Needs and gaps analysis in marine sciences to feed the SRIA

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Content

1. INTRODUCTION

Currently the level of fragmentation in marine and maritime research across Europe is very high and most of the activities related with seas and oceans are conducted and national level. The firts mapping exercise conducted by JPI Oceans in 2011 revealed that most of the activities in the field of marine and maritime research are funded, programmed, implemented and assessed at national level.

JPI Oceans aims at reducing this level of fragmentation, by increasing the coordination, and the definition of common agendas, creating critical mass, maximising efficiency of investments and existing capacities and creating synergies in marine and maritime research, technology and innovation fields across Europe in order to face the societal challenge of “Healthy and Productive Seas and Oceans”. The objective is to increase the efficiency and effectiveness of the national investments in research, technology, innovation, related infrastructures and development of human capacities through the improvement of the trans-national cooperation and coordination of actions at pan-European level.

Most of the challenges that seas and oceans are facing cannot be addressed at national level. The complexity of the challenges, the level of investment, the critical mass and the capacities needed to respond to these issues goes beyond the capacities and possibilities of any single country. Issues such as the impacts of climate change and ocean acidification on marine ecosystems and coastal areas, marine food webs, marine biodiversity and seafood production (fisheries and aquaculture), or the impacts of the increasing frequency of extreme events on maritime activities (e.g. coastal areas, aquaculture, maritime transport, energy production, etc), the preservation and protection of the marine environment and its biodiversity against human impacts (e.g. pollution, lost of habitats, biodiversity, etc) and the promotion of a maritime economy based in the sustainable used of good and servicies while ensuring the good environmental statues of seas and oceans are clear examples of challenges that require a concerted pan-European approach. In addition most of the challenges (e.g. climate change, pollution, invasive species, etc) does not have frontiers and need to be tackled in coordination from a pan-European perspective.

In addition to make the most of the opportunities that seas and oceans offer to support the development of a blue economy it is necessary to coordinate the efforts at national level, by defining common priority areas to promote blue growth in order to focus the efforts to tackle cross-sectoral and cross-cutting issues, bringing together countries and researchers from different disciplines across Europe to provide knowledge and conduct the research with the aim of boosting the sustainable growth of the maritime economy.

A high level of cooperation and integration of activities at EU level is therefore needed in order to coordinate the activities and efforts of individual countries to maximise the impact of the resources to respond to the societal challenges related to seas and oceans.

In that regard, major efforts in Europe are needed to reduce the fragmentation and improve the coordination and long term planning of marine and maritime research in Europe. This can be addressed by aligning national research priorities and developing common European programmes in marine research to increase the efficient and effective use of resources and improve the level of excellence of marine research in Europe. To achieve these goals it is necessary to have a broad overview of the complex European landscape in the field of marine and maritime research, the strategies, plans and activities conducted at national level and the available resources that potentially could be used to put in place joint actions under the umbrella of JPI Oceans. In order to avoid unnecessary duplication it is also necessary to know the activities and initiatives at EU level than have been recently funded or that currently going. The level of funding on particular issues also at EU level can provide shed light on which areas could need more investment or which where synergies could be created between national and EU investments.

A lot of work has already been conducted to map the activities, gaps and needs at EU level in marine and maritime research by various organizations, initiatives and projects at the European level. Notable examples include ongoing projects and initiatives such as SEAS-ERA, BONUS, EUROMARINE and CLAMER and strategic documents develop by science organizations such as the European Marine Board, EFARO and ICES. However, the mapping activities conducted by these organizations and initiatives are frequently focussed on specific disciplines or sectors and/or geographical areas, and have not been conducted looking the intersections between the 3 big areas targeted by JPI Oceans (i.e. marine environment-climate change, maritime economy-climate change and marine environment-maritime economy and activities), where the key challenges relevant to JPI Oceans are found. Moreover, most of the research agendas developed so far have been designed with a view to implement short term actions through call for proposals. However JPI Oceans is not only looking a call for proposal to implement actions. The objective is also to develop long term actions through fit for purpose tools and create synergies across Europe by making a better use of already existing investments (i.e. institutionalised money), through enhanced coordination and cooperation between Member States. Therefore, to built the Strategic Research and Innovation Agenda (SRIA) of JPI Oceans it is necessary to conduct a targeted mapping to identify specific cross-cutting needs and gaps to achieve the goals of this JPI. It is also necessary to map the potential actions and the most suitable tools to implement these actions (i.e. fit for purpose tools).

One of the main objectives of WP3, which is focussed on scientific research issues, is to conduct the mapping and analysis of the existing needs and gaps in marine sciences to feed the draft Strategic Research and Innovation Agenda (SRIA) of JPI Oceans. The information provided by WP3 will be complemented with information gathered by other WPs (WP4, WP5 and WP6) to build the draft SRIA of JPI Oceans. The aim of this deliverable is therefore to provide information on the current needs and gaps in the field of marine science in Europe to feed the SRIA.

2. WORK PACKAGE METHODOLOGY

2.1 CSA OCEANS CONSULTATION PROCESS

2.1.1 GENERAL APPROACH

The Strategic Research and Innovation Agenda (SRIA) of JPI Oceans is being built through an ambitious and challenging process of combining and converging the top down driven vision with a bottom up process to harmonize, align and create synergies and added value in the European Research Area related to oceans and seas. Thus it is neither the intersection of national (and regional where relevant) research agendas, nor a brand new document resulting from a bottom-up approach, nor an accumulation of all the research and technology stakeholder agendas but the interlinked combination of the three approaches. In this context, the SRIA is a collective, shared and forward-looking exercise identifying and prioritizing directions for cross-cutting research, development and innovation challenges for our seas and oceans.

