# VECTORS of Change in Oceans and Seas Marine Life, Impact on Economic Sectors

## SP1 - Cooperation

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VECTORS Overview

*'VECTORS seeks to develop integrated, multidisciplinary research-based understanding that will contribute the information and knowledge required for addressing forthcoming requirements, policies and regulations across multiple sectors.'*

Marine life makes a substantial contribution to the economy and society of Europe. In reflection of this VECTORS is a substantial integrated EU funded project of 38 partner institutes and a budget of €16.33 million. It aims to elucidate the drivers, pressures and vectors that cause change in marine life, the mechanisms by which they do so, the impacts that they have on ecosystem structures and functioning, and on the economics of associated marine sectors and society. VECTORS will particularly focus on causes and consequences of invasive alien species, outbreak forming species, and changes in fish distribution and productivity. New and existing knowledge and insight will be synthesized and integrated to project changes in marine life, ecosystems and economies under future scenarios for adaptation and mitigation in the light of new technologies, fishing strategies and policy needs. VECTORS will evaluate current forms and mechanisms of marine governance in relation to the vectors of change. Based on its findings, VECTORS will provide solutions and tools for relevant stakeholders and policymakers, to be available for use during the lifetime of the project.

The project will address a complex array of interests comprising areas of concern for marine life, biodiversity, sectoral interests, regional seas, and academic disciplines and especially the interests of stakeholders. VECTORS will ensure that the links and interactions between all these areas of interest are explored, explained, modelled and communicated effectively to the relevant stakeholders. The VECTORS consortium is extremely experienced and genuinely multidisciplinary. It includes a mixture of natural scientists with knowledge of socio-economic aspects, and social scientists (environmental economists, policy and governance analysts and environmental law specialists) with interests in natural system functioning. VECTORS is therefore fully equipped to deliver the integrated interdisciplinary research required to achieve its objectives with maximal impact in the arenas of science, policy, management and society.

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Contents



# 1. Background to the addendum

This addendum has been added to the report based on the recommendations of anonymous European Commission reviewers of the report (D1.2).

The addendum aims to:

- Summarise new findings and assessments and draw more extensive derived conclusions.
- Prioritize the drivers.
- Include further important developments in the section 'Energy Demands and New Technologies', such as energy generation from sea waves.
- Examine further the relative importance and inter-connections between drivers, as well as commonalities and differences across regions.

# 2. Summary of new findings and key assessments for each of the drivers

## 2.1 Climate Change and Related Impacts - Climatic conditions in oceans and regional seas of the EU – documentation of altered conditions in abiotic environments and their impacts on the ecosystems

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### (I) Distinction between "Knowledge from published papers", and "New findings" or assessment from within VECTORS

An exact distinction between these two categories is problematic in the case of climate change: The review initiated under VECTORS WP1, scheduled at the beginning of the project, relied on summarizing published work and expert knowledge available within the VECTORS consortium. In some cases, the summary of existing work, itself led to new knowledge – as a review should. Examples of these categories are:

1. The review of knowledge from published papers has revealed some of the key processes related to climate change:

> In the North Sea, climate change has supported a shift within major zooplankton prey, affecting the larval survival of important commercial fish species through differences in food quality, and in the timing of occurrence. Significant shifts in the distribution and abundance of fish species have occurred.
>
> In the Baltic Sea, particular conditions may occur if increased precipitation and freshwater run-off lead to a shift to species, which are better adapted than the traditional fauna and flora to warmer, less saline waters.
>
> In the Mediterranean Sea, a major climate-related threat exists from the altered conditions of survival for invasive species, and the chance of jellyfish or other species to form mass occurrences and impair the quality, particularly of coastal habitats and their utilization.

2. The new findings or synthesis arising from VECTORS related to climate change

> Three main shifts in the dominance of biological traits may be expected in marine ecosystems: (a) the increasing occurrence of jellyfish - “jellification”, (b) growing importance of cephalopods, and (c) an advantage for fast-growing over slow-growing fish species.
>
> The North Sea ecosystem appears to be particularly sensitive match-mismatch phenomena, as many taxa depend on a well-timed synergy of recruitment or growth processes with hydrographic conditions and drift patterns in particular.

The consideration of both categories led to the proposal of questions to be investigated within VECTORS, and suggestions have been taken up beyond WP 1, as given in our **final recommendations** (see Deliverable 1.2, p. 54):

> Further Work Packages of VECTORS should address and identify both, general effects relevant for marine systems, as well as the ones that are specific to a certain region.
>
> It is recommended that VECTORS WP 2.2 should pursue modelling activities that are appropriate to demonstrate key processes and mechanisms by which climate change affects selected, commercially and/or ecologically important organisms.
>
> A few groups of organisms have been predicted to benefit from climate change in temperate European Seas. These include fish species with high growth rates, cephalopods or jellyfish. …. VECTORS WPs 2 and 5 particularly should model examples for selected relevant species and scenarios of future development.
>
> Another modelling activity could be the understanding of processes leading to mass development of “nuisance species”, e.g. gelatinous plankton species, or harmful phytoplankton blooms.
>
> Furthermore, relevant VECTORS WPs should investigate which ecosystem functions and services are already, or could be affected by such species. This could link climate-related ecosystem changes to economic aspects of tourism, to issues of health and safety, or to new challenges in fisheries management.
>
> VECTORS should consider the range of proposed scenarios of future climate developments, which covers on the one hand - expectations of a long-term cyclic change of climate conditions, and on the other - expectations of a continued, steady change, as in the scenarios presented by the IPCC.”

### (II) Prioritization of Drivers

Climate change impacts the structure and functioning of European marine ecosystems. The following drivers and mechanisms appear to be particularly relevant:

**Increasing temperature** => Shifts in phenology and in species’ distribution patterns => Changes in the occurrence of match/mismatch situations, e.g. in the availability of suitable food for specific life stages of fish.

**Increasing temperature** => Changes in the abundance and dominance of biological traits: e.g., chances for “jellification”; altered chances for survival of alien (warm-water) species.

**Increasing temperature, altered freshwater run-off** => Shifts in dominance of biological traits within the ecosystem; changes in biodiversity. The consequences of these phenomena to ecosystem functioning are not yet well understood.

[Ocean Acidification has been considered separately from Climate Change in D 1.2, although the two drivers are linked, and consequently, the impact of the combination of climate change with acidification should be taken into account where relevant.]

## 2.2 Ocean Acidification

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### Summary

Whilst Ocean Acidification (OA) is a persistent global stressor, the pH of coastal waters will depend on other physical, chemical and biological processes at the regional and local scale, such as freshwater input, nutrient concentrations, primary productivity and benthic respiration. Because of the complexity of modelling these variables, lack of data and the coarseness of model resolution, coastal zones have not been well represented in global atmosphere-ocean coupled models, although research suggests that interactions between OA and nutrient concentrations could either mitigate or exacerbate changes in pH.

Species are primarily affected by OA in two ways: 1) a decrease in the availability of $CO_3^{2-}$, and subsequent decrease in aragonite and calcite saturation states may negatively affect calcification; 2) a decrease in the pH of surrounding seawater may lead to a decrease in the pH (acidosis) of extracellular body fluids. It has been difficult to predict which species may be affected by OA, as species responses have been highly varied. The ability of a species to maintain acid-base balance of extracellular fluids may determine whether a species can prevent acidosis, whilst elevating the pH in areas of biogenic calcification, has been proposed as a method of maintaining calcification in low pH conditions. Both of these processes can require energy, and food availability has been highlighted as a possible factor in determining a species' ability to tolerate low pH. Early life history stages may be more susceptible to OA, and tolerance may be at least partially affected by a species' ecology. Similarly mixed responses to OA have been observed in microorganisms. Whilst an overall increase in consumption of DIC is observed in natural plankton communities, the effect of OA on phytoplankton calcification and growth rate, and bacterial production is inconsistent between studies.

Whilst there is no conclusive evidence, it is likely that ocean acidification will facilitate the establishment of alien species, increase the likelihood of species outbreaks and significantly alter species distributions and productivity. Outbreak forming jellyfish and successful invasive species are generally able to tolerate a wide range of environmental conditions. If they are robust to OA, this may enhance their competitive ability in the future, leading to increasingly negative impacts. Whilst results from experimental testing of the effect of OA on different species have been highly variable, evidence suggests that changes in competitive interactions will occur between species, and biodiversity may decrease. It is strongly likely that OA will lead to a change in species distribution and productivity in the future.

### Conclusions

Open-ocean time-series monitoring stations have shown a relationship between the concentration of atmospheric $CO_2$ and seawater pH, indicating that increased uptake of atmospheric $CO_2$ is responsible for the decrease in the pH of surface waters. Time-series analysis of pH levels in the coastal North Sea show increasing pH levels from the 1970s into the late 1980s or early 1990s, with pH levels only beginning to decrease in the last 10-20 years, showing that coastal pH is related to more than just atmospheric concentration of $CO_2$. It is thought that the increase in pH observed prior to the 1990s is due to eutrophication from both point source and diffuse pollution, leading to conversion of the North Sea coastal zone from a net heterotrophic to net autotrophic system. Since then, tighter nutrient regulations have led to a substantial decrease in nutrient concentrations, leading to phosphorous limitation of photosynthesis, and a drop in surface water pH. An increase in the number of dams has further decreased the amount of nutrients entering the North Sea.

Similarly an increase in pH was observed up until 1998 in the western coastal zone of the Baltic Sea, which was attributed to eutrophication leading to higher primary productivity, although this increase was not observed in the Central or Eastern Baltic Sea. No long-term information on pH trends of Mediterranean waters is available. Future reductions in nutrient supply may increase the rate of acidification in coastal waters. Acidification in Dutch coastal waters is occurring on an order of magnitude faster than those recorded in the open ocean, and a similar substantial decline in the pH of coastal waters has been observed in the temperate Pacific. If pH levels continue to decline at the rate currently observed for some coastal areas, then species could be affected by OA sooner than expected, and have little time to adapt to future OA.

