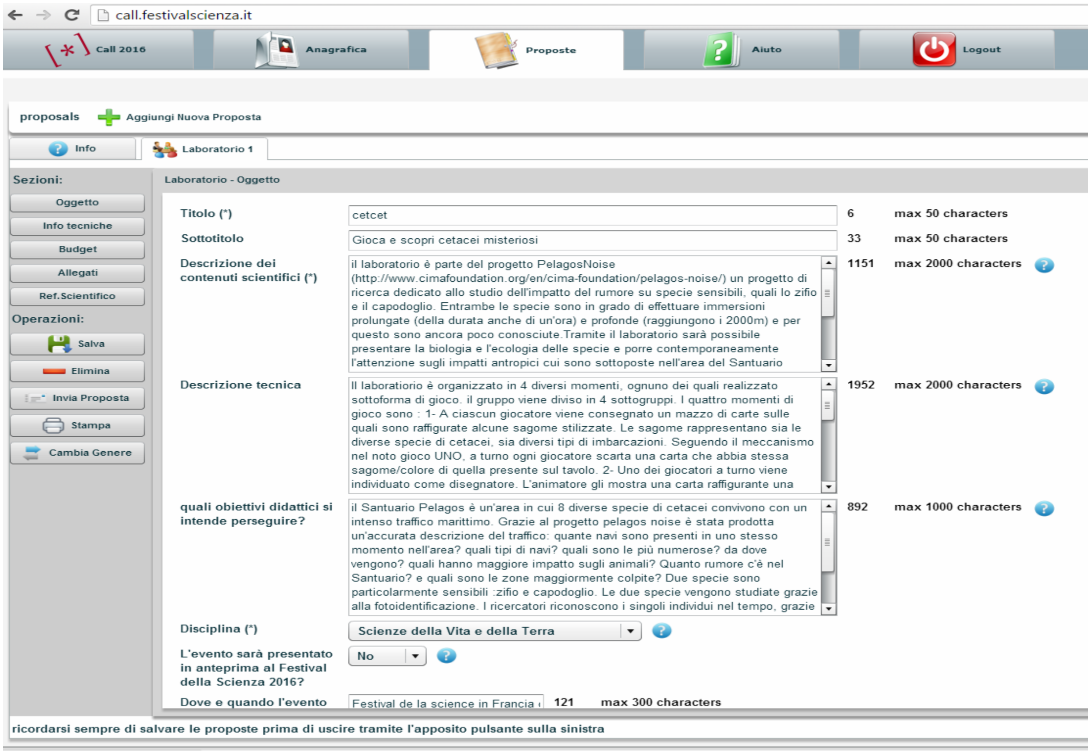


Figure 79. Proposal submitted the 15 February 2016.

9.4. Materials in preparation for dissemination

9.4.1. The learning laboratory during the Festival de la Science 2016

The learning laboratory submitted to the Festival della Scienza 2016 will be translated and implemented according to the advices of the Service Culture Sciences of Université Nice Sophia-Antipolis, coordinator of the Village des sciences de Valrose in order to be submitted to Fête de la science in PACA (represented by http://www.lespetitsdebrouillardspaca.org/). According to the coordinator of the RACA Region, the call will be published the 29 Febbruary 2016 and will close at the end of March.

9.4.2. The temporary exhibition in the Oceanographic Museum (in Monaco)

The selection of the photos are in progress. The sound media aiming to demonstrate the impact of the marine traffic noise on the marine environment will be realized in collaboration with Woods Hole Oceanographic Institution. They will provide sounds of Cuvier's beaked whale (transformed to be audible), sperm whale and vessels. A short documentary about the two species realized by Stéphane Granzotto will be projected. The final document presenting the exhibition will be produced in April in order to submit it to the Museum.

9.4.3. Papers

A least another paper describing the risk maps of the two species related to marine traffic is in preparations.

10. References

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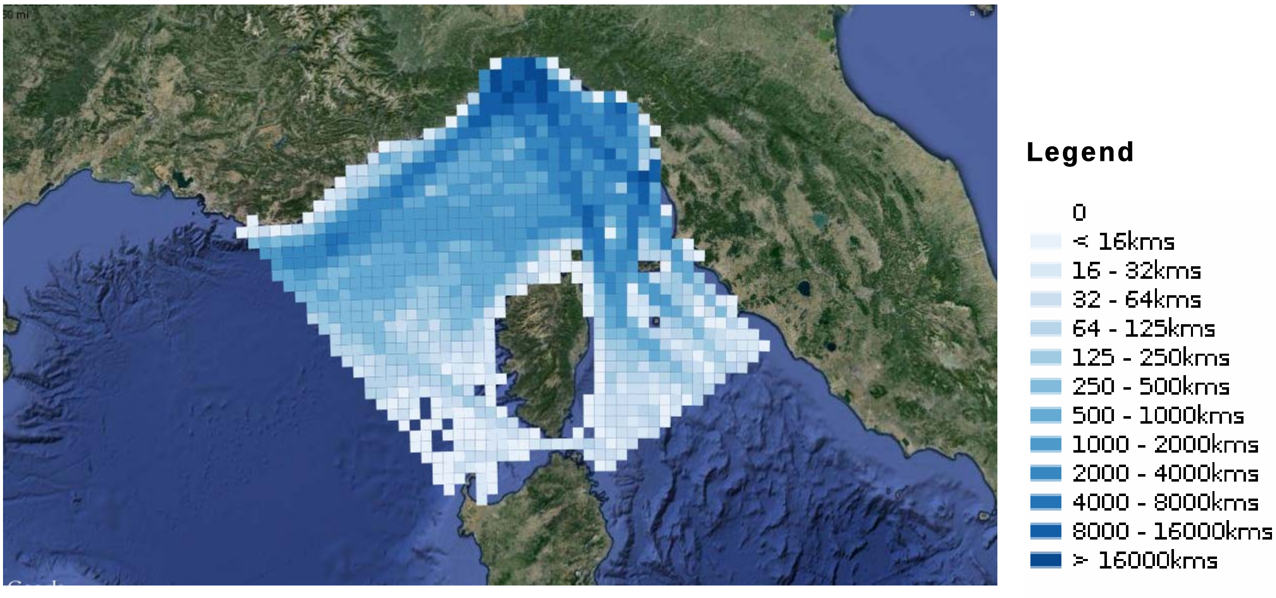
11. Annex: Static layers available into the WebGIS SEAWETRA with the metadata sheets