The identification of needs and gaps to feed the SRIA have been conducted by CSA Oceans through a comprehesive mapping that has been developed following an strategic approach towards the goals of JPI Oceans. The mapping has been conducted through consultation process consisting of 3 different pats, as agreed by CSA Oceans partners and endorsed by the Management Board of JPI Oceans. These were:

- A consultation with national research funding agencies/relevant ministries
- Several stakeholder consultation workshops
- An open web consultation

The first step in the process was to develop a single quetionnaires for research funding agencies and also a questionnaire for stakeholders to conduct the surveys. WP3 was responsible for this taks in cooperation with other WPs involved in the development of the SRIA. As part of the strategic approach adopted by CSA Oceans, the workpackages (WPs) involved in the development of the SRIA agreed to work together to provide a single questionnaire cointaining the questions relevant to different WPs, rather than using different questionnaires for each WP. The objective was to avoid duplication of work between the WPs, since many issues fall within the remits of 2 or more WPs, and also to avoid the fatigue of research funding agencies and stakeholders in having to respond to several different questionnaires.

2.1.2 STAKEHOLDERS CONSULTATION WORKSHOPS

As part of the CSA Oceans mapping exercise and with the aim of getting information on research needs, gaps and tools relevant for JPI Oceans to built the drat SRIA, 6 consultative workshops with representatives from relevant stakeholders group from different communities (science, industry and policy) and FP7 projects were organized by CSA Oceans in spring 2013 (May-June 2013).

The aim of the workshops was to get the inputs of stakeholders on:

- The most pressing issues in a 20-30 years perspective
- Potential needs and priorities that could be addressed by JPI Oceans to achieve its goals
- The instruments/tools that could be used to solve these needs and priorities.
- How JPI Oceans can add value at European level

The following table summarised the workshops held in May and June 2013 with different stakeholder groups and FP7 projects. Annex 1 provides a list of participants in the workshops.

Table 1. Stakeholders workshops organised by CSA Oceans

Stakeholder Workshop	Date	WP responsible
European technology platforms and industry associations	30 May 2013	WP4
Marine research infrastructures	5-6 June 2013	WP6
UN-international organizations/programmes, advisory policy groups and regional conventions	11 June 2013	WP5
ERANETS and BONUS	12 June 2013	WP3
European science organizations	13 June 2013	WP3
EU FP7 collaborative projects	20 June 2013	WP3

The stakeholders were indentified through the list of relevant stakeholders for JPI Oceans developed by WP8, based on the selection criteria developed by this WP and endorsed by the Management Board of JPI Oceans. In addition a number of FP7 projects were invited to participate in a workshop targeting cooperative projects. Over 50 European and international stakeholder groups, organizations, networks, platforms and projects took part in the workshops.

Previous to the workshop a short questionnaire was sent to the all participants, who were asked to fill in that questionnaire, so as to help them prepare their input for the workshop on potential needs/actions/tools to achieve the JPI Ocean goals and to stimulate the discussion. At the workshops stakeholders were asked to provide inputs and give their view on the questions of the workshop questionnaire. These inputs were debated during the workshops between participants and CSA Oceans partners which allowed to highlight a number of commonalities between the stakeholders participating in each workshop. After the workshops an extended questionnaire with additional questions was sent to the stakeholders to get more detailed inputs on other issues that were not addressed at the workshops. This questionnaire was also provided to those stakeholders that were not able to participated in the meetings.

The extended questionnaire covered a broad range of aspects relevant for JPI Oceans, from reseach needs and tools to implement actions to respond to the goals of JPI Oceans, to infrastructures, through innovation and technology needs, human capacity building needs and science to policy and monitoring aspects. The questionnaire also addressed the role that JPI Oceans could play in the science to policy landscape and where synergies can be created.

2.1.3 ONLINE PUBLIC CONSULTATION

In order to have an inclusive consultation process, in July 2013 CSA Oceans launched an open web consultation to collect inputs from stakeholders that have might have an interest in providing inputs to this process that could be potentially relevant to feed the draft SRIA of JPI Oceans (including organizations, individuals and other stakeholders interested in participating). The online open consultation allowed stakeholders from the marine and maritime community and general public to propose input on research, innovation, technology, infrastructures, human capacity building and science to policy issues needs and gaps that need to be overcome to achieve the goals of JPI Oceans. It also asked for new ways of cooperation and their view on where JPI Oceans can add value and create synergies in the current European landscape.

WP8 was responsible, with the support of other WPs, to select and put in place the tool to conduct the online survey. After analysing several options it was decided that the most cost effective tool for the purposes of CSA Oceans was “Survey Monkey”, which is a specific tools for online surveys that also allow to collect and compile the information of the survey in a suitable way for its subsequent analysis.

The questionnaire used for the open consultation was the same that the extended questionnaire sent to stakeholders invited to the consultation workhops (i.e. extended questionnaires). In total 48 responses to open consultation were received, including different types of institutions, organizatios, associations, universities industry, tech platforms, ERANETs, projects and individuals.

The profiles of the respondents by marine or maritime area revealed that most of them were involved in applied research, followed by fundamental research and monitoring; whilst industry participation remained low, as figure 1 shows.

