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Economic impact to shipping industry : Economic impact to shipping industry considering Maritime Spatial Planning and green routes in pilot case studies

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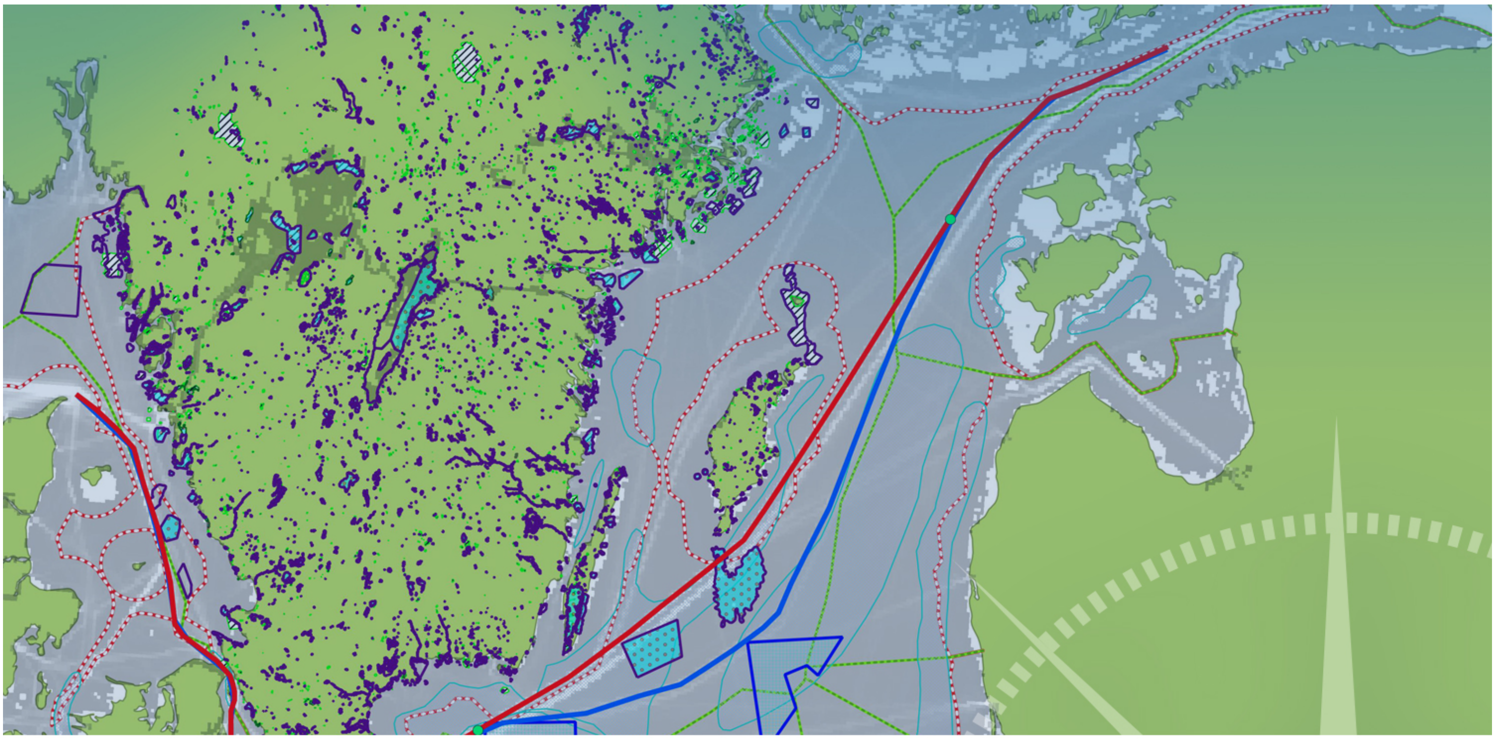

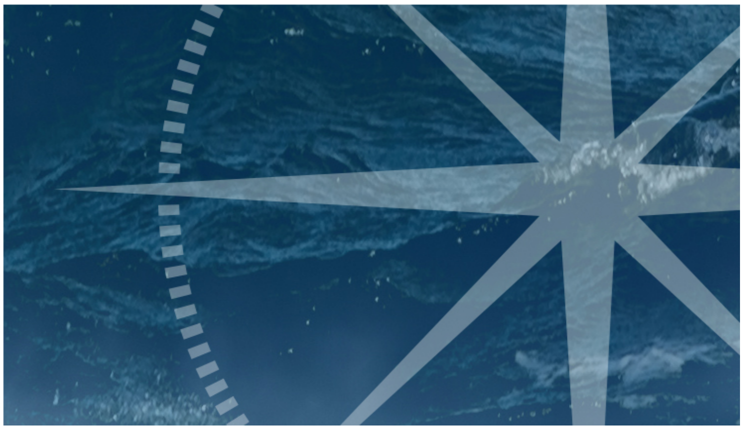

MONALISA 2.0 – Sub-Activity 1.7

Economic impact to shipping industry

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1. Estimation of the economic impacts of maritime spatial planning and rerouting on shipping industry

The Mediterranean Sea, as an enclosed basin, is particularly vulnerable to ship-associated impacts due to the high volume of shipping routes, the long history of use, and its sensitive shallow and deep-sea habitats.

Over the past half century, shipping has greatly expanded in the Mediterranean Sea. Some of the world's busiest shipping routes are in the Mediterranean Sea, and over the course of the last decade a significant increase (up to 77%) in the volume of ship cargo that was loaded and unloaded in Mediterranean ports was recorded. It is estimated that approximately 220,000 merchant vessels of more than 100 tons GT cross move across the Mediterranean Sea every year, accounting for about one third of the world's total merchant shipping. These ships often carry hazardous cargo, which in case of leakage would result in severe damage to the marine environment, and the number is expected to grow by three or four times in the next 20 years[1]. Furthermore, the various maritime-associated impacts on marine biodiversity are also expected to grow at an alarming rate.

There has been a weak integration of marine environmental aspects in the shipping industry. It has been difficult for national and international authorities to secure protection for cetaceans and other marine endangered species (e.g. sea turtles) that may be affected by human activities in coastal areas and at sea.

In this project, three case studies are considered in order to examine the economic impact of the implementation of MSP when considering environmental impact of the shipping industry. Specific characteristics and limitations of areas in the Greek Sea, the Balearic Sea and the Baltic Sea are evaluated with respect to their economic effects on the maritime transport domain.

The purpose of the above is to evaluate the economic impacts and risk implications of different scenarios and particularly:

- The economic impact of vessel traffic rerouting and/or reducing the speed in order to reduce the probability of vessel strikes or other negative impact to endangered marine species.
- Analysis and treatment of costs (constraints and penalties) from unexpected delays, in addition to the additional transit time cost.
- Estimation of the direct and indirect economic impact on the shipping industry and the effects of potential port call dislocation for the implementation of the proposed management options (e.g. speed deceleration or ship rerouting).

[1] IUCN Maritime traffic effects on biodiversity in the Mediterranean Sea_ Volume 1- Review of impacts, priority areas and mitigation measures, https://en.wikipedia.org/wiki/Mediterranean_Sea

1.1. Methodology

The purpose of the methodology is to evaluate the economic impact and risk implications of different scenarios for reducing negative environmental impact (e.g. the risk of lethal vessel strikes to marine mammals and other endangered species) by re-routing and/or slowing ships. A basic methodology is provided for analysing the cost effectiveness of potential management scenarios for optimal MSP policies in relation to the shipping industry.

We can apply this methodology to four potential management scenarios:

- Year-round mandatory speed reduction to 10 knots in the study area.
- Seasonal mandatory speed reduction to 10 knots in the study area from April to September.
- A narrowing of the Traffic Separation Scheme (TSS) or the area of main ship routes.
- A shift in the TSS.

For each case study, the selection of Management Options, according to the best alternative criteria and the achievement of optimal desired effect, are provided.

1.1.1. Economic model development analysis considering the Greek study area

In the analysis of the Hellenic Trench in the Greek study area, an economic model is taken into consideration in order to predict the financial impacts of various management options on cargo ships (bulk carriers, tankers, ro-ro vessels, reefers etc.) and cruise ships travelling through the proposed area. The model will examine the additional costs and/or fuel savings associated with speed reductions and/or alternate routes when selected management options (speed reduction, rerouting) are implemented to reduce the effects to the environment (e.g. vessel strikes to endangered mammals and marine species)[2].

[2] Vessel Traffic Management Scenarios based on the National Marine Fisheries Service's Strategy to reduce ship strikes of (North Atlantic) right whales, 2005

The following equation, which is proposed to be used in our analysis, outlines the costs affected by the proposed management options.

$$\Delta TC=\Delta VC+\Delta OC+\Delta NC+a\Delta t$$

Where:
ΔTC refers to the change in total costs
ΔVC refers to the change in voyage costs
ΔOC refers to the change in operating costs
ΔNC refers to the change in costs from a delay caused by shipping operations
αΔt refers to an additional hourly change in cost from increased time at sea

Variables data concerning distance and speed and should be taken into consideration

Within the pilot areas in consideration, the following parameters may be affected:

Vs = vessel service speed
Vsa,1 = initial average operating speed (knots)
Vsa,2 = regulation speed (knots)
Da,1 = distance travelled through the region under the current scenario (nautical miles)
Da,2 = distance travelled through the region under new management scenario (nautical miles)
α = Additional economic costs not otherwise captured by voyage costs, operating costs, or costs associated with a potential delay from shipping operations
RS = is the proposed speed restriction
RD is the distance, over which a vessel travels to reduce speed from service speed to low manoeuvring speed
T_{Vs}= is the time, it would take a vessel to travel the distance without having to reduce speed,

$$T_{Vs}=RD/Vs$$

T_{MS}= is the time to slow from service speed low to manoeuvring speed (assume 1 hour)
$\Delta T_{Vs\text{-}RS}$= is a vessel's net time, to slow from sea speed to manoeuvring speed,

$$\Delta T_{Vs\text{-}RS}= T_{MS}- T_{Vs}$$

MS is the mean or average speed over the specific time that a vessel makes when reducing* sea speed, Vs to the proposed speed restriction, RS

Collision with ships is a significant cause of mortality among endangered whales. Collision lethality increases with vessel speed and one of the most crucial mitigation measures includes slowing ships in whale dense areas. For the purposes of our analysis it will be assumed, as proposed, speed restrictions to 10 [3]knots; these proposed speed restrictions are within the range of manoeuvring speed for many of the large commercial vessels transiting the recommended study area (e.g. Hellenic Trench sperm whale waters).

Estimating vessel's net time, $\Delta T_{Vs\text{-}RS}$, to reduce speed from service speed to manoeuvring speed is quite simple with the applied model. The process entails two steps. Firstly, it is required the definition of the necessary distance (*RD)* that must be travelled in order to reduce speed. Secondly, will be determined, the time (T_{Vs}) needed to travel the same distance without having to reduce speed. Note that *MS* is the mean or average speed over the specific amount of time that a vessel makes when reducing speed from service, *Vs,* to the proposed speed restriction, *RS:*

$$\mathbf{MS = (Vs + RS) \div 2.}$$

The change in voyage cost (ΔVC) implies a change in fuel, lubricant and water costs. The change in operating costs (ΔOC) as resulted from management measures, implies a differentiation on crew costs and additional repair and maintenance costs that may or may not will be incurred due to speed reduction. Finally, an additional factor (αΔt) is also included that refers to costs that are not explicitly defined in our model; these costs may refer to the cost of delay or additional hourly operating costs that may be affected by increased operational time at sea.

1.1.2. Assumptions and considerations for model calculations of management options in vessel shipping routes (sea speed deceleration, manoeuvring)

Effects of vessel size and speed on ship strikes

The incidence of strikes is positively correlated with the number, size, and speed of ships[4]. In most cases, mammals (such as sperm whales) or other endangered species were not seen by the vessels, or were seen too late to be avoided.

Similarly, the likelihood of a vessel hitting and severely injuring or killing a mammal (whale) is related to ship speed[5].

Spatial ship data

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[3] David N. Wiley, Michael Thompson , Richard M. Pace, Jake Levenson, Modelling speed restrictions to mitigate lethal collisions between ships and whales in the Stellwagen Bank National Marine Sanctuary, USA,2011

* This assumption is made considering that most vessels must slow to take a pilot on board and that this would in part offset this additional time. It is also deliberately over-estimated the annual duration and average size of DMAs.

[4] Vessel Traffic Management Scenarios based on the National Marine Fisheries Service's Strategy to reduce ship strikes of (North Atlantic) right whales, 2005

[5] Laist et al., 2001; Vanderlaan & Taggart, 2007

In order to generate a dataset of the representative intra-annual traffic patterns of vessels within the study region during a particular period of time, we will make use of the AIS database for monthly subsets of all transits within the geographic extent of our grid. AIS data were obtained for all cargo ships, tankers, cruise ships, and “other” vessels transiting the region during this time period. We excluded vessels such as tugs, dredge vessels, towboats, fishing vessels, pleasure craft, research vessels, law enforcement and military vessels, and small passenger vessels. Each of these vessel types has been excluded for one or more of the following reasons:

- Due to the vessel size, speed, or location of operation, it is not likely to be affected by management scenarios;
- Due to the nature of the vessel's operation, it may be exempt from regulations relating to our modelled management scenarios; and/or
- The economic impacts to the type of vessel are expected to be minimal.

In the category of “other” vessels will be included ships that are mislabelled cargo ships and tankers that would likely be affected by the management scenarios.

Shipping industry cost structure

Although the cost structure of the shipping industry is complex, costs can be divided into four main groups: capital, operating, voyage, and cargo-handling costs[6].

Capital costs are very high in the shipping industry, as much as 42% of the total costs incurred by a ship, and the industry relies on a steady cash flow to finance these investments. Capital costs depend on the way the ship has been financed. They may take the form of dividends to equity, which are discretionary, or interest and capital payments on debt finance, which are not.

Operating costs are the daily expenses associated with ship operations, such as the cost of the crew, supplies, repairs and maintenance, insurance, and administrative expenses[7].

Voyage costs are the variable costs associated with any given trip, including fuel costs, additional dues (e.g. canal dues), and port fees. Port fees generally consist of dues for towage, pilotage, traffic control systems, reporting, mooring and unmooring, berth, and tonnage[8].

Cargo-handling costs include the costs of loading and unloading cargo from ships.

In the present analysis we will try to quantify certain costs for vessels traveling through the particular region to evaluate the effects of our selected management measures on the shipping industry. Management measures being considered will primarily affect a ship's

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6 Maritime Economics, Martin Stopford, 1988

7 Richard Greiner, Moor Stephens LLP, Ship operating costs: Current and future trends, 2011.

8 Notteboom & Vernimmen, 2009

voyage costs by increasing the distance travelled or reducing the speed of travel, thereby affecting the ship's fuel and lubricant consumption and the time required to transit the region. Fuel costs constitute the largest component of a ship's voyage cost, and the cost of fuel is dependent on the fuel price, vessel speed and size, main and auxiliary engine types, and hull shape and condition.

To quantify the effects of the evaluated management measures, we will try to characterise the vessel traffic traveling through the region and evaluate the effect of management on voyage costs and operating costs for vessels transiting the region.

Slow Steaming and cost savings from speed reduction

Speed reduction has recently been promoted as a method for fuel cost reduction on a vessel's voyage. With high fuel prices and an economic recession affecting profitability in the shipping industry, a number of shipping companies have turned to slow steaming or even super slow steaming to save fuel[9]. The fuel savings associated with speed reductions should be coupled with other costs associated with a change in shipping operations.

1.1.3. Estimation of the Economic Impact of Vessel Traffic rerouting management and identification of indicators and the data that could be included in the analysis.

Collisions, self-evidently, happen when either whales or vessels (or both) fail to detect the other in time to take avoidance action. Research suggests that there are several variables that, singly or in combination, may either make a collision more likely, or may influence whether a collision is likely to inflict fatal or severe injuries. These may be broadly divided into vessel-related factors, cetacean-related factors, and geographical factors. The primary purpose presently under consideration is the establishment of traffic management areas where ship traffic overlaps with whale habitat or migration routes. Ships would be required either to reduce speed when transiting these areas, or reroute around the area. Options under consideration include issues such as:

- Estimation of the total direct costs.
- Direct economic impacts relative to trade value and freight costs.
- Estimation of Indirect Economic Impacts
- Estimation of the costs of unanticipated and expected additional transit time for potential dynamic management measures, for which vessels would reduce speed to 10 knots for some period of time and distance.

Examples of Potential indirect economic impacts include:

[9] Bankes-Hughes, 2010; COSCO Group, 2009; Maersk, 2009; ZIM, 2009
*As presented in "Ship operating costs: current and future trends", the operating cost trend for the period 2000- 2010 for bulker ship shows an increase of 5,9% at a 10 year average. The same figure for tanker ships is 6.3% and for the container ship 6.5% .