Invasive species are most abundant in the Mediterranean Sea (325 established species), followed by the North Sea (144 established species) and the Baltic Sea (99 established species). Whilst the majority of invasive species in the Mediterranean have been introduced through the Suez Canal, the most common vectors of introduction in all seas under consideration are through shipping (hull and ballast water), or species movements from aquaculture. Whilst ocean acidification will not lead to a greater number of introductions, it is likely to play a role in the establishment of introduced species by changing competitive interactions between invasive and native species. For example, ocean acidification can lower species' thermal tolerance, therefore warm water species which migrate through the Suez Canal may be able to outcompete native species in the face of a combination of OA and ocean warming in the Mediterranean.

Many calcifying species of cnidarian (corals) are negatively affected by OA whilst other non-calcifying cnidarians such as sea anemones and jellyfish appear to be robust to this stressor. If jellyfish are robust to OA, this may change the competitive interactions between fish and jellyfish, leading to a greater number of outbreaks in the future. Jellyfish outbreaks are thought to increase with rising sea surface temperatures (Chapter 1), overfishing (Chapter 3), eutrophication and hypoxia (Chapter 4), suggesting that, in combination with OA, an increase in these pressures may lead to additive or synergistic effects on jellyfish outbreaks in the future.

The growth of some toxic dinoflagellate species are $CO_2$ limited, suggesting that increasing levels of $pCO_2$ may lead to increased growth and bloom formation. Whilst there is insufficient evidence that OA will affect the frequency of harmful algal blooms (HABs) in any of the seas under consideration, it is probable that a combination of OA and changes in sea surface temperature and nutrient availability will affect the distribution and frequency of HABs.

It is likely that OA will lead to changes in species distributions and productivity, although the variability in species response to OA, coupled with the fact that long-term monitoring of pH and associated changes to biota are few and in their infancy, make it impossible to predict exactly how OA will lead to changes at the ecosystem level. A decrease in pH has been shown to affect community structure and decrease diversity, although the extent at which these changes occur will vary regionally, and with habitat. Indirect effects of OA (such as changes in competition, predation and biogeochemical processes) will be important in structuring marine communities. Negative impacts on calcifying biogenic habitats such as coral reefs, maerl beds and mussel banks will have consequences for associated biota. Non-calcifying biogenic habitats such as seagrass beds are expected to respond favourably to OA, and may provide a refuge from OA to associated biota. A combination of OA and rising sea surface temperatures are expected to have particularly detrimental effects on biota. Evidence of a northward shift in species distributions in the North Sea in response to climate change has been demonstrated (Chapter 1). A reduction in species thermal tolerance in response to OA, may lead to a contraction in species range and smaller distributions.

There is evidence that OA will substantially affect all seas under consideration, although the response of organisms to changes in pH and associated carbonate chemistry varies greatly. Vulnerability to decreasing pH will not just depend on a species physiological ability to tolerate or adapt to OA, but to changes in biotic variables such as food availability, competition and predation. In order to provide a more comprehensive overview of the effect of ocean acidification there is a need to continue monitoring and experimentally assessing the effect of ocean acidification on marine organisms and ecosystems. Whilst there is not conclusive evidence, it is likely that ocean acidification will facilitate the establishment of alien species, increase the likelihood of species outbreaks and significantly alter species distributions and productivity.

## 2.3 Commercial Fisheries as a 'Vector of Change' in European Marine Waters

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### Summary

Of all of the 'vectors of change' fishing is probably one of the most intensively studied and well understood. Detailed fisheries research has been conducted for more than 100 years, especially in the North Sea and Baltic, following the establishment of the International Council for the Exploration of the Seas (ICES) in 1902. Extensive fishery-independent survey cruises are conducted each year, to quantify the status of fish stocks and collect biological information – fish landings through ports are closely monitored, to determine whether or not catches exceed levels that natural populations or the ecosystem can sustain. In VECTORS deliverable 1.2, we have primarily drawn on the many official sources available – in particular reports and publications from the European Commission, ICES, STECF, ICCAT and the GFCM. Given the large quantity of up-to-date information available, interpretation of current and future trends has required very little 'expert opinion' or extrapolation.

Perhaps some of the biggest uncertainties surround the spatial distribution of fishing effort. Collated international datasets are only available via STECF from 2000 onwards, and these are often incomplete (countries missing) or very coarse in their resolution (typically 1° Latitude by ½° Longitude grid cells). This data is completely missing in the Mediterranean, which also suffers from a lack of fisheries and fish stock data associated with the south (i.e. non-EU part of the basin), despite large fisheries existing in this region. Detailed spatial information is available for many EU fleets via the VMS (Vessel Monitoring System) satellite tracking facility. However, access to such data is tightly controlled in many countries and this has hindered progress in understanding the ecosystem consequences of such pressures.

The ecosystem effects of fishing have been well documented, but an 'arms race' exists between fishery regulators and the industry, whereby fishers attempt to maximise the efficiency of their operations – given the constraints imposed by quota restrictions, spatial closures, gear specifications etc., whereas regulators attempt to control misreporting, discarding and environmental damage. Often fisheries data is compromised by illegal, unreported or unregulated (IUU) activities, and so the absolute level of pressure exerted by fishing vessels can be highly uncertain.

The impact of fishing on the distribution/spread of outbreak-forming and invasive species is a poorly-researched topic (and has required some 'expert input'), although some non-native species and even jellyfish offer new opportunities, where these species can be harvested, marketed and are desired by seafood consumers (in Europe or elsewhere). A more familiar topic has been the inverse situation, i.e. the impact of outbreak-forming/

invasive species on commercial fisheries, since there are many recorded instances where the arrival of an invasive species has heralded significant damage to natural populations and hence fisheries.

### Conclusions

In terms of future trends and projections, existing modelling and quantitative assessments have been examined. In particular Failler et al. (2007) produced a series of fish consumption, production and trade projections for 28 countries in Europe spanning the period 1989 to 2030. However the detailed spatial and fleet-based implications of these general storylines needs to be explored further (in VECTORS WP 5.1, and 3.3) in the light of the socio-economic scenario framework that has been adopted across the VECTORS project. More than 1,200 assumptions were made in the work of Failler et al., for growth rates in captures, aquaculture, commodity production, imports and exports of commodities, and thus (as with all sets of future scenarios) the projections provided should be viewed with a great deal of caution and should not be considered a ‘prediction’.

On 13 July 2011, the European Commission presented its proposals for reform of the EU Common Fisheries Policy (CFP). The reformed CFP entered into force in 2013, and set the scene for fisheries management many years into the future. Key topics discussed in the reform documents include: the ‘ecosystem approach’ and the ‘precautionary principle’; an incentive to avoid unwanted catches (a ‘discard ban’) by means of technical solutions such as more selective fishing gear, a system of transferable fishing concessions. Other instruments and measures are conceivable in the future, depending on the prevailing socio-political environment. For example figure 3.1 illustrates some of the future changes, trends and challenges that might be anticipated (based on ‘expert opinion’) under each of the IPCC SRES future scenarios that have been adopted within VECTORS.

| | |
|---|---|
| **World Markets (A1)**<br>• Decommissioning subsidies reduced<br>• Fewer legal and technical restrictions<br>• Fish from the cheapest sources<br>• Only a few high-tech boats<br>• Heavily depleted fish stocks<br>• Rapid expansion of fish farming | **Global Sustainability (B1)**<br>• Yield vs. environmental impact<br>• Fish from sustainable sources worldwide<br>• Effective effort-based control system<br>• EU/international marine strategy<br>• Resources allocated to ‘natural’ predators<br>• Seabed set aside for nature conservation |
| **National Enterprise (A2)**<br>• Maintaining national supply important<br>• National control over territorial waters<br>• CFP mainly concerns ‘straddling stocks’<br>• Decline in fish imports<br>• Sport fisheries ‘squeezed out’<br>• Higher fish prices | **Local Stewardship (B2)**<br>• Local/regional governance<br>• Self sufficiency viewed as important<br>• Large number of small/traditional vessels<br>• Improved opportunities for ‘sport fisheries’<br>• Small scale, low-impact fish farming<br>• Disputes over ‘straddling stocks’ |

Figure 3.1. Consequences for European fisheries, envisaged under each IPCC SRES socio-political scenario.

In terms of key evidence gaps, the VECTORS review highlights the need for: (1) modelling techniques that can simulate the aggregate impact of multiple stressors simultaneously; (2) insight into the mechanisms by which fishing may hasten the spread of non-native invasive species; and (3) better quantification of the spatial footprint of fisheries as topics in need of urgent attention.

## 2.4 Land Based Pollution

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### Summary

Eutrophication is a common problem in all three seas considered. In the Baltic Sea it is mainly related to farming and managed forestry. In the Western Mediterranean Sea, eutrophic conditions are increasingly reported in the last decades in coastal and transitional waters, leading to dystrophic crises and benthic and fish kills. Some regions of the North Sea receive large quantities of anthropogenic nutrients through large rivers, and to a lesser extent from atmospheric deposition and discharges from plants that treat wastewater. The main areas affected by hypoxia in the Mediterranean Sea are coastal zones and lagoons where environmental features are: shallow depth, high productivity, organic matter enrichment and low hydrodynamic forces. In the Baltic Sea hypoxia is widespread in large areas both in the open deeper parts and at coastal stations. A side effect is increased release of phosphorous from sediments, giving a feed back to eutrophication. In the North Sea, hypoxia can occur seasonally particularly under stratified conditions in areas with high rates of production by phytoplankton.

Land-based pollution involves a number of often inter-related pressures such as eutrophication, hypoxia, turbidity, redox potential discontinuity, and various types of biological and chemical contamination. Each one of these pressures can result from specific causes and can lead to specific ecological effects and, because of this, these components are treated separately.

Eutrophication causes algae blooms and affects regulation by grazers, favouring invading amphipods and polychaetes. In addition, one of the effects of eutrophication is the development and persistence of harmful algal blooms, caused both by toxic and nuisance algae.