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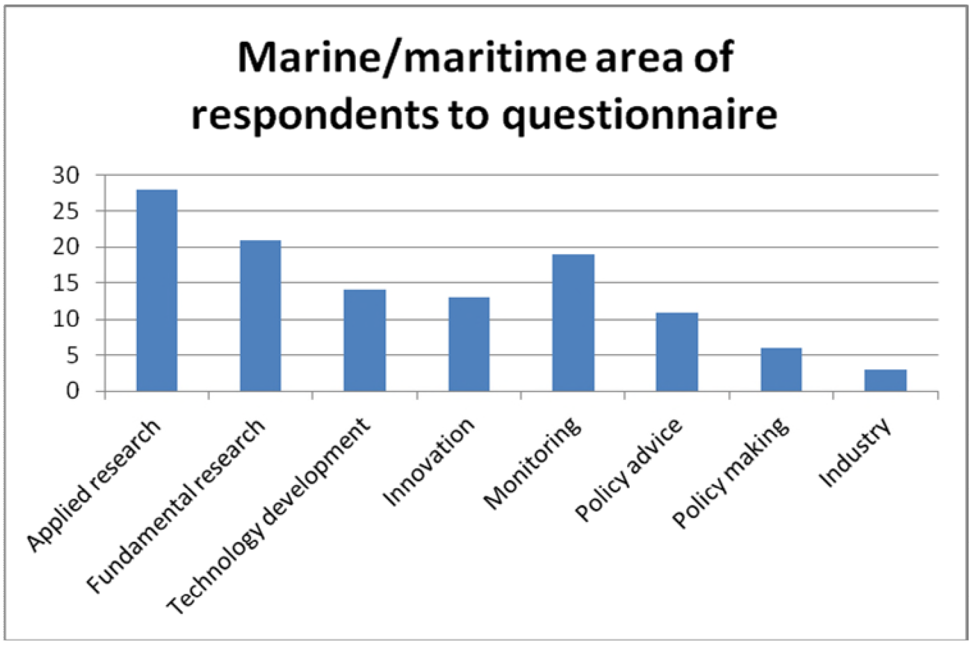

Figure 1. Areas within marine and/or maritime sectors in which the respondents participate.

2.1.4 RESEARCH FUNDING AGENCIES CONSULTATION

In order to collect information on the functioning of the different national RTD and innovation systems across Europe and also to map stategies and programmes in the field of marine and maritime research, a survey targeting national research funding agencies (RFAs) and ministries was conducted. With this aim a comprehensive single questionnaire was developed to get information on functioning of national RTD and innovation systems, with special focus on marine and maritime issues, and to map the current national strategies, programmes/plans and priorities related with marine and maritime research and innovation at national level, including information on how marine research infrastructures, monitoring programmes and science to policy systems are organised and managed at national level. The questionnaire also included a sections with questions that were intended to get inputs of research funding agencies/ministries on where they see an added value for JPI Oceans and what needs, gaps need to be addressed to achieve the goals of JPI Oceans. The questionnaire also addressed which actions need to be implemented to cover the gaps. Part of the information collected through this survey targeted to research funding agencies/ministries has been used to feed deliverable D3.1 and other deliverables produce by the rest of the SRIA WPs.

The elaboration of the questionnaire was leaded by WP3 in close coordination with the other WPs involved in the development of the draft Strategic Research and Innovation Agenda (SRIA) of JPI Oceans (WP1, WP4, WP5, WP6). The questionnaire was presented to the Management Board of JPI Oceans at its 4thmeeting in 2013 in Dublin.

The questionnaire was sent to the JPI Oceans Member Countries and observers on 31 May 2013. In addition, the questionnaire was sent to 6 Associated Countries (sea bordering countries) to the Framework Programme (Croatia, Cyprus, Greece, Israel, Latvia and Slovenia). By May 2014, 17 countries out of 26 had provided information to this consultation (Table 2). JPI Oceans Member Countries were addressed through national contact points appointed by the Management Board of JPI Oceans, while non participating countries were addressed through their representatives in the High Level Group for Joint Programming of the European Council (GPC , Groupe du Programation Conjointe) (http://www.consilium.europa.eu/policies/era/gpc?lang=en) .

Table 2. Countries that responded to the questionnaire of CSA Oceans (May 2014)

Country	Responding organisation
Belgium	Belgian Science Policy Office Fund for Scientific Research (F.R.S.-FNRS) Flanders Marine Institute
Denmark	Ministry for Higher Education and Science
Estonia	Ministry of the Environment
Finland	Academy of Finland
France	IFREMER
Ireland	Marine Institute
Italy	Ministry for Infrastructure and Transport The National Research Counci
Lithuania	Research Council of Lithuania
Netherlands	Ministry for Economic Affairs Organisation for Scientific Research
Norway	Research Council of Norway
Poland	National Science Centre National Centre for Research and Development
Portugal	Foundation for Science and Technology
Romania	Ministry for National Education
Spain	Ministry of Economy and Competitiveness (MINECO)
Sweden	Swedish Research Council FORMAS
Turkey	The Scientific and Technological Research Council of Turkey
UK	National Environmental Research Council

2.2 MAPPING OF PAN EUROPEAN AND REGIONAL MARINE SCIENCE STRATEGIES AND PRIORITIES

In order to have a broad overview of the main research priorities set out by relevant pan-European and regional marine research organizations and initatives, WP3 has maped the most relevant pan-European and regional strategic scientific research agendas, as well as the strategic documents published and the priorities identified by these relevant scientific pan-European and regional organizations and initatives.

The mapping only includes research strategies and priorities identified by relevant pan-European and regional marine research organizations focus on scientific research. The mapping does not include technology platforms, regional conventions or international organizations or initiatives alike, since these platforms and international conventions are not within the scope of WP3. Innovation and policy issues within CSA Oceans are dealt by WP4 and WP5, respectively. Likewise the mapping does not include strategies on marine research infrastrucutres or human capacities since those issues are targeted by WP6 of CSA Oceans.

For each organization/initiative a summary list with the most relevant strategies or priority issues have been developed and links to each of the organizations and initatives is provided together with links to the documents and stategies (see section 5 of this deliverable).

3. ANALYSIS OF INPUTS FROM THE CONSULTATION PROCESS

The present section provides information of the research needs and gaps idenfified by WP3 based on the inputs from research funding agencies and stakeholders collected in the consultation process conducted by CSA Oceans.