Layer title
cargo vessel density from AIS [CIMA Foundation, 2015]

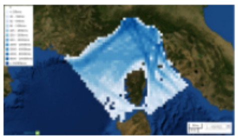


Abstract
Density of cargo vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA Foundation's AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the cargo vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Total_Kms
May_2013Km
Jun_2013Km
Jul_2013Km
Aug_2013Km
Sep_2013Km
Oct_2013Km
Dec_2013Km
Jan_2014Km
Feb_2014Km
Mar_2014Km
Apr_2014Km
May_2014Km
Jun_2014Km
Jul_2014Km
Aug_2014Km
Sep_2014Km
Oct_2014Km
Reception
Display

CARGO VESSEL DENSITY FROM AIS [CIMA FOUNDATION, 2015]



Identification info

Title	cargo vessel density from AIS [CIMA Foundation, 2015]
Date	2015-02-16T09:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	Density of cargo vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA Foundation's AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the cargo vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions**: Limitation not listed
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

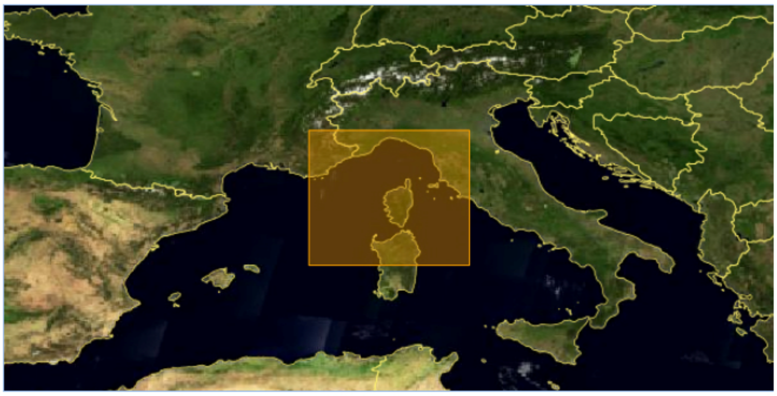
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

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Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
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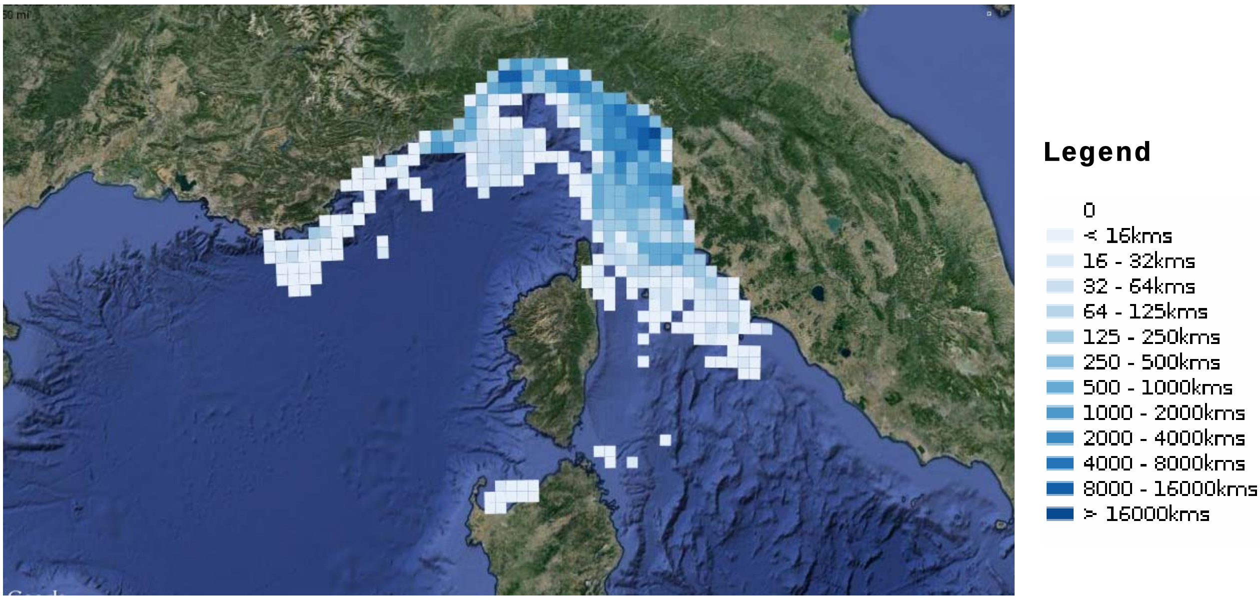
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
fishing vessel density from AIS [CIMA Foundation, 2015]



Abstract

Density of fishing vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA Foundation's AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the cargo vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea.

The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Total_Kms
May_2013Km
Jun_2013Km
Jul_2013Km
Aug_2013Km
Sep_2013Km
Oct_2013Km
Dec_2013Km
Jan_2014Km
Feb_2014Km
Mar_2014Km
Apr_2014Km
May_2014Km
Jun_2014Km
Jul_2014Km
Aug_2014Km
Sep_2014Km
Oct_2014Km
Reception
Display

FISHING VESSEL DENSITY FROM AIS [CIMA FOUNDATION, 2015]

Identification info

Title	fishing vessel density from AIS [CIMA Foundation, 2015]
Date	2015-02-16T09:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	Density of fishing vessel transits, expressed in kilometres per squared kilometres, within the spatial reference EPSG:3035 and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA Foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure, a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea. The data is produced for the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System , transport networks .
Access constraints	**Copyright**: Exclusive right to the publication, production, or sale of the rights to a literary, dramatic, musical, or artistic work, or to the use of a commercial print or label, granted by law for a specified period of time to an author, composer, artist, distributor
Use constraints	**Copyright**: Exclusive right to the publication, production, or sale of the rights to a literary, dramatic, musical, or artistic work, or to the use of a commercial print or label, granted by law for a specified period of time to an author, composer, artist, distributor
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