Hypoxia affects the behaviour, distribution and productivity of fish, through mass mortality or loss of habitat. On the other hand, prolonged hypoxia may favour species, such as jellyfish, which are known to tolerate lower dissolved $O_2$ concentrations in seawater.

Turbidity is increased by algae blooms, and can affect prey/predator behaviour in fish, as well as mating habits. Shadow effects can alter habitats of macro algae and vascular plants (Zostera).

Changes in Redox Potential discontinuity are a result of hypoxia and release of hydrogen sulfide in sediments and can have huge impacts on bottom fauna, and when re-oxidation occurs, opportunistic species can be favoured in the changing areas.

Chemical contamination with both “classical” and new contaminants is an abiotic factor, which can favour invading species with less sensitivity to contaminants, e.g. polychaetes and mud snails. Persistent Toxic Substances (PTSs) can have a major effect on marine life because of their persistence and their toxic effect on animals and plants if concentrations exceed certain thresholds.

Biological contamination is less studied, often related to aquatic farms or wastewater outlets. It can be linked to increasing infectious diseases in cetaceans.

*Western Mediterranean Sea*

In the Western Mediterranean Sea, land based pollution may result in the enrichment of the marine environment both through nutrients and organic matter enrichment. The former can cause eutrophication in the water column while the latter reduces the depth of the redox potential discontinuity in sediments. The process of eutrophication also increases the frequency and intensity of phytoplankton and macroalgal growth, which can generate hypoxia / anoxia and high turbidity conditions.

Eutrophication in the Mediterranean Sea is mainly confined to coastal areas. It is a recurrent phenomenon of shallow waters, lagoons and enclosed bays that receive nutrients from domestic and industrial waste; the main sources of which appear to be urbanization, tourism and agriculture

Similarly, the main areas affected by conditions of dissolved oxygen (DO) depletion are coastal zones and lagoons where environmental features are: shallow depths, high productivity, organic matter enrichment and low hydrodynamic forces. During the summer time, hypoxia (< 2 mg l-1) and anoxia (0 mg l-1) conditions occur in association with meteorological and hydrological conditions, such as calm weather and water stratification

One of the effects of eutrophication is the development and persistence of harmful algal blooms (HABs), caused both by toxic and nuisance algae.

By affecting oxygen and turbidity levels, eutrophication can also have an indirect effect on the abundance and distribution of organisms depending on their hypoxia tolerance and their dependency on turbidity for ecological and physiological processes, such as feeding and photosynthesis, respectively.

*North Sea*

Nutrient discharges causing eutrophication and hypoxia have declined in the last 25 years but problem areas exist seasonally within larger river plumes, particularly in eastern waters.

Eutrophication is also linked to seasonal hypoxia of deeper waters where many commercially (e.g. lobsters in the German Bight and Kattegat) and ecologically important species suffer high mortality. During certain years, hypoxia has had large impacts on the North Sea benthic assemblages, particularly in the southern North Sea and Kattegat. Prolonged hypoxia may favour species, such as jellyfish, which are known to tolerate lower dissolved $O_2$ concentrations in seawater.

Increases in turbidity resulting from local activities such as the construction of harbours and around wind turbine pylons and the dumping of dredge spoil, or due to loads of suspended particulate matter (SPM) in river runoff, mainly affect primary production by phytoplankton, performance of visual predators (e.g. fish, birds), and growth and survival of benthic organisms.

Chemical and biological pollutants are often associated with SPM, which occurs at higher concentrations in southern vs. northern waters and in coastal areas with shipping lanes that are routinely dredged.

Adverse effects of chemicals present within sediments have been documented on organisms, particularly along shipping routes. Some coastal and estuarine areas of the North Sea face especially large quantities and concentrations of contaminants.

Only a few coastal areas exceed threshold bacteria concentrations outlined in specific water quality directives but direct impacts of biological pollution on flora and fauna can occur in close proximity to sewage outflows including eutrophication-like effects as well as the transmission of faecal viruses and bacteria via SPM to shellfish and other filter feeders.

### *Baltic Sea*

The Baltic Sea is characterized by a low water exchange rate, making it sensitive to eutrophication.

Eutrophication can promote invasions by alien species in the Baltic Sea Such as phytophilous amphipod species. Concurrent with the blooms of filamentous macrophyte species in the last decade, a mass invasion of amphipod species has been observed in the north-eastern areas

Eutrophication can also affect species distribution and productivity. Eutrophication modifies biotic interactions in littoral macroalgal communities and forms the basis for increasing algal blooms, which in turn increases turbidity and hypoxia, followed by shallowing of the redox potential discontinuity and sulphide release from the sediment. As noted algal bloom can increase turbidity with consequent changes in the distribution and productivity in the Baltic Sea.

Hypoxia is a well-described phenomenon in the offshore waters of the Baltic Sea with both the spatial extent and intensity of hypoxia known to have increased due to anthropogenic eutrophication, however, an unknown amount of hypoxia is present in the coastal zone.

From the 1960s to present time, improvements in chemical contaminants have resulted in improvements in the health of top predators such as marine mammals and birds, but eutrophication and hypoxia are still widespread.

## Conclusions

### *Western Mediterranean Sea*

The increase of eutrophication conditions directly linked to hypoxic areas around the rim of Mediterranean is a severe problem, considering the loss of biodiversity due to changes in distribution and abundances of species.

Among chemical substances discarded into Mediterranean coastal waters, Persistent Toxic Substances (PTSs) are especially worrying because of their persistence and their toxic effect on animal and plant life if concentrations exceed certain thresholds.

Pollution risks are expected to increase with major discharges into the sea and rivers and a low level of pollution clean-up.

Hydrocarbons, particularly polycyclic aromatic hydrocarbons (PAHs) are persistent and originate from land-based sources, however the main source of PAHs pollution into the Mediterranean is sea transportation.

### *North Sea*

Changes in the future extent of hypoxia of North Sea waters will depend upon a number of unknown factors including changes in nutrient loading, the timing and strength of stratification, and the fate of phytoplankton biomass within the food web.

Consequently, effects of land-based pollution on species distributions and productivity, through changes in the redox environment, need to be contextualized in relation to different types and length of disturbance. In this sense, general impacts and the persistence of such impacts are difficult to predict.

In terms of chemical pollution, there is insufficient information regarding sources, spatial extent, mixture and concentrations of many of these contaminants in habitats (sediments and water-column) and organisms. Furthermore, programmes of monitoring are not hypothesis-driven or standardized and, because of this, are often poorly designed and not able to determine general patterns of accumulation from small-scale variations in space and time between habitats and organisms.

Regarding other potential impacts of chemical contamination, we speculate that (1) because many invasive species are more tolerant to contaminants than native species, there is concern that contaminated habitats make it easier for non-native species to establish by reducing the ability of native organisms to compete for food and space, (2) heavily polluted sites will display fewer species and poor productivity.

*Baltic Sea*

The Baltic coastal zone displays an alarming trend with hypoxia steadily increasing with time since the 1950s affecting nutrient biogeochemical processes, ecosystem services and coastal habitat.

The present contaminant levels in different parts of the Baltic Sea still cause biological effects in various species, resulting in genotoxicity, diseases and reproductive disorders and in some cases in chronic stress, features that may strongly affect populations and communities.

There is very little information on the extent and spatial distribution of biological contamination in the open Baltic Sea, for example, from passenger ships, which are allowed to discharge wastewater outside territorial waters.

No information is available on biological contamination thresholds regarding the causes and consequences of invasive species, species outbreaks and changes in distribution and abundance.

## 2.5 Maritime Transport

### Contributors (Overall Leader: Lola Rodríguez & Laia Piñol, LEITAT):

Lola Rodríguez & Laia Piñol (LEITAT); Matej David & Marko Perkovič (UL); Stephan Gollasch (GOCONSULT)

### Summary

Maritime transport represents a more efficient and sustainable alternative to road transport with its inherent congestion problems. Almost 90% of the EU external freight trade is seaborne and every year, more than 400 million passengers embark and disembark in European ports.

In addition, new technology will be gradually introduced to the world fleet in order to enhance fuel efficiency, including improved hulls, new surface materials and even ballast-free ships. In terms of these developments, the EC has defined a maritime transport policy until 2018 and several platforms involving the maritime industry have already started to define short and long-term objectives and implementation plans.

Maritime transport is crucial for economic development but several environmental impacts are associated with this economic activity. The transfer of harmful aquatic organisms by ballast water and biofouling, gas emissions, oil pollution, sludge, sewage, garbage, transport of dangerous goods, antifouling coatings and underwater noise are all associated with maritime transport activity. Furthermore, transport vessels, excluding military ships, are responsible for almost the 80% of the energy demand of the international registered fleet.

Today's policies and strategies promote less dependency on fossil fuels, fostering fuel efficiency and the use of biofuels, among other options for improved sustainability. Maritime transport should be in a position to cut $CO_2$ emissions by 40% (50% if feasible) by 2050 in comparison to 2005 levels. Moreover, the potential impacts of climate change on maritime transport will require new strategies for freight transport networks and facilities and even more technology-led efficiency improvements.

A €66.7 million call for proposals has been launched by the EC in the framework of the MARCO POLO programme to fight road congestion and make freight transport greener. Among its priorities are Short Sea

Shipping and inland waterways (innovative technologies for reducing emissions) and motorways of the Seas actions.

## Conclusions

Maritime transport is relatively safe and clean, but intensive and costly efforts are required to maintain this status. The international shipping industry is responsible for the carriage of about 90% of world trade and is vital to the functioning of the global economy. Without shipping, intercontinental trade, the bulk transport of raw materials and the import/export of affordable food and goods would simply not be possible. Shipping is the least environmentally damaging form of commercial transport and, compared with land based industry, is a comparatively minor contributor to marine pollution from human activities. Nevertheless, shipping represents different pressures on the environment and human health, which need to be minimised, also considering that costs of introduced measures are not higher than the effects.