- External Costs due to emissions, wastes, and discharges.
- Increased intermodal costs due to missed shipping lines and truck connections.
- Diversion of the traffic to other ports.
- Impact on local economies of decreased income from jobs lost due to traffic diversions.
- Environmental impact.

Therefore, ship rerouting may imply, an increase in navigation miles. As a result a comparison between environmental advantages (reduction of pressures on environmental components) and potential environmental disadvantages, has to take place in order to properly assess the rerouting consequences. The cost of these consequences is usually called external costs of maritime transport. In more detail external costs can vary from a few thousands euros per navigation hour to around ten thousand/hour depending on the ship and other factors.

In more detail, external costs can be divided further into three main categories:

- **Air emissions** refer to emissions from main and auxiliary engines, heaters, generators etc. and volatile emissions from bunkering and cargo spaces. These emissions are measured to the amount of various key compounds released into the environment.
- **Wastes** refer to the by-products of the various ship activities in relation to cargo and engine maintenance.
- **Discharges into water,** refer to waste by-products, that can be discharged into the sea, with a given rate and distance from shore, as regulated by international regulations.

The emissions produced from the ship are related to external costs and are essential top to properly assess the environmental effects of shipping rerouting. As presented in "emission estimate methodology for maritime navigation"[10], there are three ways or tiers for estimate emission in cruise, manoeuvring and hoteling. This approach uses both installed capacity and fuel consumption as alternative for the emissions estimates and take into account both the main and auxiliary engines.
The tier method, as adopted by the International Marine Organization (IMO), proposes a regulation on NOx emissions for diesel engines with a power higher than 130kW:

- Tier 1 refers to engines constructed on or after 1 Jan 2000 and prior to 1 Jan 2011[11]

[10] Carlo Trozzi, Emission estimate methodology for maritime navigation - Proceeding Conf, http://www3.epa.gov/ttnchie1/conference/ei19/session10/trozzi_pres.pdf
[11] Carlo Trozzi, Emission estimate methodology for maritime navigation. Proceeding Conf, http://www3.epa.gov/ttnchie1/conference/ei19/session10/trozzi_pres.pdf
* Tier I limits have to be applied for existing engines with a power output higher than 5 000 kW and

- Tier 2 refers to engines constructed on or after 1 Jan 2011
- Tier 3 refers to engines constructed on or after 1 Jan 2016

Tier 3 is the most optimum green policy proposed, as it places the limit for NOx emissions to 3,4g/KWh, for engines running below 130 revolutions per minute, and 2g/kWh for engines running higher 2000 revolutions per minute.

Apart from external costs, there is a range of factors that can be taken into consideration and are influencing a shipping line's decision to call at specific ports. These include the adequacy and suitability of port facilities and equipment, the ability of the terminal operator to quickly turnaround the vessel, the overall cargo demand, the efficiency of intermodal transportation, port charges, and the port location relative to other ports and cargo markets. If the cargo has to be diverted to other ports, this would be because the total additional costs associated with those routes are lower than the cost associated to vessel delay at the current port. Changes to shipping patterns have also a knock-on effect for other transport chains and the associated environmental impact of less efficient modes of transport (e.g. an increase in road and rail traffic). Hence it would be double-counting to also include any additional overland transport costs to the estimated impact already presented.

Ship strike management measures (rerouting, speed) increase cost of transport. It should be taken into consideration that effects can be more severe for some ports than others. Furthermore, the effects of rerouting can also relate to many other environmental impacts. These impacts may include marine sound, the scouring effect on the seabed in shallow areas and the potential environmental impact from a marine accident.

Furthermore, the increased time spend in sea, can be linked to a shift in the balance of risk of a major pollution incident and significant damage to the environment.

Finally, shipping lanes rerouting, has an effect on cost of shipping and goods, because may affect the cost of time related expenses, such as personnel wages, insurance rates, maintenance and consumables.

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a displacement per cylinder at or above 90 litres, installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000, provided that an Approved Method for that engine has been certified by an Administration of a Party and notification of such certification has been submitted to the Organization by the certifying Administration

1.1.4. Requirements and issues to be considered in the current analysis

To estimate the risk of lethal vessel strikes to whales in the Hellenic Trench, we developed and estimated a combination of whale distribution analysis and vessel traffic patterns. We used vessel traffic data transmitted by ships via the Automatic Identification System to characterise ship traffic in the region for one year. We assumed that the relative risk of a lethal strike is a function of both the relative probability of a whale and the relative probability of a ship occupying a given area.

To determine the economic implications associated with each management option we take into consideration:

- Identification of ship strike mortalities in the proposed Management Area:
  - How many occurred in the last decade.
  - How many confirmed.
  - Sighting within 30nautical miles of shore.
- Political Constraints:
  - Consideration of International and Domestic actions required to implement changes to vessel routing schemes.
  - The Role of the International Maritime Organization.
- Identification of Seasonal Management Area and the geographic extent of the proposed SMAs (assumed that the radial extent would be from 10-30 nautical miles offshore).
- Establishment of potential Dynamic Management Area (a dynamic area would simply a creation of a circle with a radius of at least 5.2 Km around the location of each whale sighting)[12].
- Analysis of Port Calls by port and vessel type.
- Analysis of vessel speed and traffic patterns.
- Estimation of Additional Transit time of vessels according to sea speed and manoeuvring speed. Methods of calculation the additional time with proposed speed restrictions or vessel rerouting.
- Develop a model to determine the change in cost to the shipping industry due to various management measures and apply it to the representative subset of options.
- Consideration of the feasibility of the various management options.
- Proposal of the most appropriate suitable and user friendly Model of simulation and visualisation of green routes.
- Stakeholder Engagement

  This is very important and an integral part in a MSP process but it is a very difficult task and various issues need to be considered:
  - Considerations and description of the stakeholders' participation
  - Identification of potential representative group of stakeholders
  - Consideration for the consultation techniques

[12] National Marine Fisheries Service (NMFS),2008 and NOAA Technical Memorandum NMFS-OPR-44, July 2010

It must be taken into consideration that there is a range of consultation techniques available to use, depending on how suitable they are to different stakeholder groups. Therefore, it is necessary to decide from the following options the most appropriate technique(s) to apply for the Stakeholder engagement in MSP process:

- Personal interviews
- Workshops
- Focus groups
- Public or 'town hall' meetings
- Surveys
- Participatory tools
- Stakeholder panels

1.1.5. Additional issues to consider in our analysis

Main elements of the MSP process and the specific navigational concerns are to be considered when assessing the impact on existing marine traffic routing and navigational safety caused by offshore developments. It is important that preparation and planning takes place to ensure that safety at sea and navigation requirements are adequately addressed. It is important that preparation and planning takes place to ensure that safety at sea and navigation requirements are adequately addressed.

- Manoeuvring characteristics (Adequate sea room for large vessels, ship characteristics etc.).
- Width of shipping lanes (Narrowing the area vessels may be a feasible mitigation option by reducing the width of the lanes reduced the probability of a collision).
- Navigation issues.
- Environmental & Commercial impact.
- Country characteristics - study area characteristics (Coastal regions, Islands and islets, Water depth, Coastline length, Study Area (km^2), etc.).
- Information about maritime transport (shipping: merchant, short-sea shipping, ferry service etc.).
- Major shipping routes (main tanker routes), Shipping Traffic (AIS,VTS, VTMIS etc.).
- Maritime activities and protection of marine area.
- Ship types travelling in the area in consideration / IMO number.
- Number of ships travelling the specific area.
- Ships' Size.
- Ships' Power plants.

- Ships' Speeds.
- Ships' Age.
- Ship's Crew.
- Ships' Flag /ships' classification society.

1.2. CONCLUSIONS

In this study, a basic methodology is provided for analysing the cost effectiveness of potential management scenarios in order to reduce the risk of vessel strikes to cetaceans and endangered species in a proposed region where strikes occur. In addition, the proposed methodology thrives to provide an analysis of the effects it may have on other environmental issues and major human activities such as fishing, aquaculture, tourism, etc.

The results of the current analysis can be categorized into groups as follows:

- The evaluation of the economic impacts and risk implications for different scenarios in the case of the implementation of a sustainable MSP with an Ecosystem-based approach by re-routing or slowing ships in the various territories.
- The economic impact (CBA) of vessel traffic rerouting or speed reduction (say by 5 to 10 knots) in order to decrease the probability of negative environmental impacts (e.g. vessel strikes to endangered marine mammals).
- The analysis and treatment of costs (constraints and penalties) from unexpected delays, in addition to the additional transit time cost.

A mandatory speed reduction has the potential to become the most prominent cost effective management option, but a further research is needed to further refine the proposed risk analysis.

By combining the results of various options/scenarios, one can determine which of the four management options results in the greatest reduction in relative risk per euro cost to the shipping industry.

2. 2. Implementation of green routes in the pilot areas

The economic and environmental consequences of planning different routes for safe passage near or through marine sensitive areas, is crucial in order to accomplish acceptance and cooperation between different organisations and the shipping industry. This study comprises three case studies in three different marine pilot areas: the Balearic Sea, the Baltic Sea and the Ionian Sea. Each area presents different characteristics and thus different scenarios are implemented. In the Baltic Sea the study provides data for two different routes, where fuel consumption and travelling time for the marine traffic are calculated.

In the Balearic Sea the study examines the environmental impact to the selected area, by calculating the emissions caused by the fleet fuel consumption using Tier3 method. In this case study the existing shipping routes are passing outside the protected areas and thus are considered eco-friendly.

In the Ionian Sea, the environmental impact for the protection of the endangered sea animals is considered. In this study, a small route deviation, the routes' meeting point relocation and two low speed crossings in the protected area are used.

The pilot areas are described by presenting the existing marine traffic, the environmental sensitive areas and the suggested green routes. The green routes should be designed to offer acceptable economic impact and improved environmental benefits, so that they can be appealing to both the shipping industry and other stakeholders (governments, environmental organisations, local communities etc.).

For each green route scenario, the total impact to fuel consumption, the travelling time, along with the corresponding external costs is calculated giving the total effect of the possible rerouting. Each route evaluation uses fleet information such as ship type, size, GRT, Dwt, speed, engine type, engine power, fuel type etc. This data is used to estimate fuel consumption, fuel costs and environmental impact factors (external costs-emissions). More specifically, emissions for maritime transport are regulated by IMO protocols with limitations to NOx, SOx, CO, particulars, CHx, $C^{O}{}_{2}$ using specific lower and higher limit factors.

2.1. The case study in the Balearic Sea

2.1.1. Description of the Balearic Sea Pilot Area

The Balearic Sea is a part of the Mediterranean Sea positioned between the eastern coast of Spain, the southern coast of France, and the islands of Corsica and Sardinia. It's bordered in the northeast by the Ligurian Sea, and it completely surrounds Spain's Balearic Islands. Significant port cities include Barcelona, Marseille, Palma de Mallorca, Toulon and Valencia, and the sea is well served by regional ferries and hydrofoils. The distance from Barcelona to Marseille is 337 km (210 mi), and from Barcelona to Sardinia the distance is 518 km (322 mi).

The colder and more saline Surface Mediterranean Waters (SMW) from the Gulf of Lyons mix through the Balearic channels with the warmer less saline Modified Atlantic Waters (MAW) from South. This phenomenon makes a very complex hydrographically area, with strong currents and eddies, with variations in salinity between 36.7 and 38 psu. The variations in surface temperature can reach 22-27ºC in August, compared to the 13-14ºC in winter.

Regarding habitats and communities in the Mallorca Channel, there are more than 100 communities and habitats classified by EUNIS[13] that have been identified on the 3 main Mallorca Channel seamounts (sea channel between Ibiza and Mallorca). At least 50 more that are pending confirmation could also be found.

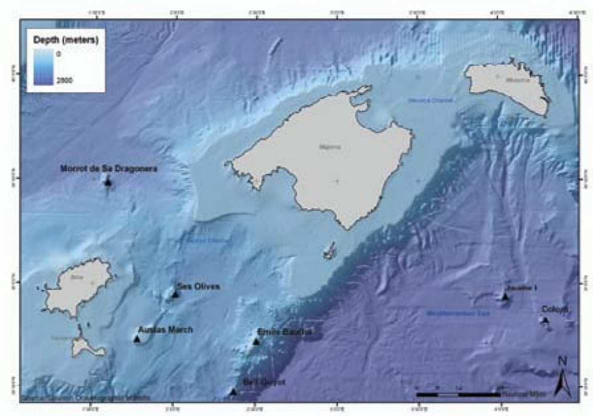

Figure 1. Bathymetry of the Balearic Archipelago. Oceana, 2010. Seamounts of Balearic Islands. Proposal for a Marine Protected Area in the Mallorca Channel (Western Mediterranean).

The Balearic archipelago is indeed considered as one off the richest European regions in terms of marine species and also characterised by a wide range of ecosystem types. The Southern Balearics[14] are characterised as a biodiversity hotspot hosting a significant

[13] EUNIS, 2010. European Nature Information System. http://eunis.eea.europa.eu/

[14] European Commission study, 2009. Exploring the potential for Maritime Spatial Planning in the Mediterranean Sea.

number of (rare or unique) habitats and species (e.g. bluefin tuna, other pelagic fish, marine mammals, marine turtles and sharks)[15]. Nevertheless, the area is threatened by a number of activities taking place in the region. The Balearic Islands have two main fishing grounds: the Ibiza-Formentera and the Mallorca-Menorca channels[16].

In the waters around the Balearics, blue fin tuna and swordfish are the main threatened species. Bluefin tuna is one of the main target species for the purse seiner fleets that are operating in the region. In recent years, the blue fin tuna stock has declined rapidly resulting from long-term overfishing and mismanagement. As blue fin tuna is known to spawn in July, its spawning areas (those that are known) around the Balearics are closed to purse seiners and long-liners during that period.

Besides blue fin tuna, swordfish is also known to spawn in Balearic waters. Similar to blue fin tuna it has been subject to overfishing. In this case, the fishing sector targets small fish under three years old, most of which have never spawned[17].

Besides blue fin tuna and swordfish, other species under pressure from trawling activities are the European hake and the red shrimp. In addition, bottom trawling is known to have a significant impact on the sea-bottom. It affects deep-water corals, which implies a decrease in biodiversity and in the density of associated organisms.

The slow growth of these organisms, combined with commercial fishery activities taking place in waters up to 1 000m[18] (i.e. red shrimps) have a significant impact on the marine environment in the region[19]. Moreover, research has shown that some Mediterranean fish are heavily threatened by pollution of different kinds. Studies showed spiny dogfish to have flesh concentrations of mercury high enough to render them dangerous for human consumption.

Deep-sea sharks on the other hand had traces of metals and organochlorine residues in their eggs, muscles, liver and kidneys[20]. In addition, coastal tourism is a very important sector to both Majorca and Menorca.

In 2005, 9.3 million tourists visited the islands. Furthermore, a total of 35 000 leisure boats are registered on the islands, which results in around one boat per 25 m of coastline. This activity puts pressure on the marine environment, as control on anchoring is limited. Consequently, all types of seabed habitat are 'targeted' and endangered. Areas

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[15] Greenpeace, 2009, High Seas Mediterranean Marine Reserves: a case study for the Southern Balearics and the Sicilian Channel.
[16] Greenpeace, 2009, High Seas Mediterranean Marine Reserves: a case study for the Southern Balearics and the Sicilian Channel.
[17] Greenpeace, 2009, High Seas Mediterranean Marine Reserves: a case study for the Southern Balearics and the Sicilian Channel.
[18] Trawl fisheries have been limited to 1 000m depth in the Mediterranean Sea, a precautionary ban aiming at protecting vulnerable, pure deep-water ecosystems which are not fully-understood at present.
[19] Greenpeace, 2009, High Seas Mediterranean Marine Reserves: a case study for the Southern Balearics and the Sicilian Channel.
[20] Greenpeace, 2009, High Seas Mediterranean Marine Reserves: a case study for the Southern Balearics and the Sicilian Channel.

with a high ecological value are suffering from repeated anchoring related to frequent diving activities. To conclude, the increase in habitation of the coastal regions, especially during the summer months, has resulted in an alteration of the breeding sites of many marine species, some of them listed as endangered[21].

From the economic activities point of view and the possible threats to be appeared, it should be noted that numerous species of commercial interest aggregate on or around seamounts, those species are extremely vulnerable to bottom trawling; being then the most obvious impact to be taken into account both commercial and recreational fishing[22].

But fishing is not the only threat to vulnerable marine ecosystems; waste dumping, pollution, mineral drilling/exploitation and climate change must also be taken into account[23]. We can summarise that the most obvious anthropogenic effects identified in the area are remnants of waste and fishing gear, plastics, food packaging, bottles, jars, canisters, metal waste, inter alia.