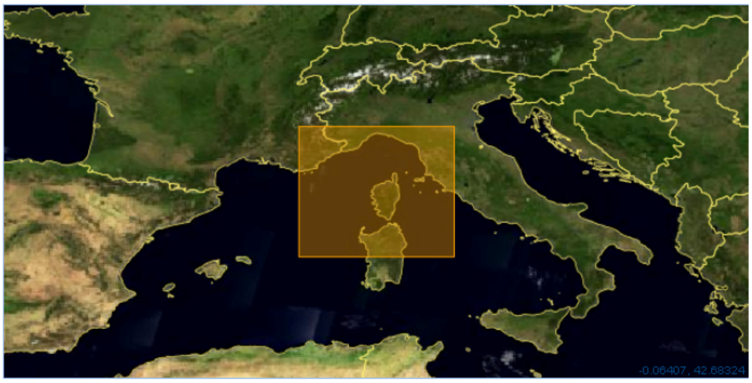
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

Metadata

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Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T17:40:44
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
Position name	BIO
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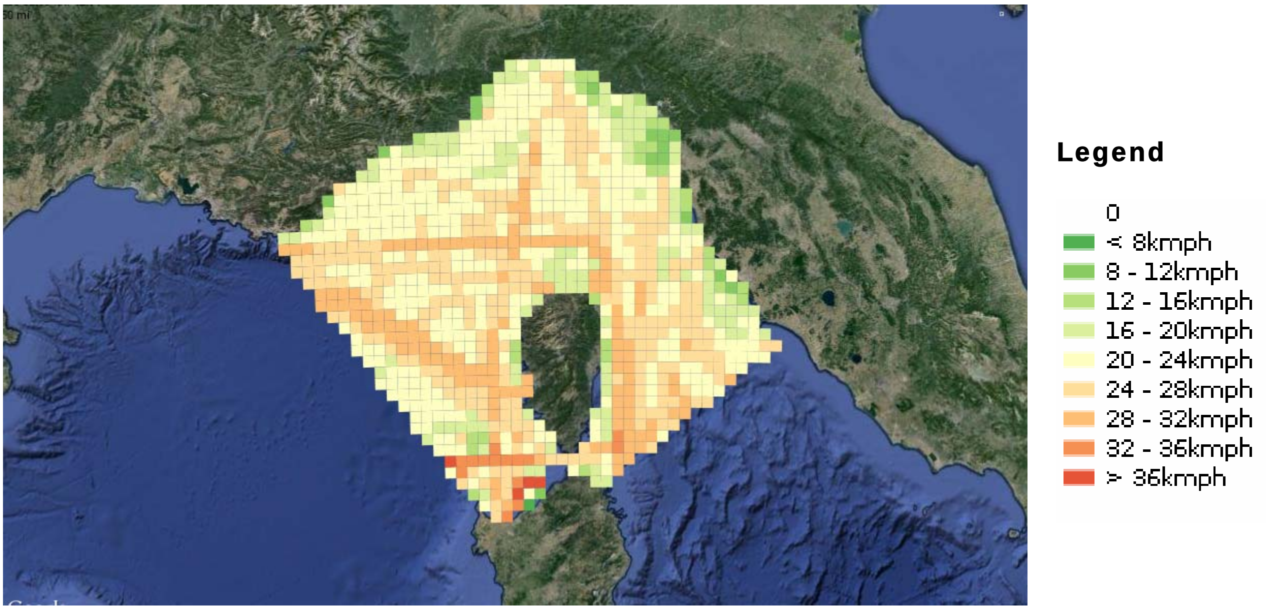
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
mean transit speed per grid cell [CIMA Foundation, 2015]



Abstract

The mean speed in kilometres per hour and knots of all the combined shipping transits that traverse each grid cell and the number of transits within 4 (5 to 10, 10 to 15, 15 to 20 and 20knts and above) speed classifications. The shipping transits were calculated from the AIS dynamic point data which was recorded from an antenna located at 4430°N and 8.45°E between May 2013 and October 2014. Both shape files were created in spatial reference system EPSG: 3035, so that the number of transits and the attributes of the transits could be summarized into each cell in a GIS platform using spatial analysis.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Kmph
Knots
Transit
5To10Knt
10To15Knt
15To20Knt
20Knt
Reception
Display

MEAN TRANSIT SPEED PER GRID CELL [CIMA FOUNDATION, 2015]

Identification info

Title	mean transit speed per grid cell [CIMA Foundation, 2015]
Date	2015-02-16T08:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	The mean speed in kilometres per hour and knots of all the combined shipping transits that traverse each grid cell and the number of transits within 4 (5 to 10, 10 to 15, 15 to 20 and 20knts and above) speed classifications. The shipping transits were calculated from the AIS dynamic point data which was recorded from an antenna located at 4430ºN and 8.45ºE between May 2013 and October 2014. Both shape files were created in spatial reference system EPSG: 3035, so that the number of transits and the attributes of the transits could be summarized into each cell in a GIS platform using spatial analysis. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations, specifically the spatial distribution of vessel speeds.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions**: Limitation not listed
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