The United Nations recognised the transfer of harmful aquatic organisms and pathogens across natural barriers as one of the four greatest pressures to the world's oceans and seas, causing global environmental changes, and posing threat also to human health, property and resources. These are transferred all-around the world by vessels ballast water and bio-fouling as prime vectors. IMO has adopted the Ballast Water Management (BWM) Convention and Bio-fouling Guidelines, which now represent solid grounds and a framework for implementation of management measures to prevent, minimize and ultimately eliminate the risks to the environment, human health, property and resources arising from the transfer of harmful aquatic organisms and pathogens. EU states are engaged on a coordinated approach to BWM under the umbrella and support of the European Maritime Safety Agency (EMSA), also noting that different regional initiatives exist. A coordinated approach in BWM as well as bio-fouling is very important as harmful aquatic organisms do not recognize political boundaries, and for effective maritime transport it is also very important to have common international requirements.

In terms of $CO_2$ emissions per tonne of cargo, shipping is the most efficient form of commercial transport, contributing to about 3% (0.9 billion tonnes) of the world's emissions. New technological developments and new Energy Efficiency Design Index (EEDI)-based designed ships may enable an approximately 15% reduction of $CO_2$ emissions sometime between 2007 and 2020.

Human error and deliberate discharges are the most common cause of oil pollution. CleanSeaNet, the European operational system for oil slick detection based on satellite-sourced Synthetic Aperture Radar (SAR) images, confirms that oil is currently illicitly pumped out across all European seas.

Sludge, sewage and garbage are important pollutants, regulated under the MARPOL convention, which may cause health hazard, oxygen depletion, introduction of pathogens and nutrients, biodiversity and habitat loss, water turbidity, and visual and marine pollution.
The transport and handling of dangerous goods has many risks associated with exposing both humans and the environment. The main dangerous goods hazards are acute toxicity, flammability, thermal radiation, blast wave, missile damage, poison, infection, corrosion, radioactivity, carcinogenicity, bioaccumulation and persistence. The Cargoxpress initiative provides "100% cargo protection", a possibility to consider and study for futures needs.

Many different approaches for antifouling paints exist but the main strategies depend on the moment the antifouling action takes place. An area of particular interest in recent years is the impact of surface patterning on fouling organisms. Present modern antifouling systems are alternatives to the TBT based paints but they are still not as effective. The AMBIO Project has detected designs with good anti-fouling properties and a list of coatings prototypes' performance and impact is included in their *Publishable Final Activity Report of the AMBIO Integrated Project.*

Even though the increase of large commercial ships represents an important source of noise pollution and the amount of cargo shipped is expected to double or triple in 2025, little knowledge is available on its effects in marine environment. There is evidence that human noise interferes with marine mammals' biological and social functions. Ambient noise may mask biological signals and reduce communication ranges for marine animals, prolonged exposure may lead to physiological and behavioural stress and chronic exposure can impair biological functions permanently. An "acoustic green label" is expected in September 2012.

Waterborne transport is among the least costly and most energy efficient modes of transportation. Transport vessels, excluding military ships, are responsible for almost 80% of the energy demand of the international registered fleet; the cargo fleet represents 66% of the total energy demand while non-cargo fleet is 20% of the total. Some mitigation measures and technologies are available to reduce air pollution from ships but some may not be economically viable, may need further development or are still at laboratory stage (e.g. Hydrogen-fuelled engines and Plasma Assisted Catalytic Reduction). The Cargoxpress vessel aims to save more than 60% of fuel consumption decreasing fuel dependence and several initiatives such as the E-harbours have created more sustainable energy models in harbour regions.

## 2.6 Energy Demands and New Technologies

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Summary

According to recent studies, the greatest potential and biggest interest in offshore renewable energies lies with wind energy.

However, depending on the country and their technological development, some plan to add a number of different installations for energy extraction offshore, as an addition or alternative to wind farms.

The Western Mediterranean areas plan to use solar systems for collecting energy as well as from marine currents, but none of these plans has been realised so far.

The North Sea countries plan to develop technologies that will use wave and tidal generation on the open oceanic coasts to generate energy and are also considering other forms of renewable energy generation (coastal wave capture devices). Although these technologies are under rapid development and test deployment, there is no public information on nearest future investments except for wave capture devices (more details in the chapter on wave energies later in this addendum). The UK plans to build three new nuclear power plants and one new gas development.

The Baltic Sea countries are also considering other ways of generating energy, such as solar panels, osmotic basins and wave energy installations. However, those installations are still in experimental phases and are unlikely to be considered for use in the near future. On the Polish coast there are plans to build three nuclear

power plants. Locations are under review at the moment (Choczewo, Gaski, Zarnowiec) and the final decision on development of one of the sites was to be made in May 2013.
Currently, there is still a big demand for natural gas, oil and coal. Countries like Spain, Poland and Italy are still dependent on coal for electricity generating. However, a growth in demand for electric power and EU regulations on $CO_2$ emission, have led to an increased interest in renewable energy like wind power. Currently in Europe there are about 6,100 offshore wind turbines producing around 1,500 MW of power. The European Wind Energy Association plans to increase this rate to 35,000 MW by 2020.

Generally problems occur with the implementation of selected new technologies when there is a lack of sufficient demonstration of prototypes in the marine environment. These problems are currently restricting development of ocean energy technologies, which in turn leads to increased difficulties for comparing environmental impacts from different technologies. The new installations will bring new problems mostly relating to the working infrastructure, which increases pressure on the ecosystems through their physical presence (long term effects on changes in water dynamics, change in the seabed properties and the coastline) and biological impacts (new habitats for invasive species, direct mortality of sensitive organisms).

The ecological indicators that could assess the impact of the energy projects are mainly connected with seabed mechanical disturbance; changes in the structure and function of benthic communities (e.g. switch from large, long living benthos towards small, short living species), waste products pressure (warm water, brine) which could have effects on local sensitive species and could cause the appearance of uncharacteristic or invasive species and also space use changes where areas covered with artificial structures or no-take zones around wind turbines could cause changes in the structure and abundance of demersal fish species, as well as sea mammal and seabird occurrence patterns.

The impact of industrial developments on marine ecosystems is based on the assumption that industrial processes are going to be carried out safely and in accordance with environmentally agreed procedures. Compatibility of energy installations with the marine environment is possible if potential impacts are well assessed from an early stage of the project, mitigation measures are successfully implemented and effects are monitored after construction. Marine spatial planning and mapping sensitive areas are highlighted as significant tools to minimise potential impacts at an early stage, since they help with careful siting and pre-construction assessment of energy infrastructures in the offshore area. Well-managed environmental impact assessments and monitoring plans will facilitate the avoidance or reduction of impacts.

In considering future scenarios it is also worth noting, that where governments planned to place great effort into alternative energies this has sometimes been hampered by the stringent economic climate of the global recession, a change that would not have been predicted by many before the event. Energy will always be central to society but replacing fossil fuels with more environmentally friendly renewables continues to be a great challenge for Europe.

## 2.7 Review of Treatment Processes and Systems for Ballast Water Management

Contributors: Matej David (UL) and Stephan Gollasch (GoConsult)

### Summary

A comprehensive review of ballast water management systems (BWMS) was conducted to address the driver ballast water and alien species introductions'. Additional information on BWMS was gathered by direct communication with vendors/manufacturers and by interviews on-board vessels conducted by the authors. This addendum focussed on BWMS which:

- are currently in use;
- treatment approaches the manufacturers have chosen, and
- technologies which are likely to be developed in the future (introduction of new technologies).

The main purpose of the review was to identify the current availability of BWMS technologies worldwide, to briefly introduce these and their use on the vessels, identify their timely availability in relation to the International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) requirements, and to identify the prospects of the global BWMS market.

By June 2012 when the D1.2 report was finalised, almost 100 BWMS were identified. BWMS use different treatment technologies mostly in combination. BWMS are in different development stages, with more than 20 of them already type approved by responsible authorities. However, uncertainty remains as to whether the BWMS production capacities will be able to accommodate the needs of the vessels. Furthermore, shipyard installation capacities may become a bottleneck in trying to meet the demand. This is a fast developing field as a worldwide market of close to 70,000 vessels will need to be equipped with such systems.

After the D1.2 report was completed in June 2012 and until December 2013 a further 10 new BWMS in development and construction were identified, and now more than 30 BWMS have been type approved.

The developments in this market are very much related to the BWM Convention entry into force, as this would enforce the needs for the installation of BWMS on vessels. The BWM Convention enters into force twelve months after the date on which more than 30 States, with combined merchant fleets not less than 35% of the gross tonnage of the world's merchant shipping, have signed this Convention. As of December 2013, 38 states ratified the BWM Convention, representing 30.38 % of the world merchant shipping gross tonnage (for an update visit Status of Conventions at www.imo.org). With this, it may be realistic to expect that the requirements for entry into force will be fulfilled in 2014 or at the latest in 2015, and the BWM Convention shall enter into force twelve months after that date.

At present BWMS are available to fit (almost) all vessels and to meet the BWM requirements set by the BWM Convention so that this aspect should not hinder the ratification of the BWM Convention. Although the most commonly used BWMS are either filtration combined with UV or electrochlorination it cannot be identified which would be the best method. This is vessel type, size and operation specific and there is almost no experience yet with different BWMS on different types of vessels.

## 2.8 Changes in Policy

### Contributors (Overall Leader: Ralf Döring & Leyre Goti, vTI-SF)

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### Summary

This overview on the legislative framework and possible policy development in the European Union with additional specific regulations in the regional seas including those which are especially important for the VECTORS project is aimed at understanding the future influence of policy changes on the Vectors of Change. The chapter on Driver 8 'Changes in policy' gives a comprehensive overview of the different regulations and policy initiatives which may lead to regulations on the level of the UN, European Union, regional seas and national level. Several policies are in the phase of implementation (like the Marine Strategy Framework Directive (MSFD) or the Natura 2000 network) or under revision (like the Common Fisheries Policy). With the new basic regulation more fish stocks should be harvested sustainably (following the Maximum Sustainable Yield (MSY) objective) and the negative impacts on non-target species and habitats reduced. The Discard Ban and the possibility of implementing protected areas for fisheries management reasons are two of the new instruments. The Conventions on the level of the regional seas, OSPAR for the North Sea and HELCOM for the Baltic Sea, are often not binding like regulations but nevertheless important as they show the political objectives which governments want to achieve over the coming years. There are additionally several initiatives on the EU level, like the EU biodiversity strategy to 2020, which will lead to legislative action in the coming years. Also at the national level in cases where countries have to implement regulations, new legislation may be generated.