For the MONALISA 2.0 purposes, Technical University of Catalonia is focused on the Spanish part of the Balearic Sea. The boundaries are shown on the map in figure3 and the coordinates are pointed out. The area is the one covering the approaches to Barcelona Port approaches together with the Balearic Archipelago including the area of connection between both of them. The criterion used has been in a first instance to cover Balearic Islands due to the number of protected areas not only from the government side but also from Natura 2000 network.

The data related to **Natura 2000** areas and **nationally designated areas** were collected through the European Marine Observation ad Data Network (EMODnet) portal – Human Activities - link: http://www.emodnet.eu/human-activities. Figure2 provides an image of the protected areas around the Balearic Islands coasts.

[21] Greenpeace, 2009, High Seas Mediterranean Marine Reserves: a case study for the Southern Balearics and the Sicilian Channel.
[22] Oceana, 2010. Seamounts of Balearic Islands. Proposal for a Marine Protected Area in the Mallorca Channel (Western Mediterranean).
[23] As indicated by the Food and Agriculture Organization of the United Nations (FAO).

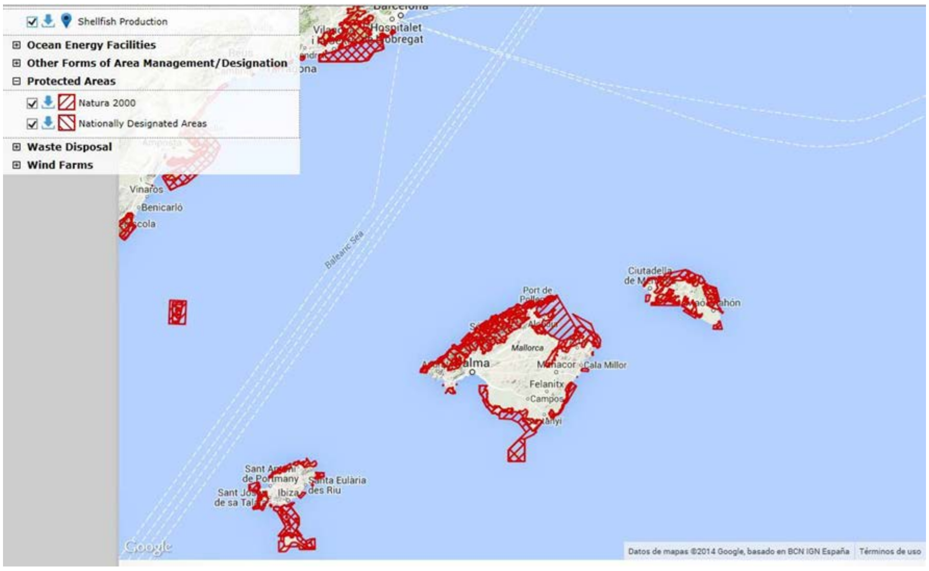

Figure 2. Marine protected areas showed by the maritime affairs atlas. EU Commission, updated to 2012.http://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/#lang=EN;p=w;pos=2.509:40.122:8;bkgd=5:1;gra=0;mode=1;theme=2:0.75:1:1,78:1:1:0,85:1:1:0,43:1:1:0,88:1:1:1,89:1:1:1,80:1:1:0,16:0.8:1:1;time=2 012;

The area selected is the one covered by the following eight points: (40.3N, 0.917E), (40.3N, 1.33E), (41.2N, 1.68E), (41.53N, 2.42E), (40.3N, 3.83E), (38.4N, 0.9E), (40.3N, 4.65E), (38.4N4.65E). Figure 3 shows the selected area and the most common maritime shipping routes. This distribution covers the area usually used for ships going from Barcelona port to different Balearic Islands ports, affording to divert the usual routes to maintain them apart from the natural protected areas. The main traffic lines crossing the selected area are linking the ports of Barcelona and Valencia with the ports of Alcudia, Palma of Mallorca and Ibiza.

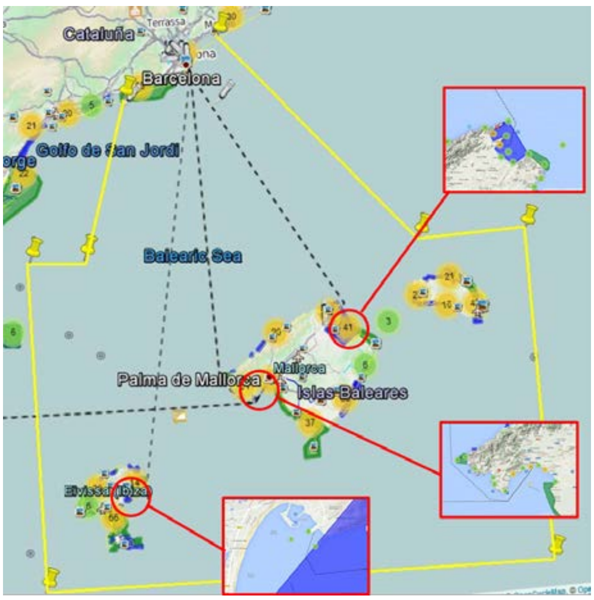

Figure 3. Picture taken from Google Earth, where the suggested pilot area is signalled.

The waypoints followed by the usual traffic are detailed above and usually pass outside from the protected areas except in the case of the Port of Alcudia, because all the bay where is placed this port is considered a protected area. This last point can be an obstacle but it is suggested that a fixed corridor could be proposed avoiding the maritime transport to affect a wider area. The viewer is able to show different chart sources overlapped. The protected and restricted areas are the green/blue polygons. The circles include conspicuous point's information like ports, lighthouses, aids to navigation, port services, repairs and communications. The dot lines represent the commercial routes. Pictures taken from the Navigation Support System.

2.1.2. External costs calculation report

This analysis considers that the environmental performance is measured using the externalities produced by air pollutants (NOx, VOCs, $PM_{2,5}$, SO_2, NH_3) and the global impact of CO_2 emissions (GHG, Green House Gases).

The following figure describes all data necessary for the environmental analysis of maritime transport:

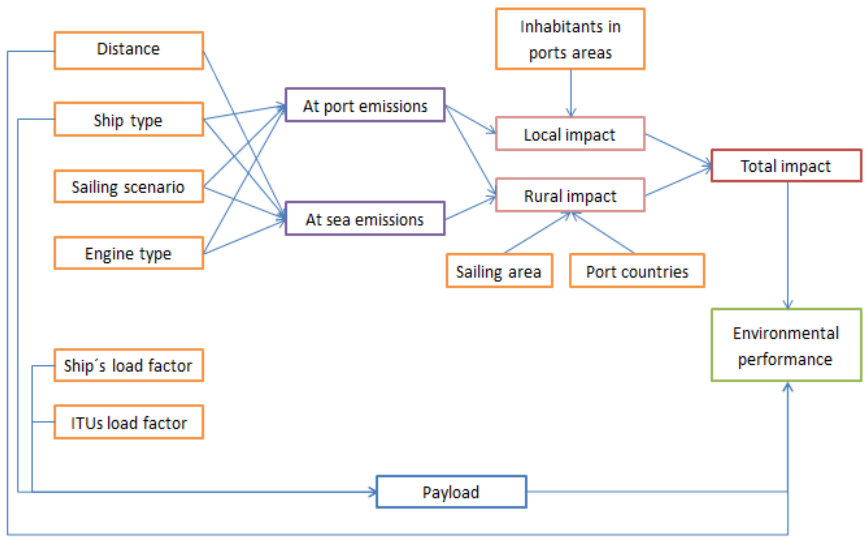

Figure 4. Environmental performance model of maritime transport.

For this analysis, we have considered regular routes as well as the ship type being used between Barcelona Port/Valencia Port and Balearic Islands Ports in June 2015. We need some specific characteristics of vessels in order to calculate external costs and obtain realistic results of these routes: ship type (Container, RoRo, RoPax, Car Carrier and ConRo ships), type of Main Engine and Auxiliary engine, engine power and engine load factors emissions. Emission factors for conventional fossil fuels have been considered (diesel fuel, heavy fuel oil, marine diesel oil and marine gas oil).

Next table shows the ship name, route and ship type of the selected area:

	Ship Name	Route	Ship Type
1	Formentera Direct	Formentera-Ibiza	Fast Ferry
2	Jaume III	Denia-Ibiza	Fast Ferry
3	Nissos chios	Denia-Ibiza/Denia-PMI	Ferry
4	Nixe	Ciutadella- Alcudia	Fast Ferry
5	Posidonia	Formentera-Ibiza	Ferry
6	Ramon Llull	Denia-Ibiza & Formentera	Fast Ferry
7	Visemar One	Denia – PMI	Ferry
8	Jaume I	Barcelona-Alcudia	Fast Ferry
9	Napoles	Barcelona-Formentera/Ibiza	Ferry
10	Martin i Soler	Barcelona-Alcudia	Ferry
11	Almudaina dos	Valencia-Ibiza	Fast ferry
12	Juan J. Sister	Barcelona-Ibiza/PMI	Ferry
13	Scandola	Valencia-Ibiza	Ferry
14	Tenacia	Barcelona-Ibiza/PMI	Ferry
15	Snav Adriatico	Barcelona-Mahón	Ferry
16	Zurbarán	Valencia-Mahón/PMI	Ferry
17	Abel Matutes	BCN-PMI	Ro-Pax

Table 1. Ships' type and routes

The main characteristics of the fleet are shown in following tables:

Ship Name	IMO Number	LOA (m)	B (m)	Draught (m)	Speed (kn)	Year	GT
Formentera Direct	8615332	49.45	14	2.43	32	1987	775
Jaume III	9135884	81	26	n/a	47	1996	4305
Nissos chios	9215555	141	21	5.3	27	2007	8126
Nixe	9316646	63	16	2	37	2004	2292
Posidonia	7717286	69059	14	n/a	16.5	1980	2819
Ramon Llull	9262065	83	13.5	n/a	30	2003	2616
Visemar One	9498743	186	26	6.85	23.5	2010	26375
Jaume I	9081693	7705	26	3.76	32	1994	3989
Napoles	9243423	186	25.6	6.5	24	2002	24409
Martin i Soler	9390367	16503	25.6	5.7	23	2009	24760
Almudaina dos	9141833	100.3	17.1	4.6	40.2	1996	4662
Juan J. Sister	9039391	151	26	6	20	1993	22409
Scandola	9019054	150.4	23.4	7.6	19	1992	19308
Tenacia	9350707	199	27	6.4	24	2008	25993
Snav Adriatico	8416308	164.4	27.6	8.1	19.5	1986	31910
Zurbarán	9181091	180	24.3	6.5	22	2000	22152
Abel Matutes	9441130	190	26	n/a	21.4	2010	29670

Table 2. Main characteristics of the ships

Ship Name	Engine	Number	Power (kW)	Fuel Type	Propeller (number)	Type
Formentera Direct	Diesel	4	2028	Marine Diesel	4	Jet
Jaume III	Diesel	4	5576	Marine Diesel	4	Jet
Nissos chios	Diesel Electric	4	7920	Marine Diesel	2	Controllable Pitch
Nixe	n/a	n/a	2352	n/a	4	Fixed Pitch
Posidonia	Diesel	2	1879	Marine Diesel	2	Controllable Pitch
Ramon Llull	Diesel	4	3752	Marine Diesel	4	Jet
Visemar One	Diesel	2	9180	Marine Diesel	2	Controllable Pitch
Jaume I	Caterpillar	4	4379	n/a	4	Fixed Pitch
Napoles	Diesel	2	9580	Marine Diesel	2	Controllable Pitch
Martin i Soler	Diesel	2	9124	Marine Diesel	2	Fixed Pitch
Almudaina dos	Diesel	4	6970	Marine Diesel	4	Jet
Juan J. Sister	Diesel	4	2737	Marine Diesel	2	Controllable Pitch
Scandola	Diesel	2	5839	Marine Diesel	2	Controllable Pitch
Tenacia	Diesel	2	12775	Marine Diesel	2	Controllable Pitch
Snav Adriatico	Diesel	4	4539	Marine Diesel	2	Fixed Pitch
Zurbarán	Diesel	4	5829	Marine Diesel	2	Fixed Pitch
Abel Matutes	Diesel	2	9003	Marie Diesel	2	Controllable Pitch

Table 3.Engine characteristics of the ships

Once all these ships have been identified, using the Lloyd's List, all relevant factors that give rise to ship airborne emissions are found (except auxiliary engine characteristics (number, type and power), for which assumptions done by ENTEC 2010[24] have been followed.

The selected ship type, the sailing scenario and the sailing distance will determine the amount of emissions, whereas the sailing area and the origin and destination ports will determine the sensitivity of affected areas, and hence enable impact calculation.

The methodology quoted as Tier 3 for airborne emissions calculation from international navigation, national navigation, national fishing and military (shipping) in the EMEP/EEA[25] air pollutant emission inventory guidebook 2009, chapter 1.A.3.d is used. This methodology requires detailed ship movement data besides technical information on ships being considered. The fleet characterisation is very important, depending on the considered ship type emission factors differ significantly.
Further focusing on the emissions estimation methodology demonstrates that this work follows the procedure using data on installed main and auxiliary engine power, engine load factors and total time spent on each navigation phase. The Tier 3 method also employs specific emissions factors depending on the engine type, fuel type and navigational phase.

$$Etrip = Esailing + Emanoeuvring + Eatberth$$

The emission factors update is made following the methodology and assumptions described in Entec 2010[26], study developed for the DEFRA and which derives from IVL and Lloyd's emissions datasets. Once emissions for each of the navigation phases are known, the impact of these must be quantified.

Maritime transport has not been regulated with regards to emissions to the air until recently. Was the MARPOL 1973/1978 convention, which through its Protocol of 1997 including the Annex VI introduced for the first time standards to prevent the air pollution from ships in May 2005. In this first version of the Annex VI a global sulphur cap limiting the sulphur content in the fuel to 4.5% was introduced.

NOx emissions resulted also limited through the adoption of the NOx Technical Code (Tier I and Tier II standards) and a more stringent SOx emission control area (ECA) was established in the Baltic Sea where the sulphur content in the fuel was limited to 1.5%. In July 2005 the MARPOL Annex VI resulted amended and new North Sea and English

[24] Entec (2002), European Commission Quantification of emissions from ships associated with ship movements between ports in the European Community. Final Report, UK.

[25] EMEP/EEA (2009) Air pollutant emission inventory guidebook 2009. Technical report No 9/2009.

[26] Entec (2010). Defra. UK Ship emissions inventory. Final Report.

Channel SOx ECAs were introduced, although these were not fully enforced until November 2007.

The last review of the MARPOL Annex VI took place in 2008 when a progressive reduction of SOx emissions from ships was planned and introduced to the annex: reducing the global sulphur cap to 3.5% by January 2012 and to 0.5% by 2020 subject to a previous feasibility review; and reducing the sulphur content in fuels used in SOx ECAs to 1% by July 2010 and to 0.1% by January 2015. Moreover same amendments also introduced new NOx emission limits for the so-called Tier III engines, applicable to ships constructed after January 2016 and operating in NOx ECAs. Finally the revised Annex will also allow to designate ECAs for SOx, PM and NOx.

After a thorough review of the regulatory framework for maritime transport, the table below presents the final environmental assessment results.

	Air Pollutant cost (€)	**Global Warming (GHG) (€)**	**Total (€)**	**Total (€/t·km)**
Formentera Direct	699	303	1002	0.0286
Jaume III	1767	1528	3295	0.0062
Nissos chios	3934	2815	6748	0.0085
Nixe	669	484	1153	0.0023
Posidonia	589	263	852	0.0250
Ramon Llull	1319	1202	2521	0.0045
Visemar One	2467	1383	3850	0.0069
Jaume I	4287	1290	5577	0.0104
Napoles	4843	1824	6667	0.0087
Martin i Soler	4387	1328	5715	0.0107
Almudaina dos	4234	2251	6485	0.0094
Juan J. Sister	3610	1236	4846	0.0063
Scandola	2542	1192	3735	0.0054
Tenacia	5801	2282	8083	0.0106
Snav Adriatico	4700	1861	6561	0.0080
Zurbarán	4590	3546	8135	0.0059
Abel Matutes	4669	1742	6411	0.0084

Table 4.Environmental assessment results

Conclusions

Comparing results it is clear a direct relation between the % of distance with speed limitation and the reductions of the environmental cost.

The same % of distance with speed limitation, the ships with higher total power the reduction cost is higher.

However total costs reduction are negligible in terms of Euros / Tm·km, also the time used by reducing speed is also very short because we are talking about 23.25’ to 8.42’, and this means only around 2.5 to 1 hours more of navigation at the studied ships cruise speeds.

This time delay would not affect the line schedules. By the environment protection side a more in depth analysis should be done. By the ships' design, a careful analysis case by case should be made, as all ships are designed for sailing at a cruise or service, speeds and stability and comfort issue, should be analysed in each case.