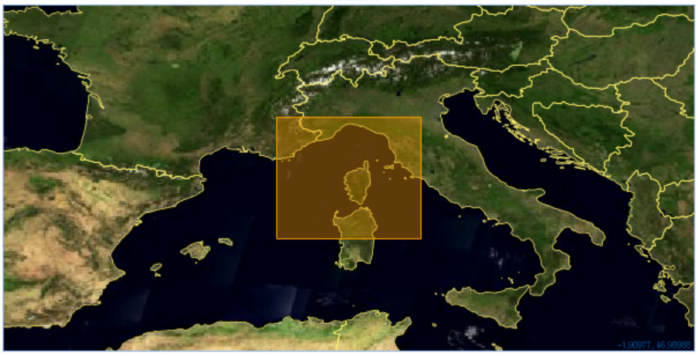
Extent

Geographic bounding box

WGS 84

North bound 44.68279

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

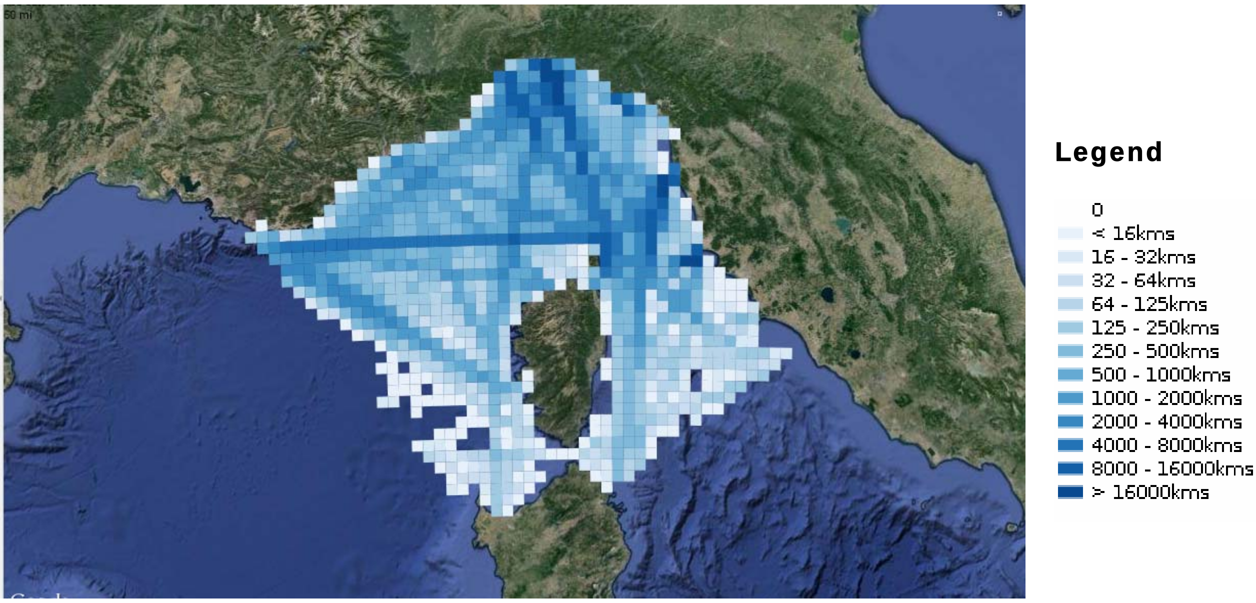
Metadata

File identifier	b1b56c70-f156-4e07-8d58-5dd32cccef23
Metadata language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T23:21:57
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
Position name	BIO
Role	**Point of contact**: Party who can be contacted for acquiring knowledge about or acquisition of the resource
Voice	0039019230271
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
passenger vessel density from AIS [CIMA Foundation, 2015]



Abstract
Density of passenger vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the passenger vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Total_Kms
May_2013Km
Jun_2013Km
Jul_2013Km
Aug_2013Km
Sep_2013Km
Oct_2013Km
Dec_2013Km
Jan_2014Km
Feb_2014Km
Mar_2014Km
Apr_2014Km
May_2014Km
Jun_2014Km
Jul_2014Km
Aug_2014Km
Sep_2014Km
Oct_2014Km
Reception
Display

PASSENGER VESSEL DENSITY FROM AIS [CIMA FOUNDATION, 2015]

Identification info

Title	passenger vessel density from AIS [CIMA Foundation, 2015]
Date	2015-02-16T09:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	Density of passenger vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the passenger vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions**: Limitation not listed
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

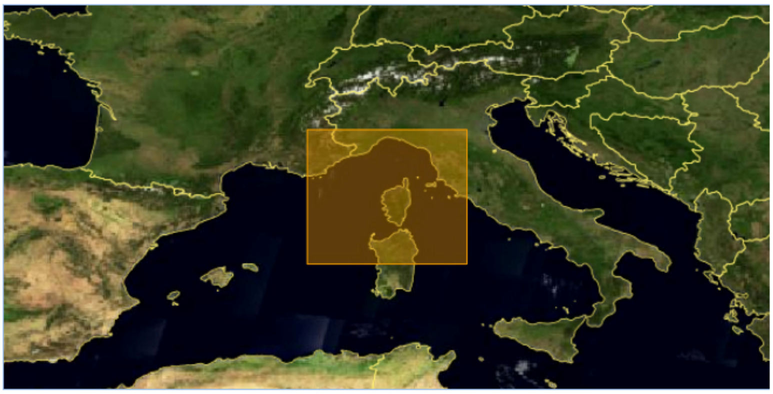
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