### Common Fisheries Policy

The Common Fisheries Policy (CFP) is the framework for fisheries management in the EU. The CFP was put in place in 1983 after the introduction of the 200 nm Exclusive Economic Zone required a common policy due to the Treaty of Rome for the formation of the European Community. In this treaty fisheries should already be managed under a common policy but this was really operationalized only after countries with strong interests in fisheries joined the EU.

The basic regulation EU 2371/2002 was under revision during 2013 and the new regulation (EU No 1380/2013) includes a framework under which specific regulation for technical measures or conservation of fish stocks are covered. The EU Commission published a proposal for the new regulation in July 2011. The decision for the new regulation should have taken place at the end of 2012 but it was delayed until the end of 2013.

The CFP is now only one element of the overall Integrated Maritime Policy (IMP) and in combination with the MSFD it shall assure the achievement of Good Environmental Status (GES) concerning marine living resources in European waters. An important objective of regulations under the CFP is to reduce the negative impacts of fisheries on the environment. The new instruments for that are, for example, the so-called Discard ban (Art. 14) and the provision for protected areas as fisheries management measure (Art. 8):

- In many fisheries fishermen catch not only the species they target but also non-target species. This includes also species for which they have no quota left. So far they are not allowed to land them and must discard the fish. The Discard Ban now includes provisions to reduce discards step by step by introducing an obligation to land them which will force fishermen to change their behaviour, e.g. leaving areas with a high bycatch rate as they now need quota for that bycatch.

- Member States of the EU can now introduce so-called fish stock recovery areas to save concentrations of small fish (nursery areas), heavy concentrations of fish below minimum conservation reference size or spawning grounds.

Several regulations had been enacted which contribute to the objectives of the MSFD and targets of the CFP are now also targets of the MSFD (like MSY for stocks). For more and more stocks in European waters the fishing mortality was reduced to a level where fisheries biologists predict that MSY is possible (which basically means the target is achieved). This is a result of the introduction of long-term management plans (LTMP), also an instrument in the new basic regulation. A LTMP includes clear instructions and instruments for how to reach the MSY objective (step by step reduction of the fishing mortality which allows the fishing sector to adapt to the situation). For an increasing number of stocks LTMP will be introduced and then more stocks will be fished sustainably (high yields). In cases where the new instruments to reduce negative impacts (e.g. discard ban or conservation areas) are introduced we can assume that the overall impact of fisheries on the ecosystem will be reduced. The changes in distribution of stocks due to climate change may lead to a change in fishing patterns but all predictions so far only see limited negative economic impacts on the fleet (see results of VECTORS WP 3.3).

The CFP is so far a top down management approach with all regulations decided by the European Fisheries Council (before adoption of the Lisbon treaty) and then in co-decision by the European Parliament with exemption of the total allowable catch and quota regulation (after the treaty came into force). As a step towards a more bottom up approach the Regional Advisory Councils (including North Sea, Baltic Sea and Mediterranean) were established with the last regulation EU 2371/2002. With the new regulation adopted in 2013 member states surrounding a regional sea can, after consultation with the RACs, anonymously adopt measures, like discard plans, which means a regionalization of decision making.

## 2.9 Tourism

### Contributors (Overall Leader: Lola Rodríguez & Laia Piñol, LEITAT)

Lola Rodríguez & Laia Piñol (LEITAT), Stephan Gollasch (GoConsult), Bella S. Galil (NIO-IOLR), Valter Suban (UL), Dan Minchin (MOI)

### Summary

Tourism represents a key sector for European countries and for employment in the EU. Europe is the number one tourist destination worldwide, mainly in coastal regions that offer beach-based tourism, nautical sports and other direct interactions with marine ecosystems and coastal environments. Seasonality remains an important issue to be addressed since 46% of Europeans' holidays are taken during the third quarter of the year.

Europeans like to choose an EU destination for holidays, with recreation, sun and beach, nature, culture and sports among their main reasons for going on vacation. Even though Europeans have environmental concerns and several sustainable tourism initiatives are already taking place throughout Europe, yachting and coastline tourism, whale watching, or cruise tourism are tourism typologies with clear negative impacts on marine ecosystems.

Non-indigenous species (NIS) and jellyfish outbreaks have also been shown to have an impact on tourism. All jellyfish species are venomous and some represent a health hazard.

Evidence has been found of small crafts spreading NIS. European and non-European research indicates that, both nationally and internationally, small recreational craft hull fouling is an unmanaged or unregulated vector that represents a significant risk in the introduction of NIS. Boats stationary for long periods at marinas represent

a risk too: stationary for long periods, they accumulate fouling, which may be spread when these boats are eventually moved.

Synergies and conflicts between tourism-related activities and other users and/or sectors are identified; conflicts such as whale collision with passenger vessels or synergies such as the economic and environmental benefits that arise when fisheries diversify into tourism ("*pescaturismo"*) are addressed.

### Conclusions

Coastal tourism is highly significant to the economies of coastal regions. It gathers most of the tourism in Europe and resident tourists mainly visit seaside regions. Nautical activities and sports constitute an important attraction when choosing a holiday destination.

Even though seasonality is an issue to combat, the EC is providing certain tools to help in this task. Marine and coastal tourism stakeholders (nautical associations, nautical SMEs, fishing tourism SMEs, cruise companies, among others) should work on being aware of Europe's tourism strategy in order to seek as many synergies as possible. The interest of the EC in the promotion of low-season and accessible tourism can easily be met by marine and coastal tourism offers such activities as fishing tourism, "pescaturismo", "ittiturismo" or whale-watching. Stakeholders should also take advantage of EC's initiatives such as "CALYPSO" or "50,000 tourists" in benefit of marine and coastal tourism. It is also important for marine and coastal tourism stakeholders and SMEs to know about international and European tourists' attitudes and concerns. Evidence shows that Europeans have concerns in relation to climate change, water pollution, loss of biodiversity or overfishing. This also represents an opportunity for marine and coastal tourism SMEs to adapt their tourism services in a way that Europeans feel involved in a sustainable kind of tourism. Europeans attitudes and target markets should also be studied in order for tourism services to involve tourists in protection and conservation actions. This up-to-date information constitutes new business opportunities, beyond peak month, for marine and coastal tourism agents. Member States school calendars will be made available in the near future for tourism stakeholders in order to help in the design of future tourism strategies. Children represent an important community for marine and coastal tourism with beach, nautical sports or "fishing tourism" activities in many cases targeted towards children. This represents another example of why marine and coastal tourism stakeholders should be aware of up-to-date EC strategies in order to benefit SMEs business.

Marine and coastal tourism have many associated impacts. Recreational boats and personal watercraft generate many impacts during their entire life cycle, starting from a non-eco design, hydrocarbon pollution, noise, waste water, antifouling coatings, garbage, anchoring, and ending with a lack of regulation framework for end-of-life recreational boats; even though eco-design and end-of-life initiatives are slowly increasing.

Small crafts spread NIS mainly by hull fouling. Actions such as obligatory maintenance of hulls and quarantine protocols may reduce the spread. Regional regulation of small craft maintenance should be called for.

Abandoned boats (both floating and sunk) should also be addressed by management authorities since they not only harm the marine environment (e.g. leakage or spills of solid and liquid wastes such as hydrocarbon, oil and liquid from batteries), but also represent a risk in the spreading of NIS. There is no legal or regulatory instrument that requires the correct management of abandoned craft in Europe. The increase of boating activities worldwide increases the probability of NIS being introduced through this vector into a greater number of habitats, regions and possibly countries. Nautical sports also impact on the environment. Diving equipment can damage ecosystems, divers feed fish causing shifts in species makeup/stress and "souvenirs" like shells or corals are taken without control.

Although the beach-based tourism sector employs about 2.36 million people, it generates many different environmental and social impacts. In this sense, original landscape is altered to build touristic and or recreational infrastructures as well as to fit and adapt natural areas (e.g. beach nourishment, equipping natural reserves, etc.). Marine ecosystems and species are affected by beachgoers, boaters and nautical activities practitioners which are in direct contact with the marine environment. Taking these considerations into account, many initiatives have been carried out in order to minimize the impact coastal tourism is causing, for instance, building softer infrastructures, considering erosion/accretion consequences, making an effort to improve water quality and knowledge, and including sustainable management criteria in decision-making processes. Nevertheless, marine and coastal ecosystems have reached such a vulnerable situation that no precaution must be overlooked. With this aim in view, a more sustainable and integrated approach should be tackled when planning new management measures and strategies in line with new modes of EU governance.

Coastal recreation is directly affected by changes in the adjacent marine zone. Mucilaginous waters in the Adriatic Sea and jellyfish swarms in the Mediterranean have had severe negative impacts on tourism. Changes in the marine ecosystem caused by warming, pollution, overfishing, may exacerbate these phenomena as well as the spread of potentially harmful NIS.

The occurrence of NIS is a previously overlooked and never summarized aspect which impacts tourism. The (potential) impact of these populations is diverse and includes injuries of beach-goers caused by sharp mussel and oyster shells and the reduction of aesthetic values by algae accumulated on shores which may discourage tourists because of the smell they cause when they bio-degrade on beaches. Small positive impacts are also known in cases where the NIS becomes a tourist attraction (e.g. the "mitten crab run" observed in Germany in the 1990s).

Cruise tourism represents a very important economy for European countries but still has a long way to go in reducing pollution even though several ongoing initiatives are tackling pollution issues (especially concerning air pollution and energy efficiency). Cruises also generate an impact by colliding with cetaceans.

Whale watching is an attractive tourism activity in Europe and an opportunity for many EU countries that do not currently engage in whale watching activities. Many positive aspects arise from whale watching such as its associated economy, increased knowledge for tourists, educational values, and scientific platform, but many negative aspects also arise from this activity such as impacting on marine mammals by altering their behaviour or impacting on the reproductive success of targeted cetaceans.