2.2. The case study in the Baltic Sea

2.2.1. Maritime traffic in the Baltic Sea

The shipping traffic has steadily increased around the Baltic Sea. Both number and size of ships have grown and this trend is expected to continue. There are around 2000 sizable ships at sea at any time. The number of ships entering or leaving the Baltic Sea via Skaw/Denmark in 2009 has increased by 20% since 2006. About 20% are tankers, carrying as much as 166 million tonnes of oil[27].

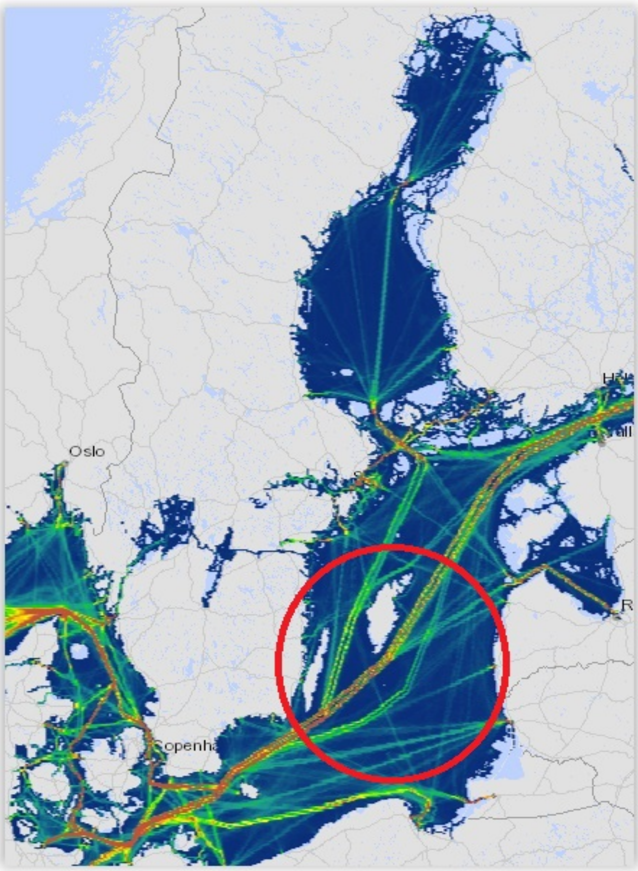

Figure 5. AIS density shipping traffic density monthly average 2011. Source: HELCOM, http://www.helcom.fi/baltic-sea- trends/data-maps

[27] HELCOM, 2010. Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region. Balt. Sea Environ. Proc. No. 123

In figure 5 the area of interest in this study is presented within orange circle. Based on AIS data, HELCOM has produced a map that shows the most frequent ship routes in 2011 based on monthly averages.

2.2.2. Maritime Traffic Emissions and environmental impact

This rise in shipping is due to the economic growth as well as increasing oil production and transportation activities. This increase in maritime traffic is estimated to cause an increased pollution and other pressure on the marine environment.28 The main environmental impacts of shipping and other activities at sea include airborne pollution, illegal deliberate and accidental discharges of oil, hazardous substances and other wastes, the unintentional introduction of invasive alien organism via ship´s ballast water or hulls and underwater noise. Shipping adds to the problem of eutrophication of the Baltic Sea with its nutrients inputs from nitrogen oxides (NOx) emissions and sewage discharges.

The Baltic Sea has always been a difficult area for ships to navigate, due to its narrow straits and shallow waters. According to HELCOM, 2010. “Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region” each year there are 120-140 shipping accidents in the Baltic Sea area. The number of accidents has risen since 2006, which can be linked to the 20% increase in ship traffic. The majority of accidents are groundings and collisions. On average, 7% of the shipping accidents in the Baltic Sea results in some kind of pollution, usually containing not more than 0,1-1,0 tonnes of oil29.

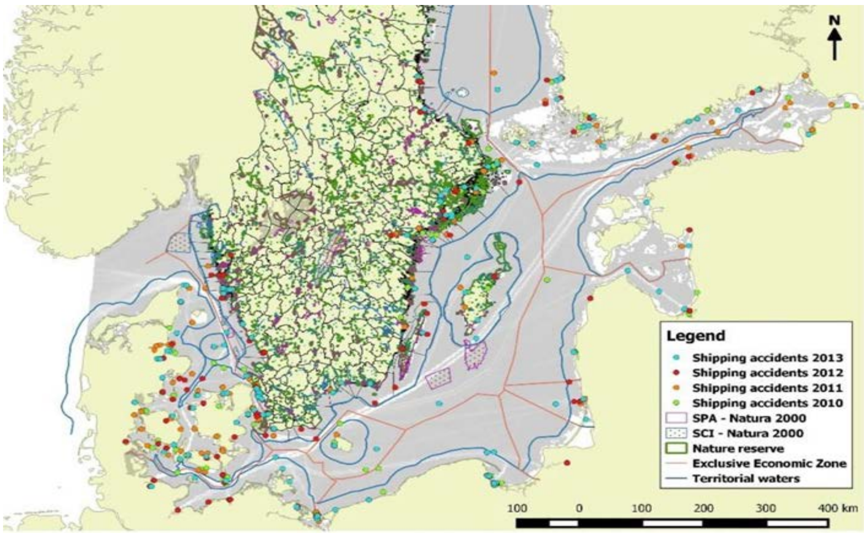

Figure 6. Shipping accidents from 2010 to 2013. Source: HELCOM, http://www.helcom.fi/baltic-sea-trends/data-maps.

[28] HELCOM, 2010. Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region
[29] HELCOM, 2010. Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region

Every ship entering the Baltic Sea must comply with the anti-pollution regulations of the Helsinki Convention and MARPOL Convention, including those resulting from the designation of the Baltic Sea area as a Special Area for prevention of pollution by oil and garbage. Even though strict controls over ships´ discharges have been established by the Baltic Sea countries, illegal spills and discharges continue to happen. Fortunately, the number of deliberate, illegal oil spills has been reduced dramatically over the last twenty years.

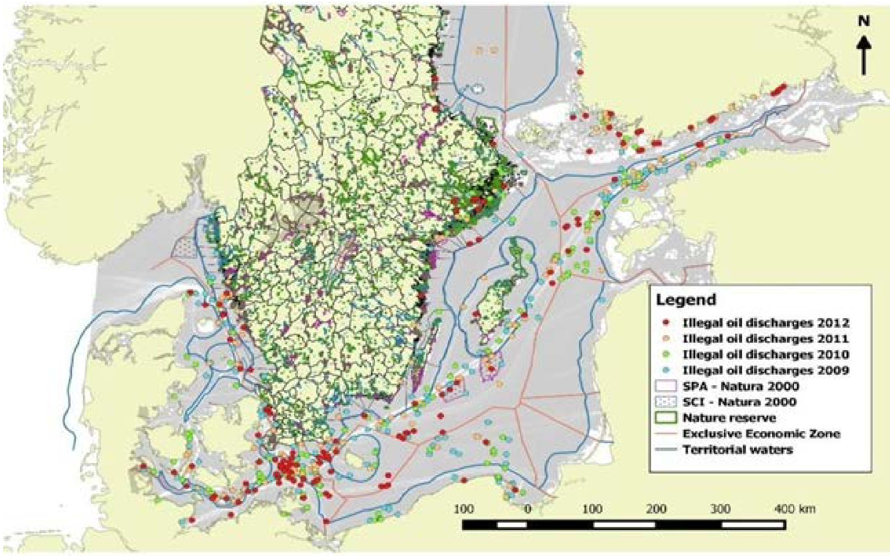

Figure 7. Illegal oil discharges from 2009 to 2012. Source: HELCOM, http://www.helcom.fi/baltic-sea-trends/data-maps

However, the cumulative effects of such smaller accidental and illegal spills have direct harmful impact. Oiled birds and mammals suffer from hypothermia or intoxication, which are particularly lethal to the avian fauna. BirdLife International estimated 2007 that 100 000 – 500 000 ducks, guillemots and other bird species die each year owing to small oil spills[30] .

Other effects caused by increased shipping are alien species finding their way into the Baltic Sea, most often by the deployment of ballast water and hull-fouling. Further the marine environment is also effected by the maritime underwater noise and anti-fouling chemicals used on ship hulls.[31]

There is an increasing concern that underwater noise generated by shipping traffic may have significant effect on fish, marine mammals and other marine organisms.
Cod (Gadus morhua) is one of the most common fish species commercially exploited in the Baltic Sea. Studies have shown that anthropogenic underwater noise can have a

[30] BirdLife International 2007): Baltic Sea Action Plan overlooks oil pollution. Available at: http://www.birdlife.org/news/news/2007/11/baltic_sea_action_plan. Html
[31] HELCOM, 2010. Maritime Activities in the Baltic Sea – An integrated thematic assessment on maritime activities and response to pollution at sea in the Baltic Sea Region

negative impact on spawning performance[32] of Atlantic cod, as well as cod larval behaviour, growth and development[33]. However as mentioned scientific studies on cod response to underwater noise where performed in confined tanks it is still not clear how cod populations at sea are affected by the increasing shipping traffic.

2.2.3. Maritime Spatial Planning (MSP) and marine environmental data

The HELCOM Baltic Sea Action Plan as well as the Ecosystem Approach underlying it, includes maritime spatial planning as an important new concept to promote cross-sectorial dialogue on the coexistence of the human activities in a limited sea area, both at the national and international levels. Regional Maritime Spatial Planning has also highlighted both in the EU integrated Maritime Policy as well as the EU Strategy for the Baltic Sea Region as an important horizontal and cross-sectorial action aiming at more integrated management structures for European Seas. The objectives of sub-activity 1.7 in the Mona Lisa 2.0 project is to promote an integration of environmental data in a process of developing green routes in the Maritime Spatial Planning.

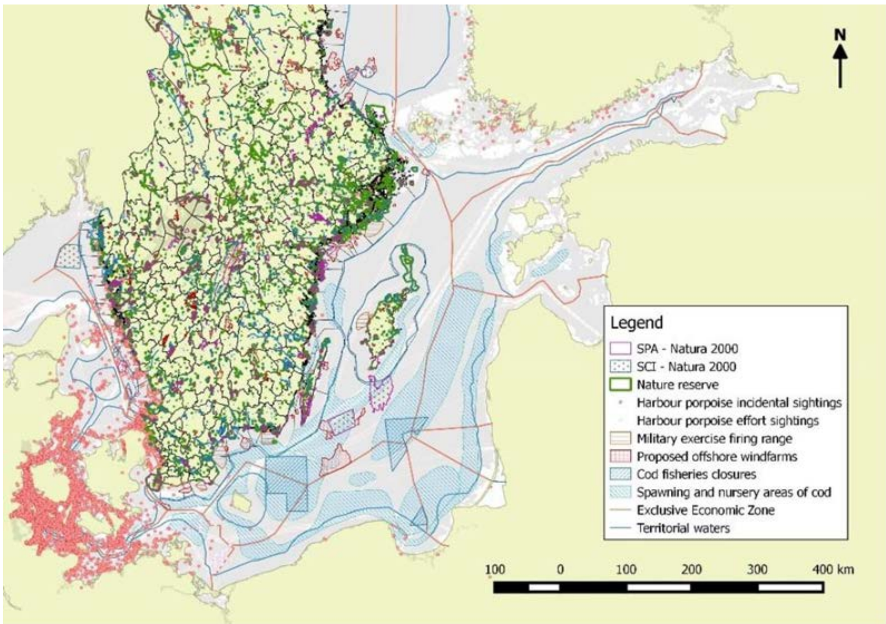

Figure 8. Marine environment- and human activity data, a background information for suggestions of green routes. Source HELCOM and EMODnet http://www.helcom.fi/baltic-sea-trends/data-maps http://www.emodnet-humanactivities.eu/view-data.php

Figure 8 visualise data that may be used for planning green routes including protected areas such as the Natura 2000 Special Protection Areas - SPA (Birds Directive), Sites of Community Importance – SCI (Habitat Directive) and Nature reserves. The map also

[32] Sierra-Flores R., Atack T., Migaud H., Davie A. 2015. Stress response to anthropogenic noise in Atlantic cod Gadus morhua L. Institute of Aquaculture, University of Stirling, Stirling 4K9 4LA, UK. Aquacultural engineering. Vol 67, P 67-76. July 2015.
[33] Nedelec S L. et al. 2015. Impact of regular and random noise on behaviour, growth and development of larval Atlantic cod (Gadus morhua). Proc. R. Soc. B. 282: 20151943.

shows areas that are important for spawning of Cod (*Gadus morhua*) and areas where sightings of porpoises (Phocoena phocoena) are most frequent. Geographical areas of suggested establishment of offshore wind farms and current military exercise firing range is also shown in figure 8. It is essential to stress the importance of an updated and easily accessible source of data for planning of maritime activities like shipping routes and navigation procedures. EMODnet34 and the data and map services of HELCOM35 are good examples of this kind of open source databases.

2.2.4. Suggested Hypothetical Green Routes

Taking into consideration environmental data and the risk of negative impact from shipping traffic a scenario was developed where dynamic rerouting depending on seasonal variation was suggested as a solution to minimize the negative impact.
The map in figure 9 show MSP data and the suggested dynamic green routes 1 and 2 that will be described more in detail below.

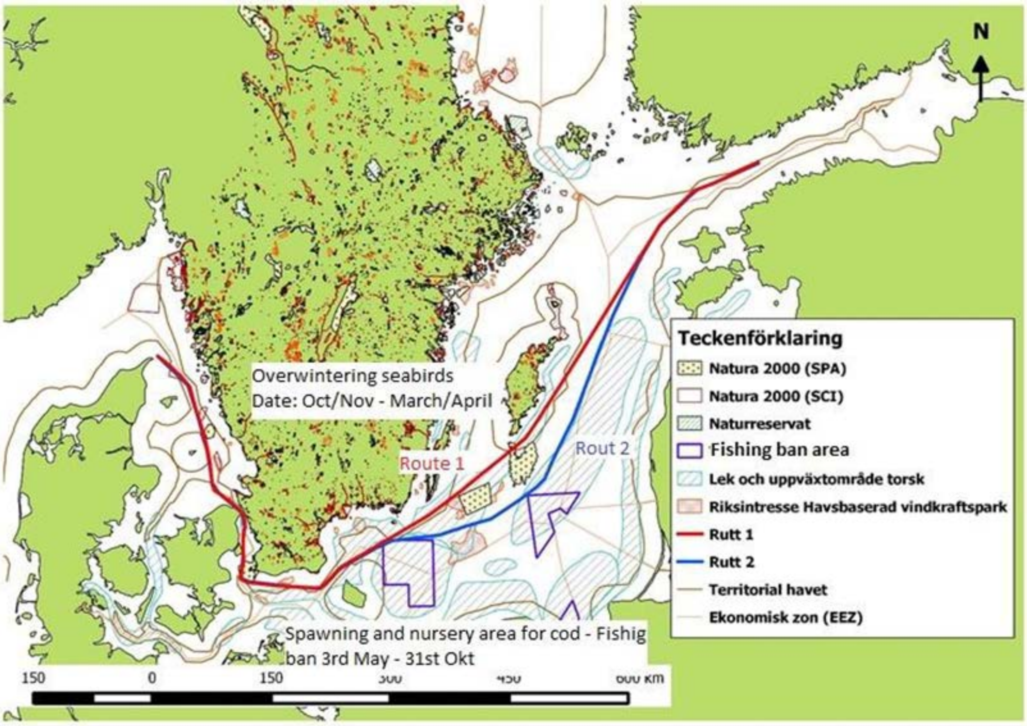

Figure 9. Suggested green routes (Route 1 and route 2) considering environmental data.

Between the two routes, route 1 is the busiest route and is passing close to the offshore banks Hoburgs bank and Norra Midsjöbank who are Natura 2000 areas protected through the Habitat Directive (SCI) as well as the Birds Directive (SPA). In addition to being important marine habitat these offshore banks are also important areas for wintering birds like long tailed duck (Clangula hyemalis) and velvet scooter (Melanitta

[34] http://www.emodnet-humanactivities.eu/view-data.php
[35] http://www.helcom.fi/baltic-sea-trends/data-maps

fusca). The wintering period for the long tailed duck is from October/November to March/May[36].

Route 2 is passing further away and on the east of the offshore banks, over the deep trench of Gotlandsdjupet. These areas are important for the spawning cod. During the period from 3st May to 31st October there is a cod fishery closure to protect the cod that gather to spawn[37].

Based on this information the hypothetical green routes are developed as dynamic routes where the seasonal separation would be the dates 2nd April to 31st October where all shipping traffic will be moved from route 2 to route 1 (protecting the spawning and nursery area of cod). During the date 1st November to 1st April all shipping traffic will be moved from route 1 to route 2 (protecting the wintering birds from illegal oil spills).