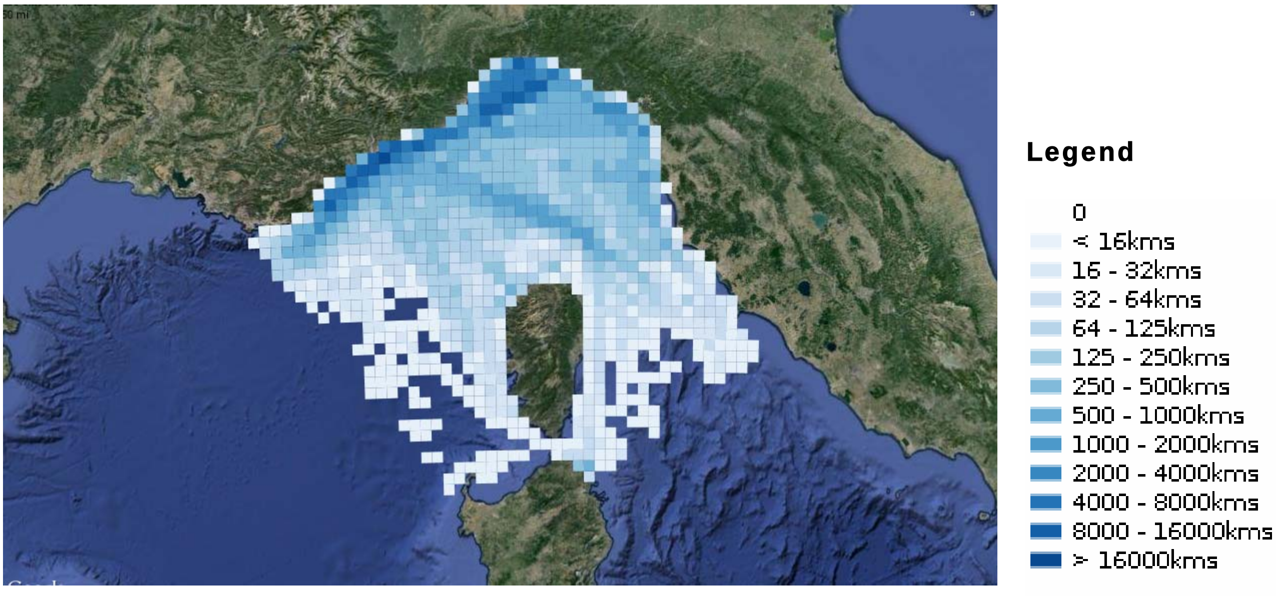
Metadata

File identifier	736d92a6-6dc1-4808-bc07-5996bbf0dd3f
Metadata language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T18:11:01
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
Position name	BIO
Role	**Point of contact**: Party who can be contacted for acquiring knowledge about or acquisition of the resource
Voice	0039019230271
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
pleasure craft density from AIS [CIMA Foundation, 2015]



Abstract
Density of pleasure craft transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the passenger vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Total_Kms
May_2013Km
Jun_2013Km
Jul_2013Km
Aug_2013Km
Sep_2013Km
Oct_2013Km
Dec_2013Km
Jan_2014Km
Feb_2014Km
Mar_2014Km
Apr_2014Km
May_2014Km
Jun_2014Km
Jul_2014Km
Aug_2014Km
Sep_2014Km
Oct_2014Km
Reception
Display

PLEASURE CRAFT DENSITY FROM AIS [CIMA FOUNDATION, 2015]

Identification info

Title	pleasure craft density from AIS [CIMA Foundation, 2015]
Date	2015-02-16T08:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	Density of pleasure vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the pleasure vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions**: Limitation not listed
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

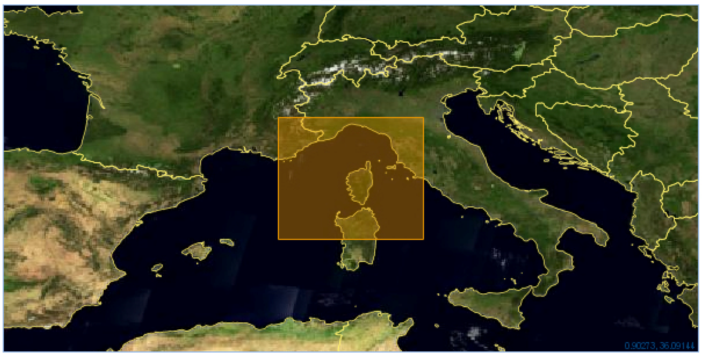
Extent

Geographic bounding box

WGS 84

North bound 44.6827§

West bound 5.97841



East bound 11.4715§

South bound 40.0685§

Reference System Information

Code	EPSG:3035

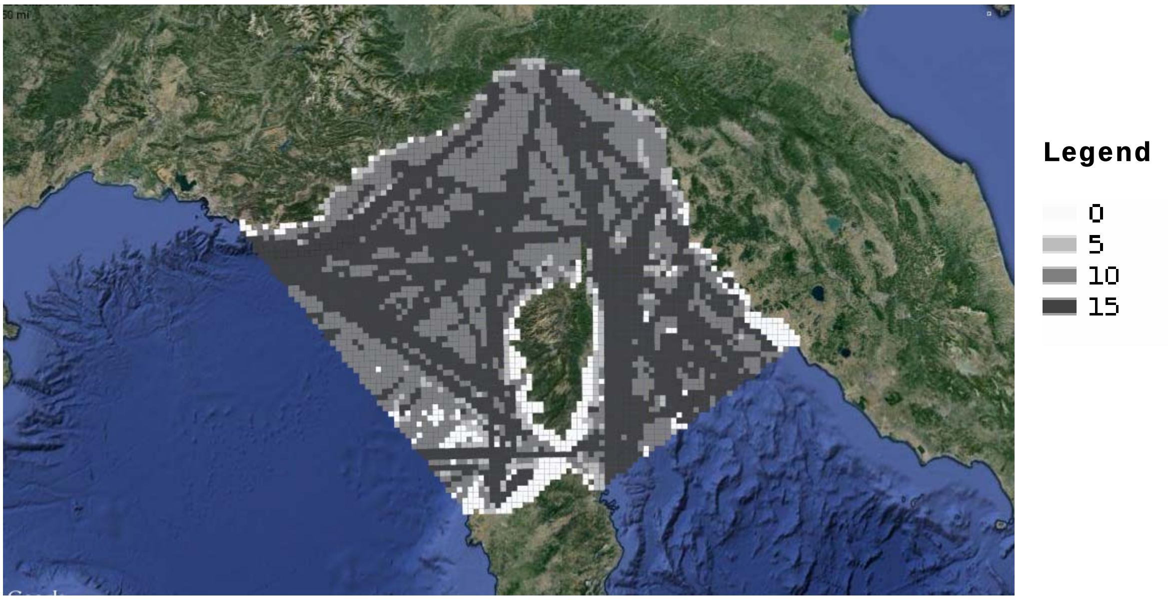
Metadata

File identifier	57f32fcc-d431-437f-9953-ddf1fc4ca10c
Metadata language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T22:34:06
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
Position name	BIO
Role	**Point of contact**: Party who can be contacted for acquiring knowledge about or acquisition of the resource
Voice	0039019230271
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
predominant vessel transiting speed classification [CIMA Foundation, 2015]

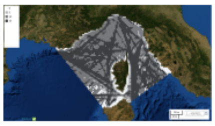


Abstract
Predominant ship speed categories plot on a INSPIRE compliant grid including the cell identifier and using the spatial reference EPSG: 3035 at 5km spatial resolution. Classifications were to 4 speed categories (5-10, 10-15, 15-20 and 20 knots plus) were attributed for each cell according to the speed category with the highest relative vessel density. Vessel density expressed in kilometres per square kilometre were calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and speed classification filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the transits for each speed classification of all pleasure, passenger, cargo and tanker vessels were then summed and the grid cell classified to the speed category with the highest density.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Info
Knot_Class

PREDOMINANT VESSEL TRANSITING SPEED CLASSIFICATION [CIMA FOUNDATION, 2015]