During recent years, tourism services have changed and adapted to Europeans needs and concerns. Thematic tourism such as cultural routes and itineraries or underwater cultural heritage related tourism represent a big opportunity for marine and coastal tourism stakeholders which can find new business opportunities by promoting a sustainable approach.

Experience has shown that diversification of tourism activities can contribute to a new complementary income for professional fishermen. Fishing tourism, "pescaturismo" and "ittiturismo" represent an opportunity for the fisheries sector to remain sustainable contributing as well to issues such as reducing fisheries impact on the environment, reducing fishing effort or bridging the gap between the fisheries community and society.

Many interactions have been identified between tourism and other sectors, both synergistic and causing conflict. Synergies such as those identified between the fisheries and tourism sectors are clear as well as conflicts such as between the visual impact of the offshore renewable energy industry and tourism. It is however clear that tourism must be considered part of maritime and coastal policies and strategies in order to achieve an integrated approach that can enable the strengthening of existing synergies, the rise of future synergies still to be detected and the correct integrated management of existing and future conflicts between sectors and users.

# 3. Prioritisation of the drivers

The aim of WP1 was to identify and disseminate current understanding of drivers, pressures and vectors of change that could be affecting the areas of concern to VECTORS; outbreaks forming species, invasive alien species and changes in species distribution and productivity, and provide the contextual scene for the subsequent modules and work packages. The EU reviewers of D1.2 had recommended a number of relatively straightforward amendments and additions to complete work package 1. A short questionnaire survey was initiated to enable VECTORS researchers to express their informed opinion on which of the VECTORS selected drivers are likely to make the greatest impact. This is a subjective but commonly used method to elicit expert opinion and we believe that the cumulative results from the VECTORS community are of wider stakeholder interest. The exercise is clearly described below and the limitations have been noted. The results should be treated as subjective and are anticipated to promote thought and discussion but are not intended as a rigorous scientific deliverable.

The objective was for members of the VECTORS community to give their opinion on the extent to which the nine selected VECTORS drivers *currently impact* on the three areas of VECTORS concern (outbreak forming species OFS; invasive alien species IAS; changes in species distribution and productivity), and this was repeated for each regional sea.

Terms of reference:

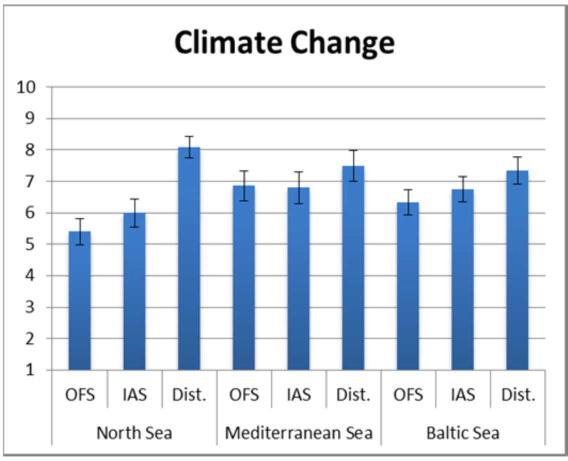
- The questionnaire allowed each area of VECTORS concern to be assessed on a relative scale between 0 and 10, with 0 as none or negligible impact while 10 suggests a very dominant change of the driver on the area of concern.
- Additional to the scale, participants were asked to score their competence in that particular subject area as “high”, “medium” or “low”. This is a subjective self-assessment where low competence indicates non-specialist knowledge while medium competence suggest some specialised knowledge and high competence reflects an area that falls under the participants expert knowledge.
- Each driver was assessed in relation to each of the areas of concern (OFS, IAS and changes in species distribution and productivity) for each of the regional seas (North Sea, Mediterranean Sea and Baltic Sea).
- A high score signified a high impact of the driver and would therefore mean enhanced occurrence of OFS and IAS, or enhanced changes in species distribution and productivity in the regional sea of interest. This applied to the following drivers:-
    - Climate Change and Related Impacts
    - Ocean Acidification
    - Commercial Fisheries
    - Land Based Pollution
    - Maritime Transport
    - Energy Demands and New Technologies
    - Tourism
- ‘Ballast water treatment systems’ and ‘changes in policy’ are responses rather than drivers/pressures and therefore the scale had to be interpreted differently. A high score still signified a high impact but would result in a reduction of the occurrence of OFS and IAS, or fewer changes in species distribution and productivity.

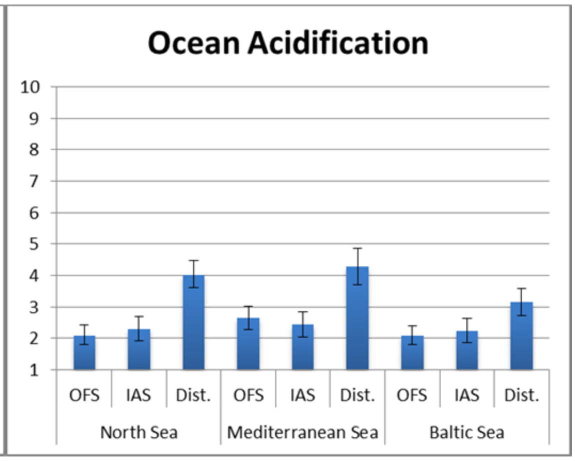
### Summary of questionnaire responses

The subjective self-assessment carried out by each of the participants to examine their 'competence' in a particular area made no significant difference to the scores for each of the responses. Therefore, all summary questionnaire output is based on the raw unweighted responses.

When interpreting the responses to the questionnaire, a high score signifies a high impact of the driver and would therefore mean enhanced occurrence of OFS and IAS, or enhanced changes in species distribution and productivity (this is different for the 'response' drivers, see below). Overall, the driver that scored the highest impact across all areas of concern and across all regional seas was climate change (Fig. 2.1). The driver that scored the lowest overall impact across all areas of concern and across all regional seas was tourism, followed closely by energy demands and new technologies (Fig. 2.1). Ocean acidification also had low scores for most responses but had a higher impact for changes in species distribution and productivity (Fig. 2.1). The responses for the other drivers, including the 'response' drivers of ballast water treatment systems and changes in policy, were more moderate and/or variable (Figs 2.1 & 2.2).

For the North Sea questionnaire responses for the driver climate change scored a higher impact and was therefore considered to enhance changes in species distribution and productivity when compared to OFS and IAS (Fig. 2.1). Climate change was thought to have a lower impact on the occurrence of OFS in the North Sea when compared to OFS in the Mediterranean and Baltic Seas (Fig. 2.1). Ocean acidification was given consistently higher impact on changes in species distribution and productivity across all regional seas when compared to OFS and IAS (Fig. 2.1).Commercial fisheries were also thought to have consistently higher impact on changes in species distribution and productivity across all regional seas when compared to OFS and IAS (Fig. 2.1). The impact of commercial fisheries on the occurrence of OFS and IAS, and changes in species distribution and productivity was placed slightly higher in the Mediterranean when compared to the other regional seas (Fig 2.1). The questionnaire responses for the driver land based pollution were more variable but consistently suggested a lower impact on the occurrence of IAS across all regional seas (Fig. 2.1). Maritime transport was considered to have a higher impact and therefore enhance the occurrence of IAS across all regional seas when compared to OFS and changes in species distribution and productivity (Fig. 2.1). Consideration of energy demands and new technologies did not differ across the areas of concern and across all regional seas, although the North Sea was slightly higher on the scale compared to the Mediterranean and Baltic Seas (Fig. 2.1). Tourism was thought to have a slightly higher impact for all areas of concern in the Mediterranean Sea compared to the North and Baltic Seas (Fig. 2.1).