2.2.5. The simulation and optimisation of the suggested routes including MSP data performed by SSPA:

The simulation of optimised green routes in the Baltic Sea is performed in cooperation with the consultant SSPA Sweden AB in Gothenburg, where following variables are examined:

- Speed (time/distance)
- Energy consumption
- Pollution
- Type of vessels

- Since the shipping traffic is relatively regular over the year SSPA used the AIS data from August 2014 as the representative month.
- All ships are assumed to run on MGO (Marine Gas Oil) fuel.
- The yellow line in figure 10 display the estimated average route based on the traffic flow
- The calculation on the amount of traffic is based on the vessels movements between the pink crossing lines displayed in figure 10.
- The traffic is filtered and comprises only merchant vessels and passenger ships.
- The traffic in Route 1 is displayed in red and the traffic in route 2 is displayed in blue, showed in figure 10.

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[36] Durinck J., Skov H., Jensen F P & Phil S. 1994. Important marine areas for wintering seabirds in the Baltic Sea. EU DG Xi research contract no. 224290-09-01, Ornis Consult report, 1994. Köpenhamn.
[37] http://www.lansstyrelsen.se/skane/sv/naringsliv-och-föreningar/fiskerinaring/pages/torskfisket_i_oresund_och _ostersjon.aspx

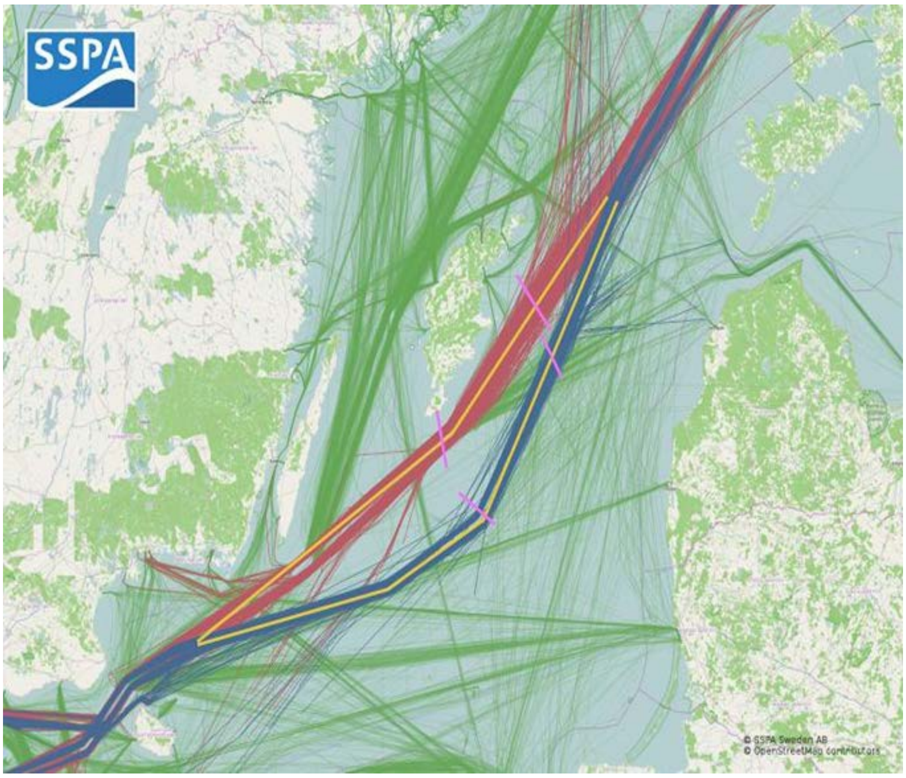

Figure 10. Simulation of route 1 and 2 performed by SSPA

Table 5 show the general information about route 1 and 2 when environmental data in MSP is not considered i.e. the current route scenario:

Route 1	Route 2
219 Nautical mile	238 Nautical mile
1020 Movements of ships	270 Movement of ships
14,1 knots, Average speed	12,5 knots, Average speed
9 014 tons, MGO consumption	3 243 tons, MGO consumption
Total MGO consumption 12 256 tons/month	
Total MGO consumption 147 072 tons/year	

Table 5. General information for routes 1 and

Table 6 summarise the information regarding the dynamic seasonal rerouting when considering environmental data in MSP:

Route 2 relocated to Route 1	Route 1 relocated to Route 2
Tot. 7 month (all traffic in route 1)	Tot. 5 month (all traffic in route 2)
Tot. MGO consumption:	Tot. MGO consumption:
11 991 tons/month	13 057 tons/month
83 937 tons/ for 7 month	65 285 tons/for 5 month

Table 6. Information regarding optimisation of shipping routes

The rerouting considering the MSP data would lead to a yearly (12 month) MGO consumption of 149 222 tons. That is an increase with 2 150 tons/year (all ships included) and is an increase of MGO consumption with about 1.5 % compared with the current state of shipping traffic in the Baltic Sea study area.

How the rerouting will affect the travelling time for vessels is shown in table 7:

Route 2 relocated to Route 1	Route 1 relocated to Route 2
Traveling time will decrease: On average 1 hour 31 minutes/ship	Traveling time will increase: on average 1 hour 21 minutes/ship
Total traveling time (of all ships): Decrease with 410 hour/month and 2 873 hour / 7 months	Total traveling time (of all ships): increase with 1 377 hour/month and 6 885 hour/ 5 months
Vessels' total travel time would increases by 4012 hours.	

Table 7. Rerouting effects on travelling time

When calculating the differences in time travelling on route 1 and rout 2 considering the seasonal change would conclude a total increase of 4012 hours including all vessels. Although for each vessel the difference in time when changing from one rout to the other would be a gain or loss of about 1 hour and 30 minutes depending if it is the shorter Rout 1 for 7 month or the longer Rout 2 for five month.

2.2.6. Comments from SSPA

It is questionable how much of the traffic on Route 2 that can really go on Route 1 of nautical reasons, such as if they are limited by their depth. According to AIS data there are on Route 1 only about 2 or 3 ships per month with depth greater than 12 meters while on route 2 there are 88 ships per month.

When distance is changed, ships fully, partially or not at all compensate with speed adjustments, with subsequent effects on consumption. The above analysis takes into account the case that the momentum is kept constant and the consequence is presented with regards to fuel consumption and time travelled (Lars Markström & Henrik Holm, April 2015, pers.comm.

2.2.7. Economic impact of shipping re-routing

The following tables, illustrates the economic impact considering the current scenario without the seasonal rerouting when compared with the green route scenario. Further, the investigation is mainly focused on the calculation of external cost related to air pollution and its effect on human health.

Table 8. Yearly emission of NOX. SO2 and CO2 in the current scenario from vessels travelling on Route 1 and Route 2 respectively.

Current scenario Route 1 (1020 vessels/month) Emission during 1 year	NOX [kg/Y]	SO2 [kg/Y]	CO2 [kg/Y]
Average SSD+MSD	9868317.896	216336	343866072
Current scenario Route 2 (270 vessels/month) Emission during 1 year	NOX [kg/Y]	SO2 [kg/Y]	CO2 [kg/Y]
Average SSD+MSD	3550361.098	77832	123713964

Table 9. Total yearly external cost considering yearly emission of NOX, SO2 and CO2 in the current scenario from vessels travelling on Route 1 and Route 2 respectively

Current scenario - external costs (Euro/year)			Nox	SO2	CO2	Total	Average min & max	Total external cost (€) current scenario route 1 and 2 during 1 year
Average SSD+MSD	Current scenario. Route 1 for 12 month	min	103617338	1081680	13754643	118453660.8	136017220	
		max	124340805	1730688	27509286	153580779.3		184952636.5
	Current scenario. Route 2 for 12 month	min	37278791.5	389160	4948558.6	42616510.09	48935416.52	
		max	44734549.8	622656	9897117.1	55254322.96		

Table 10. Monthly emission of NOX, SO2 and CO2 of the dynamic rerouting i.e. all vessels to Route 1 and all vessels to Route 2 respectively.

Green route scenario - Route 2 to Rout 1			
Total emission			
All vessels to Route 1	NOX	SO2	CO2
Average SSD+MSD	[kg/month]	[kg/month]	[kg/month]
	1093955.698	23982	38119389
Green route scenario - Route 1 to Route 2			
Total emission			
All vessels to Route 2	NOX	SO2	CO2
Average SSD+MSD	[kg/month]	[kg/month]	[kg/month]
	1191208.368	26114	41508203

Table 11. Total yearly external cost considering the seasonal dynamic rerouting when all vessels travel Route 1 during seven month and Route 2 during five month.

Green route - external cost (Euro/year)			Nox	SO2	CO2	Total	Average min & max	Total external cost (€) for green route during 1 year
Average SSD+MSD	All vessels to rout 1 during 7 month	min	80405744	839370	10673429	91918543	105547642.5	
		max	96486893	1342992	21346858	1.19E+08		187641091.7
	All vessels to rout 2 during 5 month	min	62538439	652850	8301641	71492930	82093449.16	
		max	75046127	1044560	16603281	92693968		

From these results the conclusion would be that the implementation of the hypothetical seasonal green rerouting, would lead to an increase of the external cost with 2 688 455 Euro. That is an increase with about 1.5 % of the external cost from current route scenario.

2.2.8. Conclusions

In the Baltic Sea case study the results from the simulations show an increase in fuel (MGO) consumption, travelling time and external costs for vessels taking the proposed hypothetical green route scenario.

The disadvantages of increased costs imposed on the shipping industry and the human society due to increased fuel consumption, travelling time, emission in air and water etc. should be weighed against the advantages of the implementation of green routes. In this hypothetical rerouting the expected environmental gain of protecting offshore banks and cod spawning grounds are preservation of biodiversity and a strengthening of the cod population. These environmental gains would be beneficial to human society, although there are difficulties to do a monetary assessments of this gain.

2.3. The case study in the Ionian Sea

2.3.1. Description of Ionian Sea Pilot Area

The proposed study area is a relatively large area covering the biggest part of the Hellenic Trench, from Lefkada Island in the Ionian Sea to the south-eastern edge of Crete that is characterised by steep underwater relief of depressions and trenches reaching a maximum depth of 5121m southwest of the Peloponnese[38].

The Hellenic Trench is a 1100 km long bathymetric feature that runs parallel to the western, southern and south-eastern coasts and islands of Greece. It consists of a series of linear trenches and small troughs, in which the depth increases steeply. The 1000 m contour is typically within 3–10 km of the closest island or mainland coast.

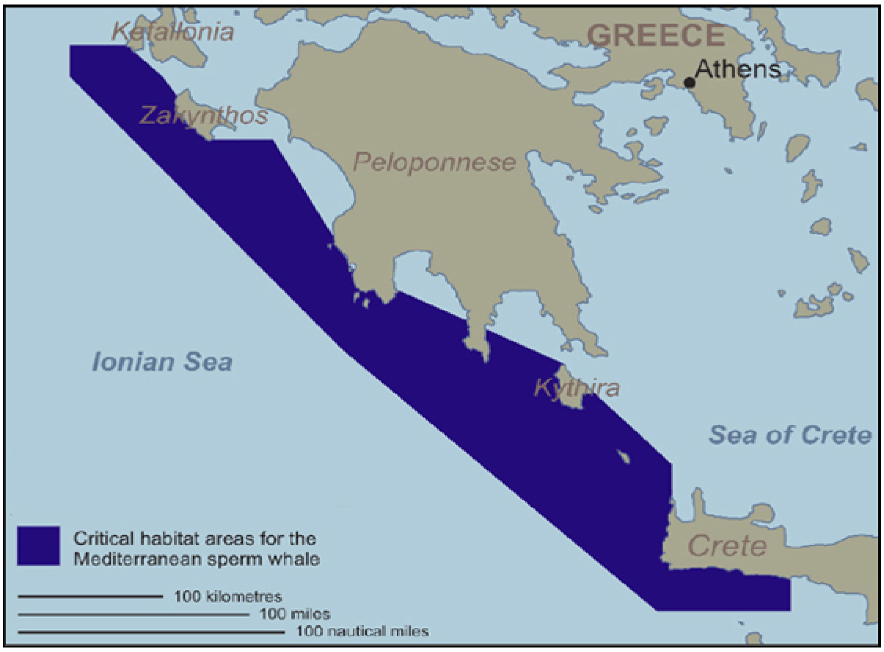

Figure 11. Proposed protected area for sperm whale at Hellenic Trench in Ionian Sea

The figure 11 represents the proposed Marine Protected Area in Southwest Crete / Hellenic Trench, as adopted by the Parties to ACCOBAMS.

This rich geomorphology creates a variety of marine ecosystems and habitats for various cetacean species. Especially, the offshore waters of SW Crete in Greece were identified as a key area containing critical habitat for the conservation of the Mediterranean sperm whales as well as the Ionian Sea for loggerhead sea turtle caretta-caretta.

[38] Stergiou *et al*. 1997

More specifically, within the study area, there is the National Marine Park of Zakynthos (N.M.P.Z.), which is established as a marine park situated at the southernmost part of the island of Zakynthos. The marine park's objectives are the preservation of the natural environment and the conservation of the ecological balance situated inside the marine and coastal area of the bay of Laganas and of the Strophadia Islands. Within the marine park, one comes across the most important loggerhead sea turtle caretta-caretta nesting rookery in the Mediterranean, which consist a habitat essential for protection. Additionally, a resident population of the critically endangered species of monk seal monachus-monachus is present at the west coast of Zakynthos. Furthermore the area is characterised by a variety of habitats, of European interest including sand dunes, posidonia oceanica beds, the critically endangered sea daffodil (pancratium maritimum), submerged reefs, as well as hundreds of species of flora and fauna, some of which are of great importance.

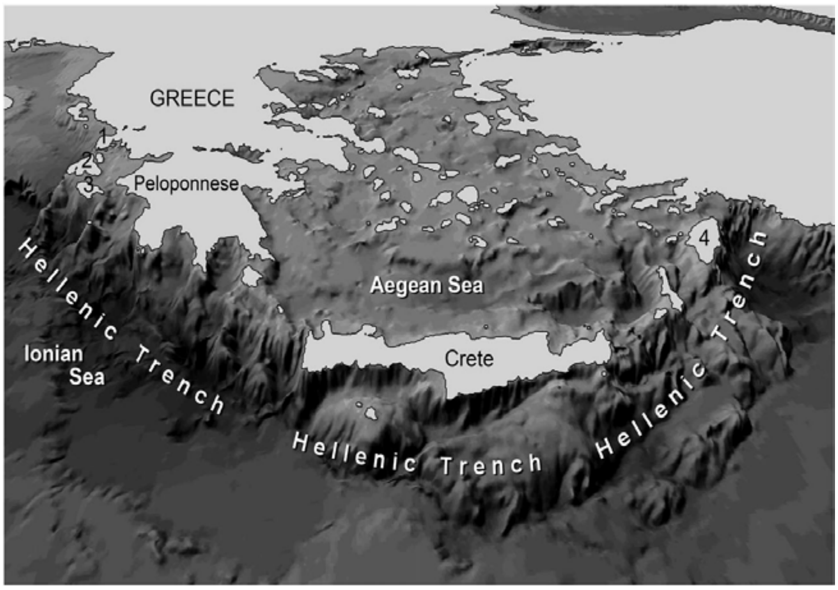

Figure 12. Topography of the Hellenic Trench using data from NASA World Wind 1.4 [39]

The sea surface in the specific area (Hellenic Trench) delimited to have a cetacean (sperm whale) visual encountered by the research vessel tracks in approximately 12 600 *km²* but our study area will be even more limited (7754 *km²)* and focused mainly to the territorial area of Ionian Sea from SE of Zakynthos to the southern tip of Peloponnese and be determined taking into consideration significant factors such as vessel traffic and shipping routes specified by various marine traffic systems (AIS, VTS, VTMIS etc.), types of vessels (mainly cargo ships, speedboats and ferries), vessel speed etc., that could have an environmental impact and have a potential to cause a collision with mammals and other endangered marine species.

According to various studies[40] a small and quite discrete sperm whale population unit is found in the Hellenic Trench. The Hellenic Trench is a key area for sperm whales in the

[39] http://worldwind.arc.nasa.gov/

eastern Mediterranean Sea and possibly constitutes the most important habitat in this basin.

Data on the abundance, the population status and trend of the endangered species at a national level are not available. However, information on the quantities in the Greek Seas and the rest of the Mediterranean Sea suggest that most cetacean and endangered species populations are likely to be declining, some even at alarming rates. In the case of sperm whales and sea turtles in Greece, mortality caused by ship strikes alone seems unsustainable, and constitutes an on-going threat to this small population[41]. Ship Strikes seem to be the most important threat for these and other endangered species in the Greek Seas. The Greek subpopulation of endangered cetaceans and other marine species is also thought to be decreasing since the suspected mortality rate from only one anthropogenic cause, namely collisions with large vessels as indicated by propeller marks on the body of stranded cetaceans, seems too high to be sustainable[18].