Identification info

Title	predominant vessel transiting speed classification [CIMA Foundation, 2015]
Date	2015-02-16T08:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	Predominant ship speed categories plot on a INSPIRE compliant grid including the cell identifier and using the spatial reference EPSG: 3035 at 5km spatial resolution. Classifications were to 4 speed categories (5-10, 10-15, 15-20 and 20 knots plus) were attributed for each cell according to the speed category with the highest relative vessel density. Vessel density expressed in kilometres per square kilometre were calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and speed classification filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the transits for each speed classification of all pleasure, passenger, cargo and tanker vessels were then summed and the grid cell classified to the speed category with the highest density. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations, specifically on the spatial distribution of vessels travelling at different speeds.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions**: Limitation not listed
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

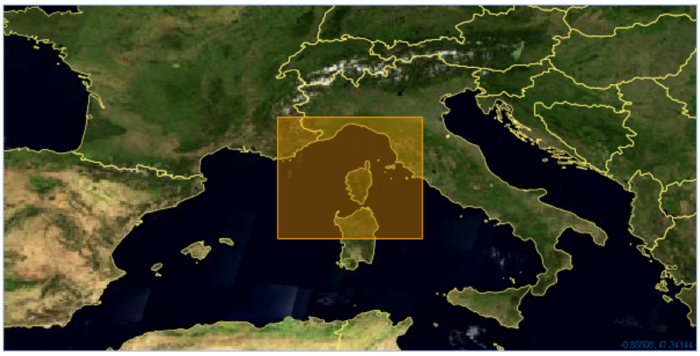
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

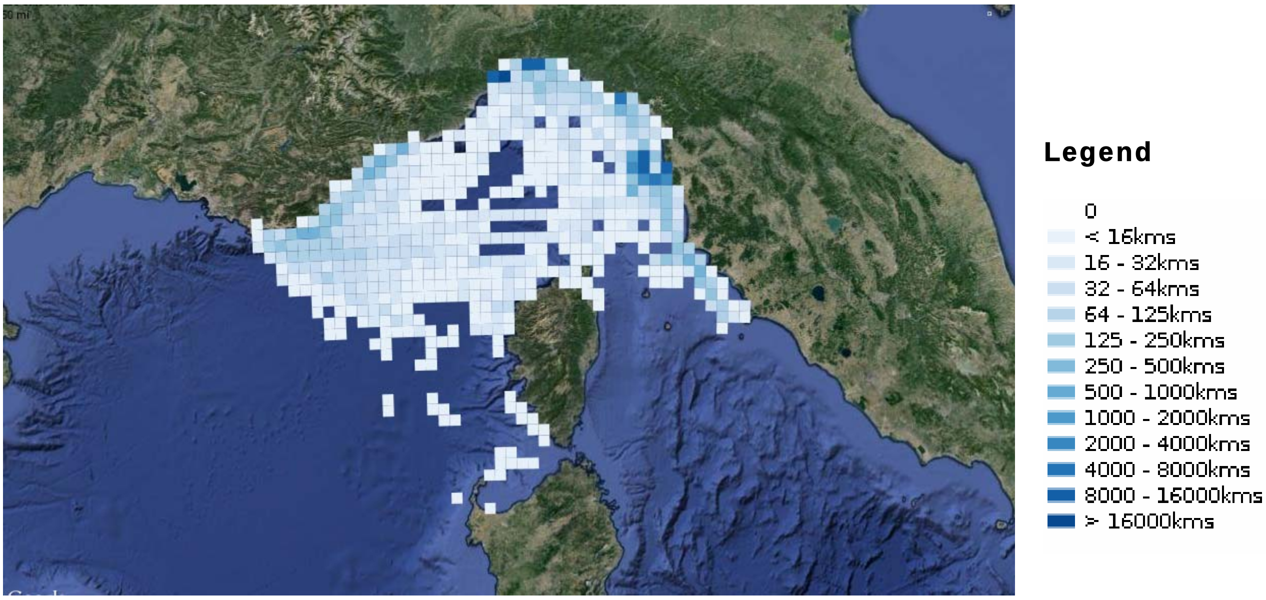
Metadata

File identifier	10942866-9815-4448-81a5-4833621856e9
Metadata language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T23:15:07
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation	Voice	0039019230271
Position name	BIO	Facsimile	003901923027240
Role	**Point of contact**: Party who can be contacted for acquiring knowledge about or acquisition of the resource	Delivery point	Via Magliotto 2
		City	Savona
		Administrative area	Savona
		Postal code	17100
		Country	Italy
		Electronic mail address	gis@cimafoundation.org

Layer title
service vessel density from AIS [CIMA Foundation, 2015]

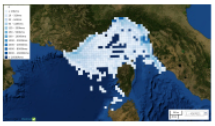


Abstract
Density of service vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the passenger vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Total_Kms
May_2013Km
Jun_2013Km
Jul_2013Km
Aug_2013Km
Sep_2013Km
Oct_2013Km
Dec_2013Km
Jan_2014Km
Feb_2014Km
Mar_2014Km
Apr_2014Km
May_2014Km
Jun_2014Km
Jul_2014Km
Aug_2014Km
Sep_2014Km
Oct_2014Km
Reception
Display

SERVICE VESSEL DENSITY FROM AIS [CIMA FOUNDATION, 2015]



Identification info

Title	service vessel density from AIS [CIMA Foundation, 2015]
Date	2015-02-16T08:00:00
Date type	**Publication:** Date identifies when the resource was issued
Presentation form	**Digital map:** Map represented in raster or vector form
Abstract	Density of service vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed:** Production of the data has been completed
Maintenance and update frequency	**Not planned:** There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions:** Limitation not listed
Spatial representation type	**Grid:** Grid data is used to represent geographic data

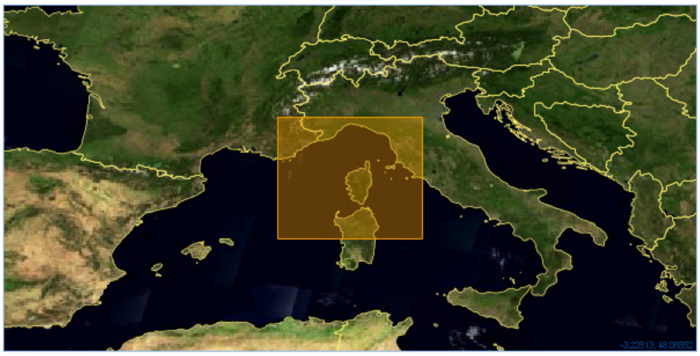
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