The analysis of the inputs of stakeholders and research funding agencies has been perfomed following the strategic approach agreed by CSA Oceans partners involved in the development of the SRIA. The approach used is a combination of top-down and bottom-up approach. Priority topics have been identified by searching for common denominators between inputs provided by research funding agencies and those provided by stakeholders. The inputs provided by research funding agencies/ministries were analysed in first place, looking for commonalities between inputs provided by research funding agencies to identify those closely connected from which common denominators could be drawn to eventually identify key topics based on them. In agreement with the rest of the WPs involved in the SRIA, only those common denominators supported by inputs from 4 or more research funding agencies were kept for further analysis. In a second step the inputs provided by stakeholders were analysed to see how they fitted to the common denominators that emerged from the analysis of inputs from research funding agencies. The stakeholders inputs that fitted into the common denominators from research funding agencies were kept and used to feed the scope of each topic, together with the inputs from research funding agencies for each common denominator.

The analysis the inputs from the consultation with reseach funding agencies and stakeholders has been focussed on scientific issues, including not only basic research issues but also applied research in support of management measures and policies dealing with the impacts of human activities on the marine environment (e.g. Marine Strategy Framework Directive, Common Fisheries Policy, Maritime Spatial Planning). According to the procedure agreed by CSA Oceans partners, only those inputs having a multidisciplinary character and relevant to the goals of JPI Oceans have been considered for further analysis. In the case of WP3, only inputs connected to Goal 2 “Ensure Good Environmental Status of the seas and optimise planning of activities in the marine space” and Goal 3 “Optimise the response to climate change and mitigate human impacts on the marine environment “ of JPI Oceans have been taken into account, since the inputs related to Goal 1 of JPI Oceans “Enable the advent of a knowledge based maritime economy, maximising its value in a sustainable way” have been addressed by WP4, which is focussed on technology and innovation issues to promote the sustainable growth of the maritime economy.

3.1 OUTCOMES OF ANALYSIS: IDENTIFICATION OF NEEDS AND GAPS

This section provides a list with the priority topics identified by WP3 from the analysis of the inputs provided by research funding agencies and stakeholders during the consultation process conducted by CSA Oceans. The identified topics have been asigned to the relevant goals of JPI Oceans for WP3 (i.e. Goals 2 and 3) and grouped into different broad areas according to the nature of each of the topics in order to facilitate their classification and presentation of the outcomes in a coherent way. For each topic WP3 partners have tried to summarised in a logic way the inputs from research funding agencies and stakeholders. The outcome of this work is a rationale for each topic where the particular research needs gaps and barriers are described. In addition the document also provides information on which research areas more cooperation is needed or which areas have more potential to create synergies and strengthen the cooperation at EU level , through the development of regional or pan-European approaches and the aligment of priorities of participating countries in JPI Oceans. The outcomes of the present deliverable will be used to feed the draft Strategic Research and Innovation Agenda (SRIA) of JPI Oceans.

It is noteworthy that there is some degree of overlap between topics. However this is consequence of the complex nature of marine ecosystems, which includes multiple processes phenomena and interactions (ranging from individual organisms to the whole ecosystem) within the different ecosystem compartments encompassing biogeochemical, and biological processes, and the coupling with physical processes. The overlap it is also due to the interactions of the multiple ecosystems components with the wide range climate change and human pressures. Therefore the overlap between thematic issues can not be avoided if the objective is to deal with complex issues in a comprehensive way, and to get the knowledge to understand marine ecosystems, the interactions and feed backs with human pressures and climate change. The overlap between topics also reflects that there is not isolated compartments in nature, but almost all processes and phenomena are in some extent interconnected. In a similar way, all the goals of JPI Oceans are connected or interlinked between them and it is impossible to set a clear border between the different goals. Similar problems have been reported to be found in the preparation of strategic documents on marine research priorities (e.g. Navigating the Future IV).

The priority topics identified, based on common denominators, and the areas in which these have been classified according to the Goals 2 and 3 of JPI Oceans are the following:

GOAL 2: ENSURE THE GES OF THE MARINE ENVIRONMENT AND OPTIMISE THE PLANNING OF MARINE ACTIVITIES

- AREA 2.1 UNDERSTANDING THE FUNCTIONING AND VARIABILITY OF MARINE ECOSYSTEMS
    - TOPIC 2.1.1. Structure and functioning of coastal and marine ecosystems
    - TOPIC: 2.1.2. Understanding and protecting marine biodiversity and deep sea ecosystems

- AREA 2.2 ECOSYSTEM HEALTH AND HUMAN IMPACTS
    - TOPIC 2.2.1 Development of indicators and guidelines to assess ecosystem health and human impacts and harmonize monitoring programmes for the implementation of the MSFD.
    - TOPIC 2.2.2. Assessing the impact of marine pollution (including litter, microplastics) and noise on marine ecosystems and risks fo human health
    - TOPIC 2.2.3. Eutrophication and harmful blooms
    - TOPIC 2.2.4. Individual and combined impacts of human activities and drivers on the marine environment and synergies with climate change
- AREA 2.3. RESEARCH TO SUPPORT THE SUSTAINABLE MANAGEMENT OF HUMAN ACTIVITIES AND MINIMISE THEIR IMPACT ON COASTAL AND MARINE ECOSYSTEMS
    - TOPIC: 2.3.1 Valuation of ecosystems good and services, assessment of socioeconomic impact of human activities on the marine environment and development of measures to support a sustainable management
    - TOPIC 2.3.2. Marine Spatial Planning (MSP) and Integrated Coastal Zone Management (ICZM)
    - TOPIC: 2.3.3. Research to support the sustainable management of fisheries