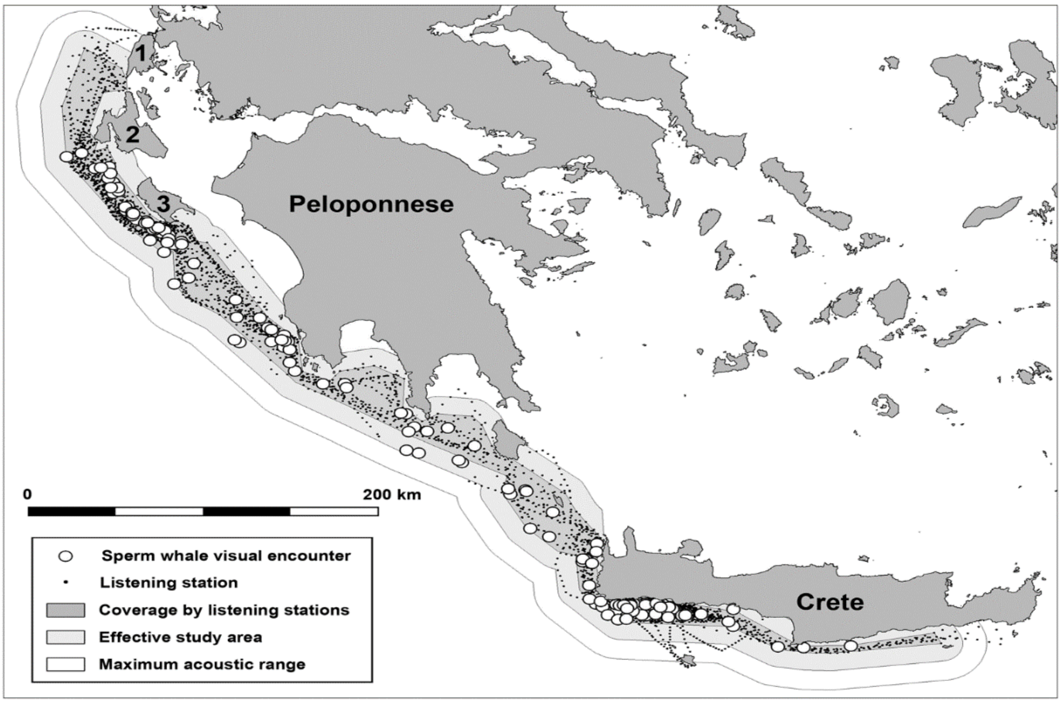

Figure 13. Sperm whale allocation areas

Furthermore, it must be mentioned that most births of cetaceans and sea turtles, occur from mid-June to end of August a period of high vessel traffic. The high likelihood of unreported fatal strikes combined with other anthropogenic threats suggests an urgent need for a comprehensive, basin-wide conservation strategy, including ship strike mitigation requirements, like real-time monitoring of whale presence and distribution to re-

40 Gannier A, Drouot V, Goold JC. 2002. Distribution and relative abundance of sperm whales in the Mediterranean Sea. Marine Ecology Progress Series 243: 281–293.

41 Pelagos Cetacean Research Institute, unpublished data, http://www.cms.int/en/legalinstrument/accobams

locate ferry routes to areas of lower cetacean and sea turtles density while reducing ship speed in high cetacean and sea turtles density areas.

2.3.2. Distribution of marine species

Sperm whales were found in the Hellenic Trench from southwest Kefallonia Island to central south Crete. The importance of the Hellenic Trench at a larger scale is shown by surveys of the eastern Mediterranean basin[42].

The eastern Mediterranean basin and especially the waters of the southern Hellenic Trench are some of the most nutrient-depleted waters in the world[43] with extremely low levels of chlorophyll a concentration[44]. The regular presence and strong preference of sperm whales for the habitat of the Hellenic Trench might seem to present an ecological paradox: the largest predator in the animal kingdom thriving in the most oligotrophic sea area of the world. This is in contrast with observations in other parts of the world ocean, where a link between sperm whale distribution and sea surface chlorophyll could be established. As noted by Jaquet et al. (1996), even if chlorophyll concentration is an important factor influencing sperm whale distribution over large spatial and temporal scales, other factors have to be considered in certain areas, and the Hellenic Trench seems to be such an area. In this sense, the Hellenic Trench is more similar to the relatively oligotrophic and less productive environment of the Azores than the areas where sperm whales have been studied in the Pacific Ocean[45].

There are few areas in the Mediterranean Sea that can be considered 'hotspots' for sperm whales. Even fewer (just two) are known social unit habitats, but it is upon these that the reproduction and the survival of this endangered population depend. Some important conclusions arise concerning the environmental importance of the particular area[46] [47]:

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[42] Lewis T, Matthews J, Boisseau O, Danbolt M, Gillespie D, Lacey C, Leaper R, McLanaghan R, Moscrop A. 2013.
Abundance estimates for sperm whales in the south western and eastern Mediterranean Sea from acoustic
line-transect surveys.

[43] Walle EB, Nikolopoulou-Tamvakli M, Heinen WJ. 1993. Environmental Conditions of the Mediterranean Sea. European Community Countries. Kluwer Academic Publisher: The Netherlands.

[44] Notarbartolo di Sciara G, Agardy T, Hyrenbach D, Scovazzi T, Van Klaveren P. 2008. The Pelagos Sanctuary for Mediterranean marine mammals. Aquatic Conservation: Marine and Freshwater Ecosystems 18: 367–391.

[45] Antunes R. 2009. Variation in sperm whale (Physeter macrocephalus) coda vocalizations and social structure in the North Atlantic Ocean. PhD thesis, University of St. Andrews, Scotland.

[46] Frantzis A, Alexiadou P, Paximadis G, Politi E, Gannier A, Corsini-Foka M. 2003. Current knowledge of the cetacean fauna of the Greek Seas. Journal of Cetacean Research and Management 5: 219–232.

1. The Hellenic Trench appears to be the core habitat for the eastern Mediterranean sperm whale sub- population, calving, nursing and very probably breeding occurs here.
2. This sub-population seems to be quite discrete and is likely to number very few hundreds of individuals; it is therefore very vulnerable.
3. Some features of the biology of sperm whales here differ from those of other well studied sperm whale populations. For example, both sexes use a limited area for feeding, breeding, calving and nursing with no obvious distant segregation at the scale that this occurs in typical oceanic populations.

[47] Frantzis A. 2009. Cetaceans in Greece: present status of knowledge. Initiative for the Conservation of Cetaceans in Greece. Initiative for the Conservation of Cetaceans in Greece: Athens, Greece.

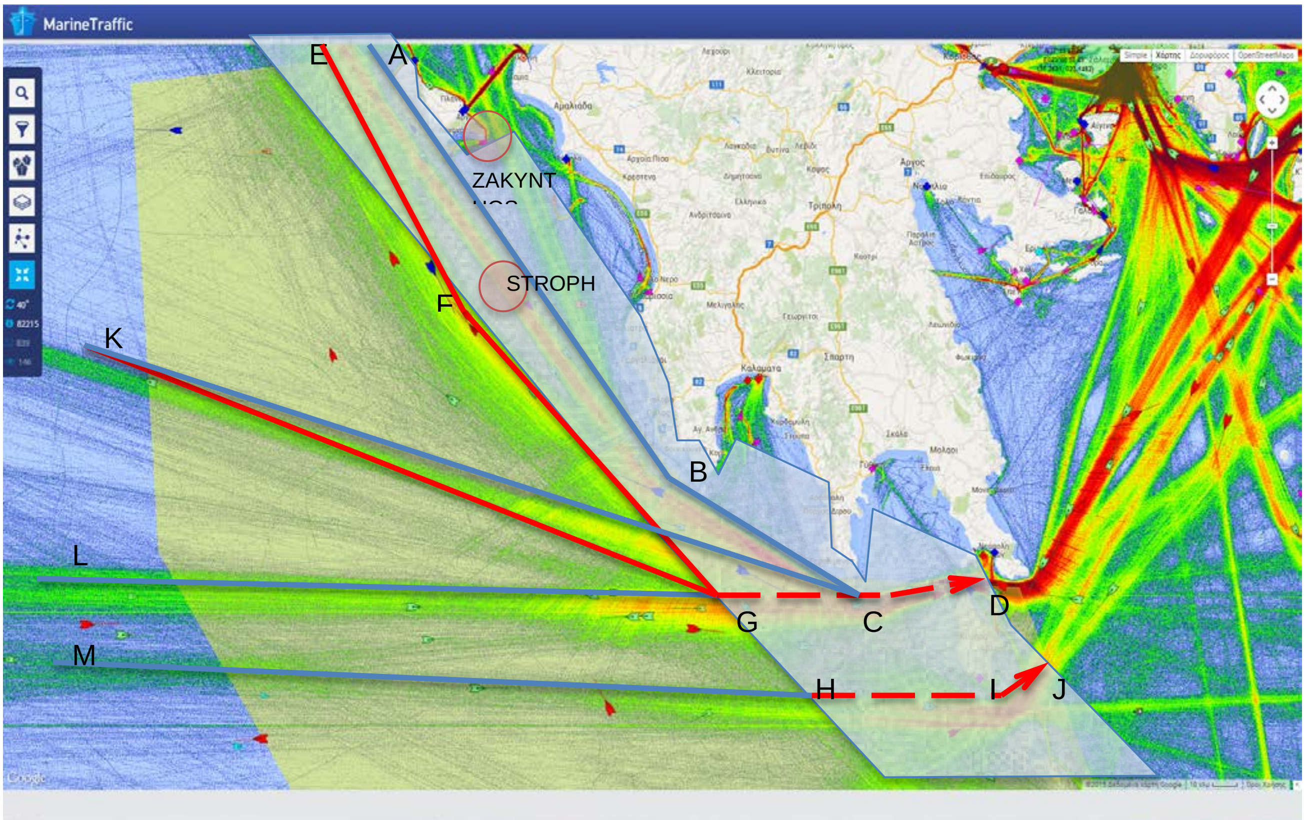

Figure 14. Alternative proposed shipping routes

DISTANCES	nm
AB	97
BC	47
CD	21
EF	63
FG	67
GC	33
KC	337
KG	304
LG	320
MH	368
HI	43
IJ	8

Table 7. Points on ship routes

POINTS	N	E
A	37,9226	20,5005
B	36,6772	21,6815
C	36,3018	22,5385
D	36,4169	22,9449
E	37,9226	20,0446
F	37,0552	20,7916
G	36,3196	21,8403
K	37,9095	15,6006
L	36,5185	15,2271
M	35,8534	14,6777
H	36,0180	22,2418
I	36,0224	23,1372
J	36,1261	23,2471

Table 8. Distances in nm

In the screen shot at the previous page the protected area is presented in white colour. In the same picture are shown the basic (most used) ship routes; four in the area in consideration. Route1 corresponds to ABCD (or DCBA) for the vessels heading to or coming from Adriatic Sea. Route2A corresponds to KCD (or DCK) for the ships heading to or coming from Messina strait. Route2B corresponds to LGCD (or DCGL) for the ships heading to or coming from southern Sicily. Finally, route3 corresponds to MHIJ (or JIHM) for the ships heading or coming from Malta.

Blue lines indicate the current situation while the red ones the proposed solution. It seems imperative to move the high congestion point (C) just out of the zone (G) where a small deviation is proposed for the vessels heading to Messina strait and a bigger deviation for those heading to Adriatic Sea. Two low speed (10Kn<) routes are also proposed following the current crossing ways northern and southern of Kithira island (GCD and HIJ).

Therefore, the proposed routes are EFGCD (or DCGFE) for the ships heading north or south – where the proposed deviation begins north-west of Zakynthos island, passes out of Strophades islands and finishes at the point G, KGCD (or DCGK) for the ships heading to or coming from Messina strait, LGCD (or DCGL) for those heading to or coming from south Sicily, and MHIJ (or JIHM) for those heading or coming from Malta. The last two proposed routes differ from the existing ones only in the speed reduction part (speeds 10Kn<) within the protected area.

The corresponding distances for each current route are 165nm, 358nm, 374nm and 419nm respectively. The proposed new distances are 184 (130+54) nm, 358 (304+54) nm, 374 (320+54) nm and 419 (368+51) nm. The coordinates of the various points and the leg distances of the ship routes are shown in the tables next to the picture above.

Regarding the **Route 1**, the examined scenarios are the following:

Scenario 1a: This represents the current situation where the vessels are following the route ABCD in both directions. The total distance equals to 165nm.

Scenario 1b: The vessels follow the route ABCD but all of them have to move with speeds equal or lower to 10Kn. Those that used to sail with lower speeds (10Kn<) continue in scenario2 to sail with the same speeds while the faster ones will move with speed equal to 10Kn.

Scenario 1c: The vessels follow the route leg EFG out of the protected area (130nm) and the route leg GCD inside the protected area (54nm). Outside the protected area hold the current speeds as monitored by the AIS system. Inside the protected area the slower ones continue to sail with the monitored speeds while the faster ones with speed of 10Kn exactly.

Regarding the **Route 2A**, the examined scenarios are the following:

Scenario 2Aa: This represents the current situation where the vessels are following the route KCD in both directions. The total distance equals to 358nm.
Scenario 2Ab: The vessels follow the route KGCD. In the KG leg continue with the AIS monitored speeds while in the GCD leg (inside the protected area) the slower ones (those with speeds 10Kn<) continue with the same speeds while the faster ones will sail with speed equal to 10Kn.

Scenario 2Ac: The vessels follow the route KGCD as in the previous scenario. The option in this case is to increase accordingly speed in the leg out the protected area in order to compensate the time loss inside the protected area. Therefore in the KG leg the slower ones continue with the AIS monitored speeds while the faster ones increase speeds. In the GCD leg (inside the protected area) the slower ones (those with speeds 10Kn<) continue with the same speeds while the faster ones will sail with speed equal to 10Kn.

Regarding the **Route 2B**, the examined scenarios are the following:
Scenario 2Ba: This represents the current situation where the vessels are following the route LGCD in both directions. The total distance equals to 374nm.

Scenario 2Bb: The vessels follow the route LGCD. In the LG leg continue with the AIS monitored speeds while in the GCD leg (inside the protected area) the slower ones (those with speeds 10Kn<) continue with the same speeds while the faster ones will sail with speed equal to 10Kn.

Scenario 2Bc: The vessels follow the route LGCD as in the previous scenario. The option in this case is to increase accordingly speed in the leg out the protected area in order to compensate the time loss inside the protected area. Therefore in the LG leg the slower ones continue with the AIS monitored speeds while the faster ones increase speeds. In the GCD leg (inside the protected area) the slower ones (those with speeds 10Kn<) continue with the same speeds while the faster ones will sail with speed equal to 10Kn.

Regarding the **Route 3**, the examined scenarios are the following:
Scenario 3a: This represents the current situation where the vessels are following the route MHIJ in both directions. The total distance equals to 419nm.

Scenario 3b: The vessels follow the route MHIJ. In the MH leg continue with the AIS monitored speeds while in the HIJ leg (inside the protected area) the slower ones (those with speeds 10Kn<) continue with the same speeds while the faster ones will sail with speed equal to 10Kn.

Scenario 3c: The vessels follow the route MHIJ as in the previous scenario. The option in this case is to increase accordingly speed in the leg out the protected area in order to compensate the time loss inside the protected area. Therefore in the MH leg the slower ones continue with the AIS monitored speeds while the faster ones increase speeds. In the HIJ leg (inside the protected area) the slower ones (those with speeds 10Kn<) continue with the same speeds while the faster ones will sail with speed equal to 10Kn.

2.3.3. Points On The Methodology Used

The model was designed to determine the change in cost to the shipping industry as a result of the management options for reducing the risk of vessel strikes to endangered marine species as these evaluated in this project. In the current paragraph, the key points of the methodology are presented together with their characteristics, the potential difficulties and the various restrictions encountered in their implementation. The key points are:

- The AIS system monitoring. Due to difficulties to buy the related data from the AIS system, every six hours, for the area in consideration, specific information for the ships (names, headings and speeds) were collected. The area was enhanced in order to catch all related vessels and even those that had temporarily closed their transmitters. Additionally this methodology gave the possibility to determine mean speed values.
- Construction of ships' DB. In order to move-on with the present analysis, for each route in consideration, all related data (name, IMO number, MMSI, type, flag, Lbp, Loa, B, T, GRT, DWT, Vmax, Vs, engine characteristics, fuel type, consumption) was gathered for the related vessels . Due to the variation to vessel sizes and types, the option to consider a representative ship in each case was impossible so, the traditional (and more time consuming) procedure was followed.
- Cost Calculations. For each vessel, the engine power, the consumption and the cost were estimated for the various speeds related to the given scenarios, as well as, the time spend in each leg of the respective route. Additionally, the total values for time (hours), consumption (tons), and cost (euro) were calculated for the scenarios' evaluation.
- Emissions' calculation. For each vessel, the power needed (KW) and the time spent (hours) in the various routes were also estimated. These were used for emission calculations, which were based on specific formulas[48].
- External costs. These were estimated based on the emission calculation using the formulas of the same paper as in the emissions' calculation.