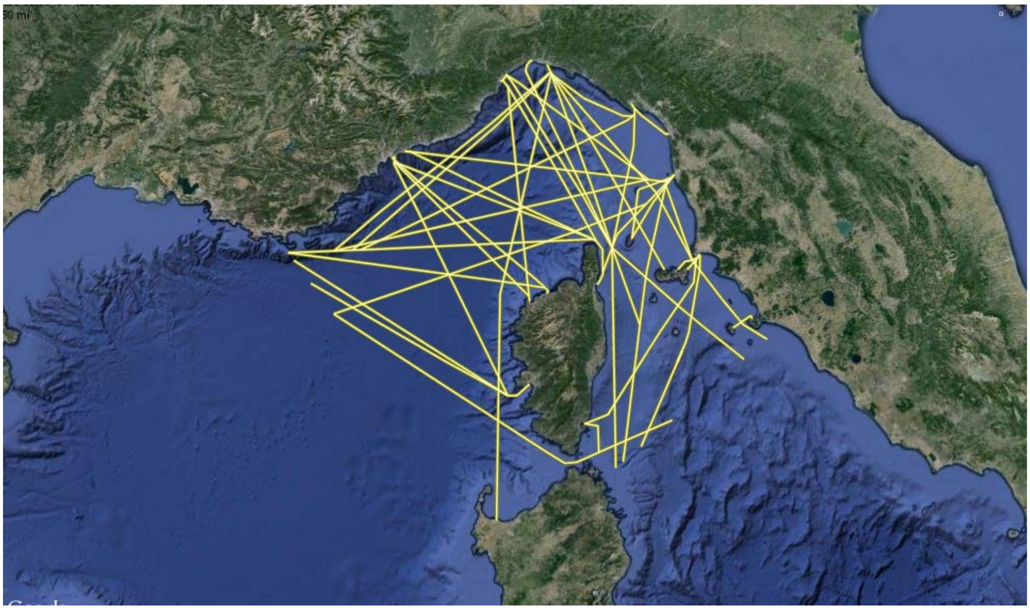
Metadata

File identifier	fb2dd750-4c34-4586-9794-6431e16cbbc8
Metadata language	English
Character set	**UTF8:** 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T22:43:03
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
Position name	BIO
Role	**Point of contact:** Party who can be contacted for acquiring knowledge about or acquisition of the resource
Voice	0039019230271
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
shipping routes based on shipping density [CIMA Foundation, 2015]



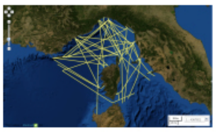
Abstract

The main shipping routes located in the pelages sanctuary. The routes were primarily identified using a 1km spatial resolution shipping density grid combined with admiralty charts and other maps. The shipping density was calculated from the AIS dynamic point data which was recorded from an antenna located at 4430°N and 8.45°E between May 2013 and October 2014. Areas of localized high shipping density relative to the surrounding sea that displayed a distinct linear distribution were considered as shipping routes. They were found by displaying the total shipping density under natural jenks divisions overlaid the current knowledge of shipping routes covering the North West Mediterranean Sea. The shipping lane shapefile was created in a GIS platform, additional information was sourced from AIS data and geometric processing on a routes destination and length with a spatial reference EPSG: 3035.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Id
Port
Direction
Ports
Directions
Length_Km

SHIPPING ROUTES BASED ON SHIPPING DENSITY [CIMA FOUNDATION, 2015]



Identification info

Title	shipping routes based on shipping density [CIMA Foundation, 2015]
Date	2015-02-16T08:00:00
Date type	**Publication:** Date identifies when the resource was issued
Presentation form	**Digital map:** Map represented in raster or vector form
Abstract	The main shipping routes located in the pelages sanctuary. The routes were primarily identified using a 1km spatial resolution shipping density grid combined with admiralty charts and other maps. The shipping density was calculated from the AIS dynamic point data which was recorded from an antenna located at 4430°N and 8.45°E between May 2013 and October 2014. Areas of localized high shipping density relative to the surrounding sea that displayed a distinct linear distribution were considered as shipping routes. They were found by displaying the total shipping density under natural jenks divisions overlaid the current knowledge of shipping routes covering the North West Mediterranean Sea. The shipping lane shapefile was created in a GIS platform, additional information was sourced from AIS data and geometric processing on a routes destination and length with a spatial reference EPSG: 3035. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed:** Production of the data has been completed
Maintenance and update frequency	**Not planned:** There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions:** Limitation not listed
Spatial representation type	**Grid:** Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8:** 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

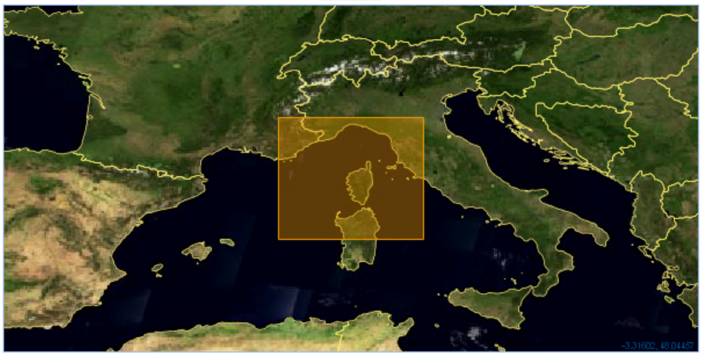
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