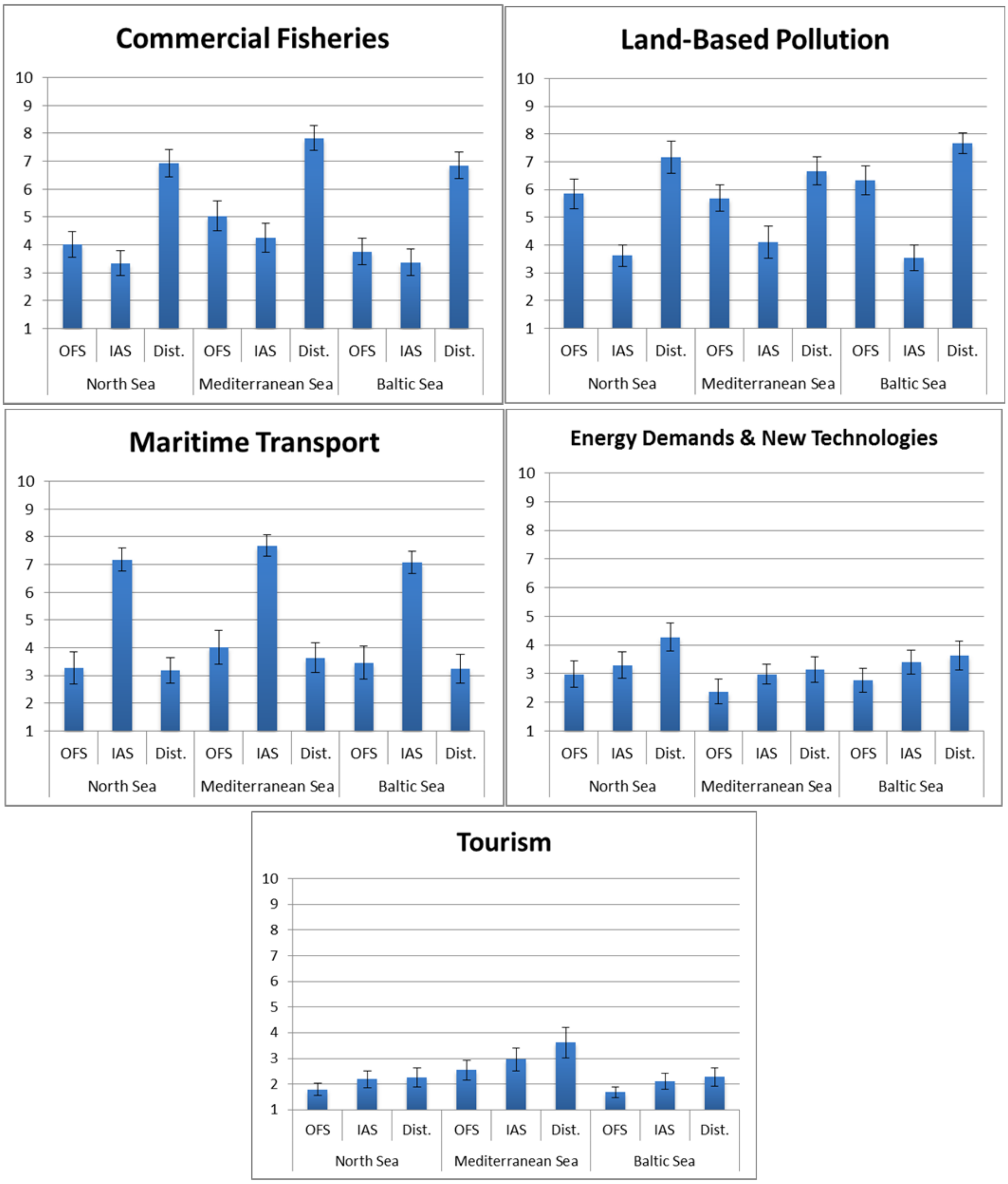



Figure 2.1. Mean of the questionnaire responses for each of the drivers and their impact on the areas of concern (outbreak forming species - OFS; invasive alien species - IAS; changes in species distribution and productivity - Dist.) within each of the regional seas. A high score signifies a high impact of the driver and would therefore mean enhanced occurrence of OFS and IAS, or enhanced changes in species distribution and productivity in the regional sea of interest. Error bars are standard error.

When interpreting the responses to the questionnaire for the ‘response’ drivers, a high score still signifies that a high impact was expected but would result in a reduction of the occurrence of OFS and IAS, or fewer changes in species distribution and productivity. Ballast water treatment systems scored a higher impact and therefore greater reduction in the occurrence of IAS when compared to the other areas of concern for all regional seas (Fig. 2.2). Changes in policy displayed no real difference between regional seas but scored higher for changes in species distribution and productivity when compared to OFS for all regional seas (Fig. 2.2).

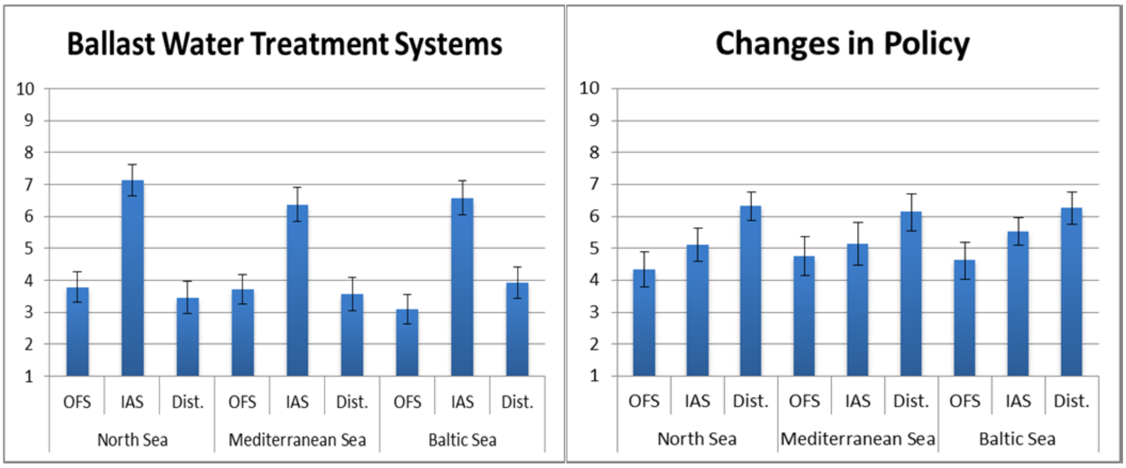



Figure 2.2. Mean of the questionnaire responses for each of the 'response' drivers and their impact on the areas of concern (outbreak forming species - OFS; invasive alien species - IAS; changes in species distribution and productivity - Dist.) within each of the regional seas. A high score signifies a high impact but would result in a reduction of the occurrence of OFS and IAS, or fewer changes in species distribution and productivity in the regional sea of interest. Error bars are standard error.

General interpretation

The drivers identified by the VECTORS consortium are considered to be the main priorities within the marine environment for European seas. The purpose of the subjective exercise in this section was to provide an informed opinion on which of the VECTORS selected drivers are likely to make the greatest impact on the areas of concern for each of the regional seas. The responses to the questionnaire offer a relative assessment of the VECTORS drivers and the participating experts suggested the following outcomes:-

- Climate change would have the highest impact overall across all areas of concern and across all regional seas
- Tourism and energy demands and new technologies would have the lowest impact overall across all areas of concern and across all regional seas
- Commercial fisheries would have a high impact and will potentially enhance changes in species distribution and productivity
- Land based pollution would have a high impact and will potentially enhance the occurrence of OFS and enhance changes in species distribution and productivity
- Maritime transport would have a high impact and will potentially enhance the occurrence of IAS, whereas ballast water treatment systems will potentially reduce the occurrence of IAS
- There were no major differences suggested between the regional seas but energy demands and new technologies have a slightly higher impact in the North Sea and tourism has a slightly higher impact in the Mediterranean Sea.

# 4. Energy Demands and New Technologies – summary of energy generation from waves for each regional sea

The idea of ocean surface waves as a source of useful renewable energy is not new. Some technologies were patented as early as 1799 (Girard & Son, France), and the first documented development of wave-powered devices was carried out under a British patent in 1855 up to 1973. Currently several research programmes, some with government and/or private support are underway mainly in the United Kingdom, Portugal, Ireland, Norway, Sweden and Denmark, aiming at developing industrially exploitable wave power conversion technologies. Wave power is especially important for countries with high resource demand for energy, where it could cover a significant part of the energy budget. Moreover, it could even become a primary source of energy.

North Sea

The Denmark Wave Energy Programme started in 1996, by assigning 5.3 MECU for the period 1998–2002. The aim of the project was to promote wave energy technology. The potential annual wave energy resource has been estimated to be about 30 TWh accounting for an annual wave power of between 7 and 24 kW/m coming from a westerly direction. However, the technology so far is still in a testing and development phase.

In Ireland the potential power from wave action was estimated to be 375 MWh/m, however, a total incident wave energy was estimated to be around 187.5 TWh. In 1997 there was a first approach to test this technology by assigning a grant from EU grant-aid, however, the offer was withdrawn on the basis that wave technology had not advanced sufficiently beyond the research stage to justify assistance under the European Infrastructure Operational Programme. At present a strategic study on wave energies has been finalized and conducted by a partnership of the Hydraulic & Maritime Research Centre, University College Cork, Irish Hydrodata Ltd, Ove Arup & Partners Ltd, the Department of Mechanical and Aeronautical Engineering, University of Limerick and the Marine Institute.

Norway's involvement in wave energy was started in 1973 by the Department of Physics in the Norwegian University of Science and Technology- NTNU. The University also gained official governmental support in 1978. In 1980 two wave converters were developed and tested (Multi- Resonant Oscillating Water Column- OWC and Tapered Channel- Tapchan) and five years later the OWC was built by Kvaener Brug A/S and the Tapchan by Norwave A/S in Toftestallen about 35 km north-west of Bergen. Both were destroyed during storms in 1988 and 1991, with plans for a rebuild settled only for the Tapchan plant. However, Energy and Electricity Balance established a plan that by 2020 a small share (0.5 MWh) of wave energy will contribute to the Norwegian electricity supply, from small-scale developments.

Portugal started research on wave energy in 1978. The main lead was taken by Instituto Superior Tecnico (IST) in Lisbon and after 5 years, in 1986, Instituto Nacional de Engenharia joined with IST. This cooperation resulted in the successful planning and construction of a shoreline wave energy converter, the Oscillating Water Column in Pico off the Azores. This project was supported by the government, the EU Programme Joule and the utility companies in the Azores and the mainland. The projects were financed by The Ministry of Science and Technology which provided funding for R&D and Demonstration projects (led by companies) through different programmes. Most of the funding for energy projects is provided by the Ministry of Economy using national funding, in addition to European money. So far, Portugal utilizes annual wave power of between 30 and 40 kW/m.

Sweden started wave energy research in 1976 and in 1979 it was calculated that the availability of resource could be as high as 5-10 TWh per annum. A Wave Energy Research Group was founded, consisting of four departments at Chalmers University of Technology, and the private consultant company Technocean. In 1980 the first absorber buoy was installed as a trial and a year later, the full time operating buoy was launched. Another large project was developed (the Hose-Pump project), with sea trials between 1983–1986. The project was funded by Swedyards later Celsius Industries and run by Technocean which also evaluated a large number of wave energy converters as part of the Swedish National Wave Energy Programme (1980–1986) and participated in the CEC project OWEC-1. Apart from the Swedish involvement in the Wave Energy Network, Sweden has no national research programme at this time.