[48] Hans Otto Kristiensen "Cargo Transport by Sea and Road – Technical and Economic Environmental Factors", Marine Technology, Vol39, No4. OCT2002, pp.239-249

2.3.4. Assumptions/Limitations

This topic negotiates the features, the limitations and the assumptions for the data used in the calculations. Different sources have been used and several assumptions have been chosen, in order the methodology to best simulate the realistic conditions, given the data and time restrictions.

- Ship data. Vessels' data was gathered from AIS system, NTUA-LMT databases, and from internet. In many cases the data provided from AIS system was inadequate or was entirely missing. The various databases were used to fill the gaps but, where this was not possible, best fit curves from the global fleet or from the existing (in the database) vessels were used.
- Type of fuel. Two fuel types were considered. One with S content in oil less than 3% (IFO180) and one with S content in oil less than 1% (LS380). The first was used for the low speed engines and the other one for the medium speed engines (used mainly at PASS, RORO PASS, RORO CARGO vessels).
- Engine power estimation. The engine power estimation for the various vessel speeds was calculated using the $P=K*V^n$ formula (P=power, K=constant, V=speed) where n takes value (2 and 3 in our case) according the ship speed.
- Consumption. It is assumed that the consumption is directly related to the engine power for the speeds in consideration.
- Vessels sailing with speeds below 10Kn (as monitored in the AIS system) will continue sail with the same speeds.
- Due to time constrains, the final results, which correspond to three-month period, derive from the multiplication of the results of the monitoring period (sampling of 10 days during the busiest period).

2.3.5. Analysis and Results

AIS System Monitoring

The ships in the area are moving in four directions: towards north to Adriatic Sea, northwest to Messina strait, west to southern Sicily and Malta. For the purpose of the study four routes were considered: route1 for the ships heading (or coming from) north, routes 2A and 2B combined together for the ships heading to or coming from Messina and southern Sicily, and route3 for the ships heading to or coming from Malta. In each route many vessels were sailing at very low speeds (under 10 Kn). The next three diagrams pinpoint the corresponding percentages. In the first two routes the percentage ratio is 20 / 80 % while in the third 10 / 90%.

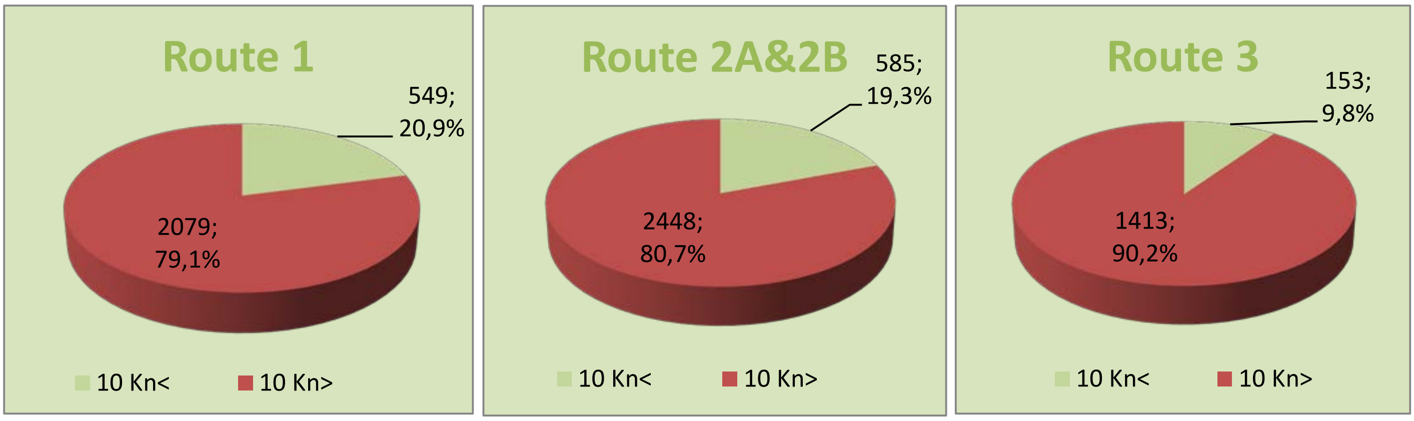

Diagram 1. Sailing information for each route

There is also a variety in the ship types sailing in the selected area. More specifically, these may grouped in Passenger & RoRo passenger ships, Tankers & Chemical Tankers, LNG&LPG vessels, General cargo vessels, Container & Cargo/Container ships, Bulk carriers, Wood chip carriers, Reefers, Vehicle carriers, and RoRo Cargo ships. The table below shows their number according their type, their route and speed.

SHIP TYPE	ROUTE 1		ROUTE 2A & 2B		ROUTE 3		TOTAL
	10 Kn<	10 Kn>	10 Kn<	10 Kn>	10 Kn<	10 Kn>	
BC	27	297	54	477	9	351	1215
CARGO/CONT	9	18	18	27		18	90
CONT	18	360	9	630		162	1179
GEN.CARGO	396	216	432	369	54	108	1575
LIVESTOCK	9	27		18	9	54	117
LNG/LPG	9	63	9	36		126	243
ASPHALT	9		9	9			27
OIL TANK		126	9	180	9	144	468

CHEM/PROD	45	243	45	333	72	324	1062
PASS	9	243		99		18	369
RORO-CARGO	18	351		108		27	504
RORO-PASS		18					18
VEHICLES		117		144		45	306
REEFER				9		18	27
WOOD				9		18	27
TOTAL	549	2079	585	2448	153	1413	7227

Table 9. Ship type and speeds passing through each area

The following diagram also depicts the percentage of various ships monitored in the area.

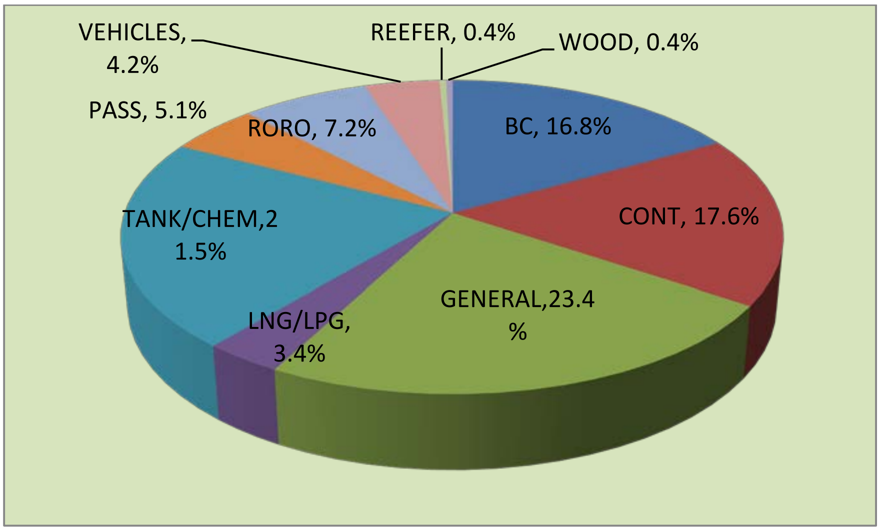

Diagram 2. Ship categories monitored in the area.

In the diagram below (number of ships versus type of vessel for speed equal or lower of 10 Kn), it is evident that, when considering speeds below 10 Kn, the prevailing ship type is General Cargo vessels.

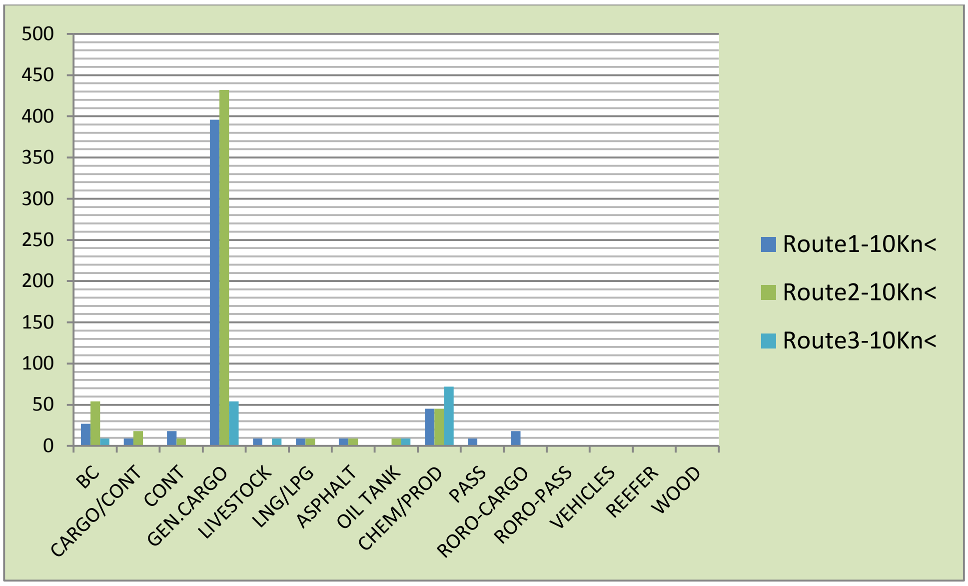

Diagram 3. Ship type sailing at low speed (10Kn<) for each route

Next diagram gives the distribution per ship type in the three routes in consideration. Bulk Carriers, Containerships, General Cargoes, Chemical Tankers, Passenger vessels and RoRo Cargoes are the majority in route 1. Bulk Carriers, Containerships, General Cargoes and Chemical Tankers are the majority in route 2. Bulk Carriers, Containerships, Crude Oil Tankers and Chemical Tankers are the majority in route 3.

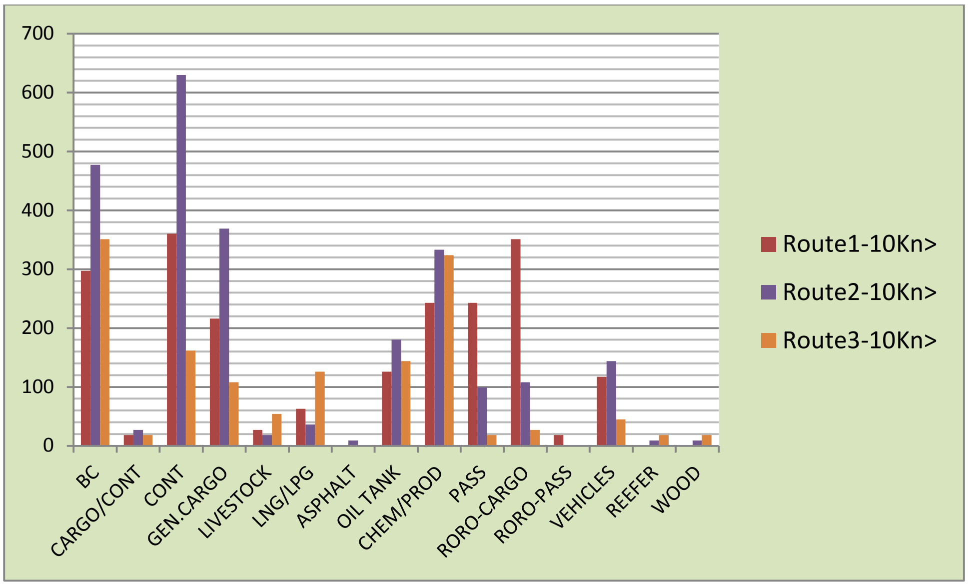

Diagram 4. Ship type distribution in each route for speed higher to 10Kn

Cost Calculation

Direct Costs Due To Fuel Consumption

The following table depicts the three variables (time, consumption, cost) per route and scenario in consideration (columns 3-5). Additionally, the differences related to the present situation – first row in each route – are presented in the last three columns (negative values for less consumption and cost).

		TimeTotal (h)	ConsTotal (t)	CostTotal (euro)	TimeDiff	ConsDiff	CostDiff
Route1	Scenario1a	35998,24	42178,5	14812167			
	Scenario1b	45634,19	28423,2	9782612	9635,9	-13755,3	-5029555
	Scenario1c	43297,07	42533,7	14874527	7298,8	355,2	62359
oute2A	Scenario2Aa	18148,81	18212,7	5932122			
	Scenario2Ab	18780,86	17360,8	5642682	632,05	-851,9	-289441
	Scenario2Ac	18148,81	19252,4	6295378	0,00	1039,7	363256
Route2B	Scenario2Ba	75839,73	76106,7	24788981			
	Scenario2Bb	78367,91	72699,3	23631218	2528,18	-3407,4	-1157763
	Scenario2Bc	75839,73	79611,6	26041550	0,00	3504,9	1252569
Route3	Scenario3a	52775,67	53244,0	16350028			
	Scenario3b	54454,17	51565,3	15826581	1678,49	-1678,7	-523446
	Scenario3c	52775,67	54364,9	16707458	0,00	1120,9	357430

Table 10. Time, consumption and cost for each scenario

The time needed for the ship to sail across the examined area, following a specific route, is estimated by dividing the total distance (S) by the speed (V) of the vessel.

$$Time\ (h) = \frac{S\ (nmiles)}{V\ (knots)}$$

Summarising all these time values, the Total Fleet Time, for each scenario, is estimated. The results are shown in the 3rd column of table 10.

In general, the specific consumption for each vessel is given by the curve of engine power vs. consumption. In most of the cases, unfortunately, only one or two sets of values (power and consumption) are given corresponding to maximum (Vmax) or service (Vs) speed. Respectively, the necessary engine power to move a vessel with a specific speed is related to the speed raised to n-power according to the relation

$$P = k * V^n \quad \text{where n = 2,3.}$$

Therefore, for a given speed the corresponding power can be calculated using one of the following relations:

$$\frac{P}{Pmax} = \left(\frac{Vmax}{V}\right)^{n} \quad \text{or} \quad \frac{P}{Pservice} = \left(\frac{Vservice}{V}\right)^{n}$$

Furthermore, the specific consumption in most of the cases is also given (or predicted) only for a certain value of engine power. Hence, the specific consumption corresponding to another engine power, necessary to maintain a specific speed, is estimated using direct linear relationship. The consumption for each vessel is given multiplying the specific consumption by the time needed to sail across the area in consideration. The sum of the consumptions of all vessels, per type, related at a certain route and scenario represent Total Consumption that is presented in column 4 of Table 10.

The direct cost (in our case represented by the fuel cost) is estimated multiplying the value of the consumption, for a specific vessel sailing at a specific speed, by the fuel price. In order to come up with more realistic results, the marine oil prices used in the current analysis differ for each vessel type: for cruisers and ro-ro cargo vessels a more expensive oil (LS380) containing lower sulphur (<1%) is used, while for other ship types a different marine oil type (IFO180) containing higher sulphur rates (<3%) and producing higher SO_2 emissions, is used. The specific oil type has a lower market price.
The marine oil prices used are Rotterdam’s stock market prices in 25/7/2015: IFO180 at 329, 00 $/ton, LS380 at 442, 50 $/ton while the Euro exchange price at the same time was: 1 euro (€) = 1, 0995 dollars ($).

The Total Cost, at the 5th column in the Table 10, is the sum of all direct costs in the given scenario.

The last three columns of Table 10 depict the differences between the current situation (first scenario) and the proposed green routes in terms of time consumption and cost.

Next table (11) presents the differences between the examined scenarios, for each of the three variables (time, consumption, cost), in percentages related to the current situation.

		TimeDiff %	**ConsDiff %**	**CostDiff %**
Route1	Scenario1a			
	Scenario1b	26,77	-32,61	-33,96
	Scenario1c	20,28	0,84	0,42
Route2A	Scenario2Aa			
	Scenario2Ab	3,48	-4,68	-4,88
	Scenario2Ac	0,00	5,71	6,12
Route2B	Scenario2Ba			
	Scenario2Bb	3,33	-4,48	-4,67
	Scenario2Bc	0,00	4,61	5,05
Route3	Scenario3a			
	Scenario3b	3,18	-3,15	-3,20
	Scenario3c	0,00	2,11	2,19

Table 11. Percentage differences in time, consumption and cost for each scenario

Examining the route1, it is obvious that when the entire fleet follows the same route but with lower speed (scenario 1b, 10 knots), the necessary time for crossing the area increases significantly (+27%), the total consumption decreases (-33%), and the cost of fuel decreases respectively (-34%). When the scenario 1c is considered, there is also an increase in the necessary time to cross the area (smaller than in the previous case, restricted only in the lower crossing - 20%), and a very small increase in consumption >1%. Therefore the proposed green route can be easily implemented by the maritime industry as the additional fuel cost is negligible and the difference in time manageable. The increase in time at individual ship level is small - in any case lower than 2 hours - and therefore could be overcome by a small increase of speed in the remaining route leg, or to compensate the queuing at the port of arrival.