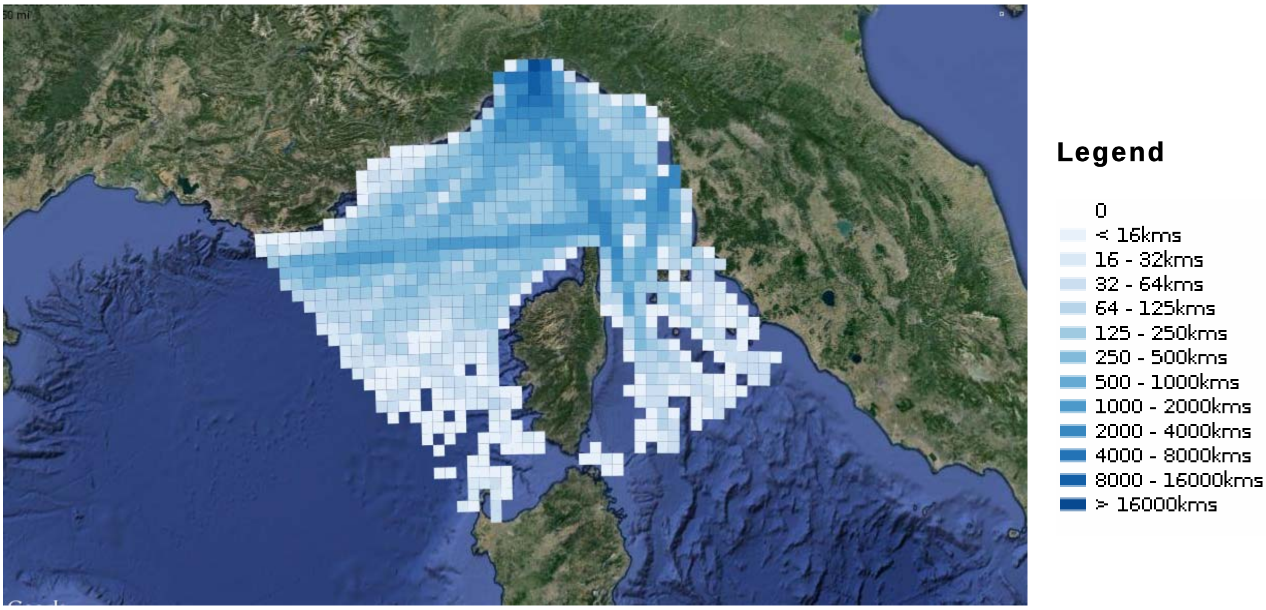
Metadata

File identifier	e2b6a167-7b30-4f4d-acef-3b71a858b4bf
Metadata language	English
Character set	**UTF8:** 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T23:00:28
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

Contact

Organisation name	CIMA Foundation
Position name	BIO
Role	**Point of contact:** Party who can be contacted for acquiring knowledge about or acquisition of the resource
Voice	0039019230271
Facsimile	003901923027240
Delivery point	Via Magliotto 2
City	Savona
Administrative area	Savona
Postal code	17100
Country	Italy
Electronic mail address	gis@cimafoundation.org

Layer title
tanker vessel density from AIS [CIMA Foundation, 2015]

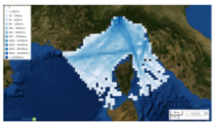


Abstract
Density of tanker vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the passenger vessel transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea.
The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.

Fields

Cellcode
Ship_Type
Start_Time
End_Time
Total_Kms
May_2013Km
Jun_2013Km
Jul_2013Km
Aug_2013Km
Sep_2013Km
Oct_2013Km
Dec_2013Km
Jan_2014Km
Feb_2014Km
Mar_2014Km
Apr_2014Km
May_2014Km
Jun_2014Km
Jul_2014Km
Aug_2014Km
Sep_2014Km
Oct_2014Km
Reception
Display

TANKER VESSEL DENSITY FROM AIS [CIMA FOUNDATION, 2015]



Identification info

Title	tanker vessel density from AIS [CIMA Foundation, 2015]
Date	2015-02-16T08:00:00
Date type	**Publication**: Date identifies when the resource was issued
Presentation form	**Digital map**: Map represented in raster or vector form
Abstract	Density of tanker vessel transits, expressed in kilometres per squared kilometre, within the spatial reference EPSG: 3035 at a 10km spatial resolution and including the INSPIRE compliant cell identifier. Transit distance was calculated from the CIMA foundations AIS dynamic point data which was recorded from an antennae located at 44.30°N and 8.45°E between May 2013 and October 2014. After an initial preparation, cleaning and filtering procedure a GIS platform was used to create line transits from the positional points for each unique vessel for each day. The length of the transits were then summed within each grid cell for total and monthly composites covering the North West Mediterranean Sea. The data is part of the Pelagos Convention No. 01/2014 project to provide a description of the vessel traffic in order to address the impact to cetacean species as part of the Pelagos Sanctuary MPA regulations.
Status	**Completed**: Production of the data has been completed
Maintenance and update frequency	**Not planned**: There are no plans to update the data
Descriptive keywords	BIO , environmental impact assessment , marine environment , Pelagos Sanctuary , shipping , marine transportation , Automatic Identification System (AIS) , transport networks .
Use constraints	**Other restrictions**: Limitation not listed
Spatial representation type	**Grid**: Grid data is used to represent geographic data

Equivalent scale

Denominator	1000000

Language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Topic category code	Transportation

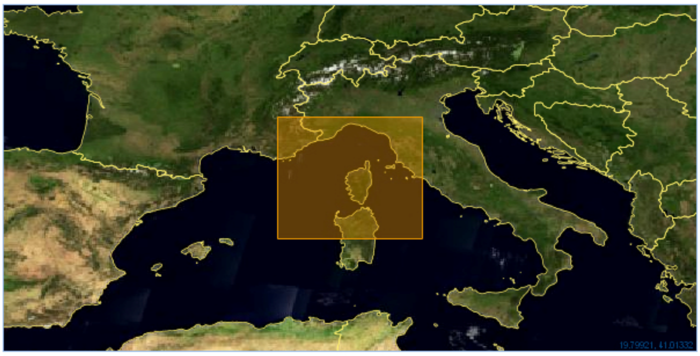
Extent

Geographic bounding box

WGS 84

North bound 44.68275

West bound 5.97841



East bound 11.47158

South bound 40.06850

Reference System Information

Code	EPSG:3035

Metadata

File identifier	d001f600-f489-458f-b18b-77c8c9575c7c
Metadata language	English
Character set	**UTF8**: 8-bit variable size UCS Transfer Format, based on ISO/IEC 10646
Date stamp	2015-03-22T22:52:14
Metadata standard name	ISO 19115:2003/19139
Metadata standard version	1.0

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