GOAL 3. OPTIMISE THE RESPONSE TO CLIMATE CHANGE

- AREA 3.1. IMPACTS OF CLIMATE CHANGE AND OCEAN ACIDIFICATION ON THE MARINE ENVIRONMENT
    - TOPIC 3.1.1. Impact of climate change on the functioning of marine ecosystems, biodiversity and organisms: past, present and future perspectives
    - TOPIC 3.1.2. Effects of ocean acidification on marine ecosystems: synergies with global warming and other stressors
    - TOPIC 3.1.3. Ocean – Atmosphere interactions: The role of Oceans on Earth's climate
- AREA 3.2. INTERACTIONS BETWEEN CLIMATE CHANGE, HUMAN ACTIVITIES AND THE MARITIME ECONOMY
    - TOPIC 3.2.1. Impact of climate change on coastal areas
    - TOPIC 3.2.2. Impact of climate change on marine and maritime activities
    - TOPIC 3.2.3. Addressing the uncertainty and risk of climate change by improving modelling and forecasting to support early warning and adaptation measures

On the other hand , some of the topics are closely connected to Goal 1 of JPI Ocean, such as for instance the topics 3.2.2, 2.3.3, 2.2.2 or 2.3.2 , since they include scientific aspects that are relevant to support the management measures and policies that are also relevant or linked to the sustainable growth of the maritime economy. The relatively close link of these topics to Goal 1 also reflects the the close connections between the different goals of JPI Oceans, as stated above.

3.2 GOAL 2: ENSURE THE GES OF THE MARINE ENVIRONMENT AND OPTIMISE THE PLANNING OF MARINE ACTIVITIES

AREA 2.1 UNDERSTANDING THE FUNCTIONING AND VARIABILITY OF MARINE ECOSYSTEMS

TOPIC 2.1.1. STRUCTURE AND FUNCTIONING OF COASTAL AND MARINE ECOSYSTEMS

Basic understanding of system behaviour

The advance on the basic understanding of marine ecosystem behaviour is the basis for the sustainable management and use of marine resources and for the protection of the marine environment. Resource exploitation needs the best available evidence and information on the natural living and non-living resources at a regional scale so that economic gains can be maximised and environmental impact minimised. A better understanding of the structure and the functioning of marine ecosystems and the role of different components of the marine and coastal ecosystems, including both biotic and abiotic processes, will therefore serve as "license to operate" for the marine-maritime industry (e.g., fisheries, energy, raw materials) of the future.

Currently the science evidences are fragmented and there are important gaps in data and knowledge on marine ecosystems functioning. In part this is due to the fact that marine ecosystems are quite complex, there is not tight compartments while there are lots of complex feedbacks within the system. Due to this complexity further efforts in research and observation are needed to deepen in the understanding of ecosystems, their components and the dynamic of processes at different temporal and spatial scales, including major changes in the composition and structure of coastal and marine ecosystems, through a multidisciplinary approach to ocean science as basis for sustainable management and exploitation. Currently research is too compartmentalised and it is necessary address the problem from a holistic point of view through a better integration of observations, experimentation and modelling.

Marine ecosystems are seriously threatened by climate change, ocean acidification and the pressures of human activities. Baselines for natural variability of ecosystems functioning and processes are needed in order to assess any potential impact on the marine environment, both from climate change and human activities. In relation to a changing environment it is also necessary to develop the ability to consider change, adaptation and acclimatisation processes at all levels of biological organization, from cells to ecosystems, and to separate inherent natural variability of the system from anthropogenic signals of change. This also requires a deeper knowledge on the interactions between marine biodiversity and the physical and chemical environments, and better knowledge on biodiversity in terms of structure and functioning of ecosystems. We also need to develop baseline data and environmental thresholds in undisturbed systems, characterise the resilience of major ecosystems and improve the understanding of biological regulation processes at a wide range of spatio-temporal scales, from short-term to interannual variability in the marine realm, as well as to expand our knowledge on eco-physiology, life history traits, phenology, phenotypic plasticity, ecogeochemistry . The use of genetic and molecular tools can provide new insights on the genetic and molecular mechanisms of organisms and help understand biological processes in the ocean and the genetic and molecular basis that govern adaptation and acclimatization process, as well as the flexibility of marine species in a fluctuating environment and a changing climate.

It is necessary to deepen the knowledge on process regulating ocean productivity, the phenology of biological mediated processes, and also the dynamic of marine organisms. In connection with processes that affect ocean productivity, it is necessary to develop further knowledge on effect of long term ocean circulation on the biological component of ecosystems (e.g. species and populations distribution, etc), and processes (including primary production, biogeochemical cycles and key carbon sequestration pathways) and improve our knowledge on food web interactions. Knowledge gaps also need to be covered in highly dynamic ecosystems, such up-welling systems where the energy turnover is highly variable depending on climate variability, adding difficulties and uncertainty to the management of human activities in the spatial and temporal scale.

However, processes governing marine ecosystems functioning are not enough regarded from chemical ecology and ecogeochemistry. Development and used of new tools, such as integrative models, organic and isotopic tracers or sensors to observe the dynamics of these ecosystems and study in situ the relationship between organisms and their environment and their role in the biogeochemical processes. Environmental omics approaches need to be further developed to resolve the major issues of understanding the functioning of marine ecosystems and their evolution in the context of global change.

Most of the deep ocean waters remain unknown, we know very little about the biodiversity of species, dynamic of populations, and biological mediated processes occurring there that can have global implications. Substantially more research is needed to address knowledge gaps on key processes and organisms inhabiting these deep waters. For instance, according to recent discoveries the biomass of mesopelagic fish has been largely underestimated. New available data indicates that the current biomass could be 10 times higher than initially foreseen. To the light of this new discovery the role of mesopelagic fishes in the ocean ecosystems and global cycles should be revised since this may have important implications in the balance of the global biogeochemical cycles and other processes.