The United Kingdom started to research wave energy technology in 1973 through the University of Edinburgh. In 1974 initial research on the offshore wave energy converter (the Salter Ducks) was started. In 1999 the UK government declared a budget supporting R&D on wave energy. The budget for research was estimated at about £3 (EUR 4.92) million for three years from 2000–2003. In 1999 a Commission for Wave Power in Scotland was launched and three wave energy projects with a total of 2 MW capacity were awarded with a 15 year purchase contract. In the near future two organizations, involved with wave energy development, are going to be formed. The first one is the Marine Energy Technology Network (METN). It will be a virtual network incorporating Universities, companies and consultants, and the other is the 'Sea Power Association' which will work closely with METN and the British Wind Energy Association (BWEA). The Marine Management Organization (MMO) has granted consent to Cork-based Ocean Energy Ltd (OEL) to deploy a wave energy converter at Wave Hub, around 16 km off the north coast of Cornwall in South West England in the eastern extremes of the Atlantic Ocean. Wave Hub consists of a 12 tonne electrical hub on the seabed that is linked to the UK's grid network. It provides shared offshore infrastructure for the demonstration and proving of offshore renewable energy technologies. OELs wave energy converter is currently being tested at the FaB Test marine energy test site in Falmouth Bay, south west England before potentially being deployed at the Wave Hub site. A number of wave energy convertors have been deployed and tested at the European Marine Energy Centre (EMEC) in Orkney, Scotland. EMEC was funded through a mixture of public funding and provides grid connected berths for testing of wave and tidal energy devices. The facility has been used to test full scale devices, including Pelamis P1 & P2 (E.ON) and Oyster (Aquamarine). EMEC is undergoing an expansion of its grid connected facilities with the addition of a nursery testing area.

Due to political reasons, mainly because of a focus on other energy sources or lack of feasible resources, wave energy conversion has not undergone significant development in Belgium, Finland, France, Germany or the Netherlands in the past years.

In Belgium, Germany and the Netherlands, so far, all research on wave energy has taken place in Universities, research centres and private companies. In the Netherlands the Teamwork Technology BV is developing a wave power conversion device, the Archimedes Wave Swing, a pilot scheme which is currently being finalized. In Germany, different companies and research institutions from the fields of offshore engineering, power engineering and other engineering sectors that are closely related to wave power conversion, are currently involved in European wave power developments.

In France, during the early part of the last century, a number of successful wave energy projects were operated but wave energy conversion has not undergone significant development recently. The most significant resource at the coast is in the area off the Gulf of Gascoigne. It was calculated that annual power levels can reach up to 40 kW/m and the total resource in this area is around 28 GW. In 1980 under the supervision of IFREMER (Institut Francais de Recherche pour 1'Exploitation de la Mer) a number of projects were conducted. Although the funding has stopped on the initial development phase, ECN (Ecole Centrale de Nantes) took over the programme, but it has been reoriented since 1995 towards the dynamic absorption problem. The same research group became a partner in the development project of the European wave power pilot plant on Pico Island (Azores), mainly involved with (sub)-optimal control strategies for wave energy OWC devices.

### Mediterranean Sea

In Spain, wave energy installations are not planned for full development in the Western Mediterranean. Wave energy is specifically included in the Renewable Energy Plan 2011-2020, with expected market competitiveness in the long-term (by 2030), but mainly in the Cantabrian Sea and the Atlantic. where there is significant marine energy potential due to the characteristics of the coast. The Cantabrian coast and the northern facade of the Canary Islands have the greatest energy potential. The southern peninsula also has great potential, but its viability is limited by the severe restrictions of the maritime traffic in the area and its environmental value. Several prototypes are already being tested, mainly in the Cantabrian Sea and the Atlantic Ocean, with the aim of transforming the wave power into a renewable energy source in a few years. . A ¼-scale prototype of a wave power generation system developed by the company ABENCIS Sea power, based on Spanish Technology is installed in the Mediterranean Sea, off the coast of Girona (Catalonia);. The prototype consists of a float-arm structure with a hydraulic system that allows the simulation of any kind of load. Tests data is being collected and used to optimize the control strategies. The results from the ¼-scale prototype are intended to be used to design a demonstration power plant in the Atlantic Ocean.
The Spanish Institute for Energy Diversification and Saving (IDAE) in collaboration with the Institute for Environmental Hydraulics at the University of Cantabria has carried out an evaluation of the potential wave energy in Spain to be considered in the Spanish Renewable Energy Plan 2011-2020. This evaluation examined the existence of local winds and the local sea setting which as a consequence produced greater spatial variability of waves. The analysis of annual and seasonal wave power averages on the Spanish coast show that the Mediterranean area presents annual averages of less than 10 kW/m. In addition, when characterizing the Mediterranean Sea climate, propagation has only been estimated at MLWS tide level. The conclusions outlined that wave energy is strongly dependent on its location on the coast, and the analysis excluded the Mediterranean area among those areas with greater resource potential.

Greece has a coastline with large wind energy potential, particularly over the Aegean Sea, in a prevailing North-South direction. It has a relatively intense wave climate with an annual average of 4–11 kW/m. However, the only parties interested in the development of the wave energy facilities are Universities and the Centre for Renewable Energy Sources. All work is still in a 'developing projects' phase.

Italy like Greece has quite a long coastline; however studies show that in general the annual average for wave energy is less than 5 kW/m. Despite this, R&D on ocean energy exploitation is being conducted, mainly by the ‘La Sapienza’ University of Rome and by Ponte di Archimede nello Stretto di Messina S.p.A. The University of Rome has developed a novel wave energy device, which is suitable for moderate wave power (mostly for closed seas). Ponte di Archimede nello Stretto di Messina S.p.A. is developing the ENERMAR plant, utilizing marine currents. There is also a 130 kW prototype plant with a 6 m diameter turbine, which is currently being constructed and will be deployed off the Italian coastline.

### Baltic Sea

In Poland wave energy is quite a new field of research. Since the successful trials of prototypes and the launch of devices in other European countries (such as France, Portugal or Scotland) two Polish companies have prepared projects for wave energy devices (Szczecin Polytechnics and Skotan S.A.). So far, the Polytechnics have had their project partly funded by the TEAM programme which facilitated building a model of the device to be tested in monitored conditions. Skotan S.A. in 2012 was partly funded by the European grants. The company claims that the research will be finished in 2014.

# 5. Interconnections between drivers – commonalities and differences across regions

## Interactions between drivers

The European Environment Agency (EEA) has increasingly adopted the use of the DPSIR framework, in order to distinguish driving forces, pressures, states, impacts and responses. The framework is seen as giving a structure to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made. According to the DPSIR framework there is a chain of causal links starting with 'driving forces' (economic sectors, human activities) through 'pressures' (emissions, waste) to 'states' (physical, chemical and biological) and 'impacts' on ecosystems, human health and functions, eventually leading to political 'responses' (prioritisation, target setting, indicators). The DPSIR framework is used here to visualize the VECTORS drivers, how they relate to one another and to identify common drivers, pressures, state changes, impacts and responses.

Within the DPSIR framework not all of the VECTORS 'drivers' actually fall under the DPSIR driver heading. Climate change, ocean acidification, commercial fisheries and land based pollution fall under the 'pressure' heading (Table 4.1). Ballast water treatment systems (BWTS) and changes in policy, as mentioned in section 2 of this addendum, fall under the 'responses' heading (Table 4.1). Whereas maritime transport, energy demands and new technologies and tourism fall under the 'drivers' heading (Table 4.1).

The DPSIR framework highlights commonalties amongst the VECTORS drivers. Increasing urbanization, agriculture and industrialization in combination are seen as the key drivers for climate change, ocean acidification and land based pollution (Table 4.1). Whereas tourism and energy demands and new technologies share a common pressure of 'infrastructure demands' (Table 4.1). Maritime transport and ballast water treatment systems are seen as opposite ends of the DPSIR 'chain of causal links' in that BWTS are seen as a response to the driver of maritime transport. Although the impacts associated with the VECTORS drivers of change are occasionally idiosyncratic, a common impact is their effects on ecosystem services, whether these are positive and/or negative depends on the driver (Table 4.1).

Table 4.1 VECTORS of Change placed in the DPSIR framework – From Drivers through Impacts to Policy Responses

| Driver | Pressure | State Change | Impact | Response |
|---|---|---|---|---|
| Increasing urbanisation, agriculture and industrialisation | *1.1 Climate change and related impacts* (natural and anthropogenic) | Changes in temperature regimes and weather patterns (storminess); effects on structure and functioning and on Ecosystem Services | | Local adaptation, compensation; policy, economic and legal mechanisms |
| | *1.2 Ocean acidification* Increased $CO_2$ and decreased pH | Reduced calcification | Reduced ecosystem services, ability for waste removal | Global agreements |
| | *1.4 Land based pollution* | Polluted components; HAB formation | Environmental and food quality reduction, reduced ES | Diffuse and point-source discharge controls |
| Demand for food | *1.3 Fisheries* | Changes to local populations, spawning sustainability, by-catch and habitat damage | Stock viability, ecosystem services reduction | Economic and legal instruments |
| | Aquaculture | Changes to local ecology | Ecosystem services (+ and -) | |
| *1.5. Maritime transport* (demand for movement of goods, etc.) | AIS introduction, infrastructure demands, pollution, dredging | Community change, habitat alteration | Pest introduction, invasive and nuisance species; effects on ecosystem services | *1.7. Introduction of new ballast water technologies and practices* |
| *1.6. Energy demands and new technologies* | Infrastructure demands | Habitat loss and gain, energy/hydrodynamic change | Effects on ecosystem services (+ and -) | Marine spatial planning, economic and legislative constraints |
| *1.9 Tourism* (recreation) | | Loss of natural habitats, reduction in resilience | | Planning controls, coastal spatial planning |
| Total societal demands | *1.10 Interactions between multiple users and sectors* | Cumulative effects on natural structure and functioning | Effects on ecosystem services | *1.8 Changes in policy* |

## Commonalities and differences across regions

The drivers of change identified by the VECTORS consortium are considered to be the key priorities within the marine environment and as such are influencing all the regional seas. The subjective exercise in section 2 of this addendum provided an informed opinion on which of the VECTORS selected drivers are likely to make the greatest impact on the areas of concern for each of the regional seas. It identified that most of the individual VECTORS drivers are equally important across the three regional seas, although some idiosyncratic affects are likely due to differences in the species and the ecosystems present in each sea (see the relevant driver sections in D1.2 for detailed descriptions). Energy demands and new technologies were considered to have a greater impact in the North Sea when compared to the Mediterranean and Baltic Seas. Whereas, tourism was considered to have a greater impact in the Mediterranean Sea when compared to the North and Baltic Seas.