Finally, as it can be revealed from the current analysis, with the only exception of the ‘extreme’ scenario 1b where all vessels move with very low speeds for the entire route1 (165nm), the effect in the cost is lower or equal to 6.12% in all of the proposed scenarios. The negative results indicate positive economies but this happens paying the price of the increased time. Time differences in most of the cases may be considered acceptable (low) and probably may have none or very low effect in crew wages and contractual penalties.

Route3-Case Study1- Time delay difference per ship	Route3-Case Study1- Consumption difference per ship	Route3-Case Study1- Cost difference per ship	Route3-Case Study2 - Time delay difference per ship	Route3-Case Study2- Consumption difference per ship	Route3-Case Study2- Cost difference per ship	
-0,91	0,7	213	0,00	-0,2	-74	Bulk Carrier
-1,72	2,7	809	0,00	-2,5	-755	Container Ship
-0,88	0,3	95	0,00	-0,1	-26	General Cargo
-0,84	0,2	71	0,00	-0,1	-25	Livestock Carrier
-1,55	1,3	391	0,00	-0,8	-255	Lpg Tanker
-0,94	1,1	323	0,00	-0,4	-105	Tanker
-1,07	0,8	249	0,00	-0,3	-94	Oil/Chemical Tanker
-2,32	8,2	3323	0,00	-9,6	-3890	Passenger Ship
-1,82	1,2	367	0,00	-1,0	-299	Reefer
-1,78	1,4	582	0,00	-1,0	-420	Ro-Ro Cargo
-2,02	2,0	603	0,00	-1,9	-567	Vehicles Carrier
-1,13	0,6	180	0,00	-0,2	-71	Wood Chips Carrier

Table 12. Differences in time, consumption and cost for each scenario/ ship type

Although the mean time delay and the mean consumption are relative low for the entire fleet, per each route in consideration, there are certain ship types that are more affected by the respective scenarios especially the faster ones and those that use more expensive fuel. The table above shows for the route 3 the differences per ship type in time, consumption and cost - negative values for additional time (hours), consumption (tons) and cost (euro).

External Costs

The external costs represent the damage to society that is not paid by the transport users and providers. The most important environmental transport costs are due to atmospheric pollution and to the greenhouse effect. In the present analysis, the limits corresponding to external costs outside urban area shown to the following table are used. These were based on European research projects COWI 1999, INFRAS & IWW 2000, Friends of the Earth 2000.

	Urban area (Euro/kg emission)	Outside Urban area (Euro/kg emission)
CO_2 emissions	0.04 – 0.07	0.04 – 0.08
NOx emissions	11.1 – 12.5	10.5 – 12.6
SO2 emissions	9 - 12	5 - 8
Particulates	90 - 340	20 - 23
HC emissions	1.4 – 2.6	1.1 – 2.6
CO emissions	0	0

Table 13. Upper and lower limits for external costs

In the following tables, using the values for emissions outside urban area (emissions during the trip at sea), the External costs (min and max) for each examined scenario are estimated[49].

Route1: Table 14 depicts the data related to external costs for the three scenarios of the Route1 (scenario1a represents the current situation).

EXTERNAL COSTS (EURO)		TOTAL
Scenario1a	min	817.725.761
	max	2.041.856.590
Scenario1c	min	824.456.890
	max	2.058.664.181
Scenario1b	min	550.574.776
	max	1.374.782.095

Table 14. External costs in Route1

Comparing the results for the three scenarios of the Route 1, it is easily extracted that Scenario 1b has the lowest external costs, as vessels are required to move with speeds lower or equal to 10Kn. This results a lower consumption and emissions as well as lower environmental costs. On the other hand, Scenario 1c presents higher external costs as a result of the longer route (additional 19 nm) the vessels have to sail in this particular scenario.

[49] The total value for the emissions for the various scenarios is estimated in the next subchapter. Multiplying these values by the provided upper and lower limits of Table 13 the external costs can be estimated.

Route2A: Table 15 shows the external costs for the three scenarios of the route 2A (scenario2Aa represents the current situation).

EXTERNAL COSTS (EURO)		TOTAL
Scenario2Aa	min	560.552.761
	max	1.399.697.067
Scenario2Ac	min	678.662.193
	max	1.694.615.649
Scenario2Ab	min	310.216.258
	max	774.608.238

Table 15. External costs in Route2A

In Scenario 2Ab the external costs are lower than in the other scenarios of the Route 2A, because the vessels that move in high speeds are now obliged to move with 10kn, despite the slightly longer voyage time. Oppositely, external costs are increased in scenario 2Ac, as vessels are obliged to move in higher speeds outside the protected area in order to compensate the time loss inside the protected area. As a result, consumption, emissions and environmental costs are increased.

Route2B: Table 16 presents the external costs for the three scenarios of the route 2B (scenario2Ba represents the current situation).

EXTERNAL COSTS (EURO)		TOTAL
Scenario2Ba	min	2.342.421.594
	max	5.849.013.443
Scenario2Bc	min	2.492.996.732
	max	6.224.998.711
Scenario2Bb	min	2.232.986.195
	max	5.575.753.872

Table 16. External costs in Route2B

In scenario 2Bb external costs are decreased, as the slower vessels (those with speeds 10Kn<) continue with the same speeds as in scenario 2Ba, while the faster ones will sail with speed equal to 10Kn. Additionally, in scenario 2Bc higher external costs are caused by the increase of speed outside the protected area in order to compensate the time loss inside the protected area.

Route3: Table 17 depicts the external costs for the three scenarios of the route 3 (scenario3a represents the current situation).

EXTERNAL COSTS (EURO)		TOTAL
Scenario3a	min	893.983.504
	max	2.232.271.743
Scenario3c	min	915.887.931
	max	2.286.966.973
Scenario3b	min	867.164.090
	max	2.165.303.818

Table 17. External costs in Route3

Regarding the Route 3 the scenario 3b is the one with the lowest external costs, due to lower sailing speeds (the ships are 'obliged' to move with speeds >10kn in the protected area) and the scenario 3c presents higher external costs, due to the increase of speeds outside the protected area.

Concluding, it can be observed that a potential rerouting or speed change in the examined area can easily change the impact of the shipping industry to the environmental costs.

Emissions Estimation

The precise estimation of the ship's emissions is almost impossible, as this requires direct input from each vessel's engine. Therefore, in this analysis a more simplified procedure has been followed multiplying the energy demand by the specific emission factors for different emission components. More specifically, for the NOx emissions the IMO limits that marine engine manufactures have to fulfil are used, while for the HC, CO and particulate emissions, representative mean values together with information from marine engine manufactures are applied. Hence, for the specific calculations, the following indicative limits for normal service conditions (according Lloyd's Register 1995) were used[50].

[50] Hans Otto Kristiensen "Cargo Transport by Sea and Road – Technical and Economic Environmental Factors" , Marine Technology, Vol39, No4. OCT2002, pp.239-249

	min(t/KWh)	max(t/KWh)
NOx	8	20
HC	0.2	1.0
CO	0.4	4.0
Particulates	0.1	2.0
SO2	6.0	10.7

Table 18. Min and max limits used for emissions' estimation

For this reason, in order to find the energy demand in each specific scenario, the total fleet sailing time (T) multiplied by the respective total power (P) was used.

T (h) x P (KW) = Energy (KWh)

These total values derived by summing the respective values for each ship type. Additionally, the SO2 calculations correspond to values indicative to RORO cargo vessels that use low S content in oil 1%< (min) and to Container & BC vessels that use high S content in oil 3%< (max).

Multiplying the energy demand of the vessels in each scenario, by the min & max limits of emissions in table 18, the emissions for each route scenario is estimated.

Energy (KWh) x Emission Factors (t/KWh) = Emissions (t)

The following tables correspond to the three routes in consideration and depict the difference of the estimated emissions among the proposed scenarios (green routes) and the scenario representing the current situation.

Route1: Difference in emissions among the three scenarios

Scenarios 1b-1a	**min(t)**	**max(t)**
NOx	-15294,6	-38236,5
HC	-382,4	-1911,8
CO	-764,7	-7647,3
Particulates	-191,2	-3823,7
SO2	-11471,0	-20456,5
Scenarios 1c-1a	min(t)	max(t)
Nox	385,4	963,4
HC	9,6	48,2
CO	19,3	192,7
Particulates	4,8	96,3
SO2	289,0	515,4

Table 19. Difference in emissions in Route1

At the upper part of table19 the difference among the scenario 1b and the current situation is shown. The negative values indicate that the emissions of the proposed scenario are much lower compared to the ‘standard’ route of the scenario 1a, as vessels move with lower speeds (<10kn). Unlike this first case, the difference in the emissions among the scenario 1c and the current situation is positive. There is an emissions increase due to the longer route the vessels have to sail but this is relatively small (environmentally close to the present condition).

Route2A: Difference in emissions among the three scenarios

Scenarios 2Ac-2Aa	**min(t)**	**max(t)**
NOx	6761,9	16904,7
HC	169,0	845,2
CO	338,1	3380,9
Particulates	84,5	1690,5
SO2	5071,4	9044,0
Scenarios 2Ab-2Aa	min(t)	max(t)
NOx	-14332,0	-35829,9
HC	-358,3	-1791,5
CO	-716,6	-7166,0
Particulates	-179,1	-3583,0
SO2	-10749,0	-19169,0

Table 20. Difference in emissions in Route2A

In the route 2A, the scenario 2Ac has the highest level of emissions, as vessels are obliged to move with increased speeds outside the protected area, while scenario 2Ab presents lower level of emissions as faster vessels move with speed equal to 10kn (slower than their average speed).

Route2B: Difference in emissions among the three scenarios. New increased speed in the 320nm leg and 10Kn speed in the second leg (within the protected area) compared to the present situation. Reduced speed 10Kn in the protected area, original speed in the 320nm leg compared to the present situation.

Scenarios 2Bc-2Ba	**min(t)**	**max(t)**
NOx	8620,5	21551,4
HC	215,5	1077,6
CO	431,0	4310,3
Particulates	107,8	2155,1
SO2	6465,4	11530,0
Scenarios 2Bb-2Ba	min(t)	max(t)
NOx	-6265,3	-15663,2
HC	-156,6	-783,2
CO	-313,3	-3132,6
Parriculates	-78,3	-1566,3
SO2	-4698,9	-8379,8

Table 21. Difference in emissions in Route2B

In scenario 2Bb the emissions are decreased (negative values), as the slower vessels (those with speeds 10Kn<) continue with the same speeds as in scenario 2Ba, while the faster ones will sail with speed equal to 10Kn. On the other hand, in scenario 2Bc, higher emissions (positive values) are caused by the increase of speed outside the protected area in order to compensate the time loss inside the protected area.

Route3: Difference in emissions among the three scenarios

Scenarios 3c-3a	**min(t)**	**max(t)**
NOx	1254,0	3135,1
HC	31,4	156,8
CO	62,7	627,0
Patriculates	15,7	313,5
SO2	940,5	1677,3
Scenarios 3b-3a	min(t)	max(t)
NOx	-1535,4	-3838,6
HC	-38,4	-191,9
CO	-76,8	-767,7
Patriculates	-19,2	-383,9
SO2	-1151,6	-2053,6

Table 22. Difference in emissions in Route3

Regarding Route 3, the scenario 3b is the one with the lowest emissions, due to lower sailing speeds (for those vessels moving with speeds >10kn). Contrary, the scenario 3c presents higher emissions, due to the increase of moving speeds outside the protected area.

2.4. Conclusions from the case studies

The case studies in the Balearic Sea, Baltic Sea and Ionian Sea are examined with respect to marine sensitive areas in the respective case study. In each one, green shipping routes are evaluated with respect to costs and environmental impacts, taking into account the protection of endangered sea animals, sensitive sea ecosystems and rich fishing areas.

The ship rerouting, inside and/or outside the sensitive areas, is realistic from the time the effects in fuel consumption and travelling time are within the acceptable limits of the shipping industry. There may be some additional problems that must be resolved (narrow passages, heavy marine traffic, depth limits etc.) but new technologies (e-navigation services) in Sea Traffic Management can be used to overcome these difficulties and to achieve the main scope of the study: the protection of the sea environment.

In the current analysis, the assessment of the external costs were based on measuring the effect of the ship' emissions on atmospheric pollution and greenhouse effect. Additional external costs due to wastes from various ship activities and discharges into water from the vessels (legal or illegal) are not taken into account, due to the difficulty to evaluate a number of parameters and the time limitations. However this does not devalue the results; it provides a very good indication of the total effect, because ship emissions are the leading factor of this type of costs.

Other environmental impacts due to the rerouting of ships away from coasts and sensitive areas, that are also very difficult to estimate, are the reduction of marine sound, the scouring effect on the seabed in shallow areas, and the potential environmental impact from a marine accident. The increased time spent at sea increases the risk of a major pollution incident and significant damage to the environment. Finally, rerouting may have an effect on the cost of shipping and goods due to the fact that it may potentially affect the cost of time related expenses, such as personnel wages, insurance rates, maintenance and consumables.

A common conclusion of the current study is that a smart design of green routes may provide low additional costs of fuel and/or transition time (increase of costs around 5-7%), which probably is very much acceptable for the shipping industry. Additionally, low speed crossing through the sensitive areas, in order to avoid accidents with marine life, leads to a very important emissions reduction.

3. List of acronyms and definitions

Examples of Acronyms and Abbreviations: all the abbreviations will be included to a separate table.

AIS:	Automatic Identification System
ATBA:	Area To Be Avoided
B:	Ship Beam
CBA:	Cost-Benefit Analysis
CHx:	Hydrocarbons
CO:	Carbon Monoxide
CO_2:	Carbon dioxide
DB:	Database
DEFRA:	Department for Environment, Food and Rural Affairs
DMA:	Dynamic Management Area
Dwt:	Deadweight Tonnage
ECA:	Emission Control Area
EEA:	European Economic Area
EMEP:	European Monitoring and Evaluation Program
EMODnet:	European Marine Observation ad Data Network
ENTEC:	European Commission Quantification of Emissions
EUNIS:	European Nature Information System
FAO:	Food and Agriculture Organization
GHG:	Green House Gases
GRT:	Gross Register Tonnage
GT:	Gross tonnage
IMO:	International Maritime Organization
IVL:	Swedish Environmental Research Institute
LBP:	Length Between Perpendiculars
LNG:	Liquefied Natural Gas
LOA:	Length Overall
LPG:	Liquefied Petroleum Gas
MAW:	Modified Atlantic Waters
MGO:	Marine Gas Oil
MMSI:	Maritime Mobile Service Identity
MSD:	Medium Speed Diesel
MSP:	Marine Spatial Planning
N.M.P.Z.:	National Marine Park of Zakynthos
NH_3:	Ammonia
NOx:	Nitrogen Oxides
$PM_{2,5}$:	Particulate Matter
PSU:	Practical Salinity Unit
SCI:	Sites of Community Importance
SMA:	Seasonal Management Area
SMW:	Surface Mediterranean Waters

SO_2:	Sulphur dioxide
SOx:	Sulphur Oxides
SPA:	Special Protection Areas
SSD:	Slow Speed Diesel
TSS:	Traffic Separation Scheme
	Vessel Traffic Monitoring and Information System
Vmax:	Maximum Velocity
VOCs:	Volatile Organic Compounds
Vs:	Service Velocity
VTMIS:	Vessel Traffic Management Information System
VTS:	Vessel Traffic Service

Examples of Definitions: at least the most relevant definitions may be included in the annexes.

- **Eco-system approach:** The eco-system approach is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way.
- **Integrated Coastal Zone Management:** Integrated Coastal Zone Management (ICZM) is designed to link all the different policies that have an effect on the coastal regions. It is about both planning and management of coastal resources and coastal space. It is not a ‘one off’ solution but an on-going dynamic process that will evolve over time. ICZM is not just an environmental policy, it also seeks to improve the economic and social well-being of coastal zones and help them develop their full potential as modern, vibrant communities
- **Marine Protected Area:** Any area of the intertidal or sub tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment.
- **Maritime activity:** Activity within the maritime areas, such as fishing, shipping, cruise tourism, marine conservation, offshore oil and gas exploration, offshore renewable energy, etc.
- **Maritime Spatial Planning:** Maritime Spatial Planning is a process of analysing and allocating parts of three-dimensional marine space (ecosystems) to specific uses, to achieve ecological, economic and social objectives that are usually specified through a political process. It is a tool for improved decision-making and provides a framework for arbitrating between competing human activities and managing their impact on the marine environment. Its objective is to balance sectoral interests and achieve sustainable use of marine resources in line with the EU
- **Conflict:** A conflict is a situation in which two or more maritime activities are based on methods or objectives that are incompatible if implemented simultaneously, either in space or time.

- **Spill over effect:** The effect caused by the presence (either physically or in time) of one activity on another activity or activities. A spill over effect can either be negative or positive.

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