In addition, we also have a poor understanding of the role and effect of virus, parasites and pathogens on the dynamic of the marine organisms and on the overall health and functioning of marine ecosystems. In order to address these gaps it is necessary to conduct more experimental and field studies and couple ecological studies with metagenomics, gene expression and immunological studies to understand the full chain of mechanisms involved from genes to ecosystems.

From field observation to experimental approaches

More field and experimental research are needed to cover the knowledge gaps and improve our understating of ecosystems processes, food web interactions and populations dynamics, by using new observation and experimental methods. New systems for mapping and monitoring complex chemical, biological and chemical processes in the marine ecosystem are also needed. Likewise, experimental and new theoretical approaches need to be developed to test the complexity of organisms and the ecosystem reactivity. Support is also necessary to ensure shared development of methodologies and agree on multifactorial approaches so that predictive experiments reflect accurately environmental conditions and variability.

We need to identify new model organisms for advancing basic biological, ecological and evolutionary processes and coordinate novel research on existing marine model organisms, for biological, environment to improve understanding of regulatory mechanisms operating from genes and molecular to ecosystem level. This needs to be supported by experiments and observations with an adequate spatial and temporal scale in order to capture the natural variability of ecological and biological processes under study (e.g breeding only at some time in the year). In order to improve our knowledge of ecosystems and their functioning we also need to enhance our understanding of the complexities of biological interactions involved in communication and interfaces in the marine environment. Currently our knowledge on this issue is very scarce.

Theories and models developed to explain and understand the observations in natural ecosystems require experimental verification. However experimentation in the field of marine ecology is complex , since it requires to reproduce natural conditions, this needs to be supported by cost efficient access to different European marine ecotypes as well as coordinated access to European marine biological stations. In some cases experimental approaches require continuous real-time measurement of various parameters in larger controlled trials setup to provide robust results.

Coastal areas

Primary production in coastal shelf areas and margins account for around 25% of the total primary production of oceans and they sustain over 90% of the world fisheries, providing food resources for a growing world population. Moreover these are key areas in the dynamic of the ocean and the exchanges between land and sea (e.g. sediment transport), playing a key role in the life cycle of many species and also on the global biogeochemical cycles. These areas are under increasing pressures of human activities (e.g. tourism, fishing, aquaculture, etc) and they are densely populated and urbanised, particularly in some sea basins (e.g. Mediterranean), which usually leads to their permanent degradation.

In order to ensure the sustainable management of human activities we need to cover the existing gaps in the basic understanding of the structure and dynamic of the coastal and marine ecosystems, including estuaries, deltas and lagoons among others. We will be able to have a better understanding of the coastal areas if we have more in-situ data available for research, including data to develop more accurate high resolution models, in particular to understand processes and interactions involving the coastal zone, including land sea interactions and coastal-open sea exchanges. In particular the understanding of interactions between major rivers and their inputs on the marine environment marine needs to be improved. It is also necessary to better understand the interactions between coastal shelf areas and their catchment areas and develop improve innovative observation and data management systems, tools and methodologies to cover specific regional gaps in marine information needs, particularly in those areas or regions where there are insufficient environmental data to improve the understanding of processes.

Regional specificities

Special focus must be put on to understand the ecosystem functioning and processes in semi-enclosed European Sea basins (Baltic Sea, Mediterranean and Black Sea), the so called "marginal seas". These regional seas are often forgotten in global perspectives despite they have very specific features that make them particularly sensitive to the pressures from human activities and climate change. They also hold unique ecosystems and some of them are important hotspots for marine biodiversity (e.g. Mediterranean Sea). Moreover some of the processes occurring at sea basin level may have implications at global level (e.g. to outflow of Mediterranean waters contribute to the water masses and circulation in the North Atlantic Ocean). The process in these sea basing are complex due to their particular features and impacts, especially in the coastal areas.

It is necessary to conduct more research to improve the current knowledge on the physical and biogeochemical processes in these sea basins, understanding the circulation and vertical water and particulate exchanges, microbial activity, bio-geo-chemical processes, including exchanges between oxygenated and anoxic areas in the case of the Black and the Baltic Sea..

There is a need to improve cooperation, exchange of knowledge and the interaction between researchers at regional scale. The collaboration between scientists from different sea regions needs also to be enhanced in order to share experiences, data and information on physical, biological, chemical, hydrological processes and also on social and economic aspects

Ecosystems evolution in a changing environment

Understanding the process of evolution of interactions between biotic and abiotic components that governs marine ecosystems networks requires the development of new tools as well as new macroecological approaches (including models and scenarios). New tools are needed to investigate ocean processes on global scale as well as to get deeper insights on the evolution of the “marine regions” under the influence of past and present climate changes. This will help provide a robust assessment of natural processes and variability and how anthropogenic activities are interacting with natural processes.

The change in environmental conditions may have dramatic consequences on marine ecosystems leading to regime shifts with large changes in biological communities, biodiversity and food webs structure. We need to improve our current knowledge on the consequences of regime shifts for species abundance, distribution and food web interactions. Moreover, current community ecology models do not allow to predict the relationships between species richness of marine biodiversity and levels of perturbation intensity, which call for further research efforts in this field and also to improve the knowledge on the functional properties of marine biota in order to understand long-term processes. It is also necessary to link marine biodiversity and ecosystem features such as stability and functioning to climate change.

Integrating observation and modelling

Models are a fundamental tool to understand the functioning and variability of marine ecosystems, including food webs dynamics and marine biogeochemical processes The current ecological and biogeochemical models (at the ocean level, regional level and local level - e.g. coastal) lack of suitable capabilities to make accurate prediction of processes in marine ecosystems. It is necessary to adopt new approaches and combine disciplines, integrating classical methods of observational ecology with those of omics and numerical models to address complex questions.

It is therefore necessary to support the improvement of current modelling tools by defining and implementing a common strategy to develop the next generation of ocean ecosystem models. Such models can be used to increase general knowledge of the system functioning, and also serve as tools in ecosystem based approach to resource management and the development of mitigation measures. This will require the development of research to validate the models.

To improve the accuracy of models and predictions the key processes governing marine ecosystems functioning need to be included in models. For instance, in relation to biogeochemical process the current models do not consider the whole complexity of the ecosystem, particularly in relation to the biodiversity functioning of microbial systems and their impact on the global cycles. So there is a need to integrate the microbial systems in the modeling of physico-chemical and biological processes, so as to tale into account their role in the biogeochemical processes. The particular ecosystem features and other environmental effects that may affect ecosystem dynamics (e.g. climate change) also need to be taken into account at a the proper geographical scale (i.e. local , regional and global scale).

In order to further advance in the development of ecosystem models, it is necessary a multidisciplinary approach to ensure a closer linkage between modeling, field observations and experiments. Such as interaction between research communities is also needed to ensure that observations and experiments are designed in such a way that they deliver the knowledge and the data require to improve the predictive capability of models. Field and experimental research at several level, including agreements of multifactorial approaches, are needed. Also the shared development of methodologies will help ensure that predictive experiments reflect accurately environmental conditions and variability. In particular, experimental and theoritical approaches will contribute to develop new insights on the complexity of organisms and ecosystems reactivity

Data needs to understand ecosystem functioning

Enhanced predictive capacities of models and understanding of marine biological and biogeochemical processes, food webs and variability in space and time of diversity and population will also require more data and better resolution (both spatial and temporal scales), including fixed point (biogeochemical time series) and dynamic surveying, to capture dynamics in ecosystems in order to improve and validate models. A key issue is the improvement of the baseline data and set reference levels for non-commercial species, benthic organisms and habitats. Such needs for data would not be fulfilled without a substantial increase in observation capacities, including long term series, related infrastructures for monitoring and development of capacities, systems and technologies for management large amounts of multidisciplinary data and enhanced coupled data bases.

Improvement of models also requires to have access and make use of available high quality and standardized. This needs to be supported by measures to facilitate and promote access to marine data. Measures should be also encourage the sharing of research outputs in order to understand, quantify, and synthesise within Earth system models the marine components of key global biogeochemical cycles (elements of and processes ruling the environments), and how they respond to and drive environmental change, and the role of physical, biogeochemical and microbial processes.

TOPIC 2.1.2. UNDERSTANDING AND PROTECTING MARINE BIODIVERSITY AND DEEP SEA ECOSYSTEMS

Enhancing the knowledge on marine biodiversity

In order to protect and preserve marine biodiversity it is necessary to improve our understanding on its role in marine ecosystems by deepening research on interactions between marine biodiversity and food webs, and the physical-chemical environment. This also includes and better understanding of marine habitats, their distribution and characteristics, and the physical and ecological processes that govern these ecosystems and sustain biodiversity. This basic knowledge is essential to understand the perturbations caused by human activities on marine habitats and biodiversity and to ensure the sustainable management of these activities.

Currently there are large knowledge gaps on marine biodiversity in terms of structure and function of marine ecosystems, functional traits in marine organism, species diversity, species turnover, genetic biodiversity and key species. In addition the current knowledge on habitats distribution and their ecological features is also very limited.

It is also necessary to analyse and understand the role of biodiversity in the resilience of marine and coastal ecosystems. Current community ecology models do not allow to predict the relationships between species richness and levels of perturbation intensity. It is necessary to develop macro-ecological scenarios of the evolution of biodiversity. More research (including modelling) on marine biodiversity dynamics at various spatio-temporal scale is needed, including paleontological data, to better understand how biodiversity respond to environmental changes and integrate transition processes across scales.

Surveying vast ocean areas with limited resources requires a substantial increase in observation capacities, including long term series and related infrastructures. Research on marine biodiversity should be supported by a large-scale pan-European observatory network for biodiversity.

Deep sea biodiversty and habitats

Deep sea is under increasing pressure of human activities such as fisheries, oil and gas exploitation and deep sea mining. However relatively few is known about the deep sea, the largest area of the ocean, including knowledge regarding the potential resilience of the deep ecosystems. There still are many knowledge gaps on deep-sea morphology and the distribution and functioning of deep sea vulnerable ecosystems. In addition their biodiversity and genetic richness is poorly unknown. It is also necessary to enhance our understanding on the relationship between biological and chemical processes, biodiversity and resources in the deep sea.

This call for further research on deep-sea ecosystems, environment and processes implied in sustaining and structuring benthic communities in deep sea. This kwnoledge is needed to underpin evidence-based governance of human activities that may have an impact on the deep-sea environment and to establish protection measures. It will require an extensive fine scale habitat mapping (including high resolution sediment type) to identify and characterized habitats. This should be done through coordinated seabed and habitat mapping programmes, for instance through the establishment of a European Seabed Mapping Programme. The mapping could be implemented at sea basin level to maximize the potential for common use of regional infrastructures to cover the existing gaps on deep sea habitats and benthic environments through high resolution seafloor topography.

The development of an ecology of marine landscapes based on integrated modelisation of biotic and abiotic parameters should be supported. More effort in harmonisation of habitat classification systems are also needed, together with measures supporting open data access and the use and reuse of existing data (previous cruises, industrial surveys etc.). In relation to this, JPI Oceans can help maximise the utility of all observations by encouraging the sharing of data, information and knowledge.

An extensive mapping of environmental data and biodiversity from potential areas of harvesting is necessary to provide baselines for sound management of deep sea resources in a sustainable way. Also detailed mapping of habitats and benthic environments is necessary to underpin the accuracy of predictive models and identify key tectonic /volcanic sites, (e.g. geological release of gases), where ecologically and economically important (and potentially undiscovered) species and habitats (e.g extreme environment inhabited by extremophiles) may be found, particularly in some regions such as the Atlantic Ocean.

Up to date most of the research on deep-sea ecosystems has been conducted at relatively small-scale and has been mostly focused on specific sites or particular topics. Therefore the links and connectivity between these ecosystems and their significance for management purposes are not well understood, for instance there is a lack of knowledge on the interconnectivity between the deep sea habitats (including long distance waters e.g. international waters, west African waters, etc.). Therefore more research is needed to strengthen the basic knowledge about the process involved in the connectivity of marine systems including. Research activities to cover the knowledge gaps on deep sea should be supported by deep sea observatories that could be part of an integrated marine observing network at European level, including seafloor and subseafloor.

Impacts of climate change on biodiversity

The interaction of climate change and acidification pose significant risks to ecosystem functioning, ecosystem health and the diversity and distribution of marine species and communities. We need to improve our knowledge of the response of marine biodiversity to climate and sea-scape use change and how it biodiversity and organisms adapts to climate changes and the possible changes. Most reference documents and legislation do not pay the due attention to climate change issues and it is necessary to assess the existing reference documents on climate change for their usefulness towards marine biodiversity.

In order to assess the impact of climate change and acidification on the ecosystems and understand how it will affect biodiversity and organisms, it is necessary more research on the sensitiveness and tolerance of species as well as on the adaptability of marine species in a fluctuating environment. It is necessary to understand the role and functionalities of biodiversity in the context of climate change and ecosystem resilience, and develop capacities to forecast the evolution of biodiversity. In addition it is necessary to expand our knowledge on eco-physiology, life history traits, phenology, phenotypic plasticity, ecogeochemistry to better understand the adaptation and acclimatization process of marine organisms.

Nevertheless, beyond emphasizing the effect of climate change on a few marine organisms or systems, there now remains considerable uncertainty about the expected climate change impacts on ecosystems and global marine biodiversity. At the level of marine ecosystems, there is a concern on the potential effects of climate change and acidification on very sensitive ecosystems, such as deep sea vulnerable ecosystems and also on MPAs. We do not understand well how the environmental changes induced by climate change are affecting these benthic ecosystems and their biodiversity, and how they will evolve under these pressures. More knowledge is needed to assess the impact of climate change pressures on these ecosystems to develop suitable management measures.

To get further insights on the effect of climate change on marine biodiversity it is necessary to establish long term monitoring programs on marine biodiversity at national and supranational scale to monitor the consequences to marine species and assessing their capacity for adaptation. It is also necessary to develop models for the analysis of climate related effects upon marine life based on best available scenarios for climate change.

Impacts of human activities on biodiversity

In addition to climate change the increasing pressures and impacts of human activities from land and maritime activities, and the use of marine resources may lead eventually to the deterioration of habitats and the loss of biodiversity. We do not really know the proper connection between impact of human pressures, biodiversity and ecosystem function. In addition there could be synergistic effects between changes in the environment caused by human activities and the effects of climate change. But currently we do not have enough knowledge to understand and assess the combined effect of climate and human pressures on biodiversity. It is necessary to put more research efforts in understanding and foreseeing how biodiversity respond to human and environmental pressures and impacts human activities (e.g. coastal modifications, pollution, fisheries, etc), and enhance the knowledge about the vulnerability of species, habitats and ecological processes. To develop proper management measures we also need understand how human activities respond and adapt to biodiversity changes.

The impacts on biodiversity are particularly important in coastal margins (estuaries, the littoral zone, and near-shore waters), where most of the population interacts with the marine environment, where economic activity takes place, and where loss of habitats and environmental damage is most apparent, including land based man interactions. However, we lack of information about the real extent of marine biodiversity loss. We need to collect new data and develop knowledge needed to assess the status of biodiversity and the current loss rate. In this regard, further research and long term assessment of biodiversity loss, using past and present data, needs to be done considering not only charismatic species or commercial species, but also microscopic organisms, since they play a key role in the functioning of marine ecosystems.

The assessment of the impact of human activities on marine biodiversity requires of reliable and sound indicators of biodiversity, however there are large data knowledge gaps in order to decide on the best descriptors for good environmental status (GES), and indicators of biodiversity. There is also a need to harmonize indicators of biodiversity in order to reach consensus at pan-European level on how to measure GES and biodiversity. Moreover, it is necessary to develop a scheme for assessing and monitoring biodiversity status at the ecosystem scale. In particular aggregation and integration techniques need to be developed. The development of assessment criteria (especially for species) that take into account regional differences and also achieve a common agreement on the most appropriate geographic divisions are also necessart. Further research of the impact of pressures that are insufficiently understood and biological changes in population which origin is unknown is required.

There is a need to mitigate the human impact on biodiversity and manage its sustainably. Marine protected areas (MPA) contribute to the achievement of GES, through their role in the protection of vulnerable and diverse marine habitats and their biodiversity from direct anthropogenic pressures. In order to establish MPAs and representative networks of them marine planning is necessary. The network architecture of MAPs and their management instruments are not optimized and there is a weak integration of knowledge on connectivity of marine systems and management and conservation biology policies. To overcome these gaps it is important to strengthen the knowledge on i) habitats and their functional role in key areas (eg spawning areas), ii) mechanisms of transport and dissemination of larvae or of adult migration, including a better understanding of deep sea currents (e.g. through development of models), iii) the functioning of trophic networks and connectivity between different habitats population. On the other hand, the management of MPAs may benefit from a European wide perspective to develop an understanding of how the networks work together. Monitoring programmes are also needed to properly manage MPAs.

Monitoring biodiversity is very costly and it is necessary to do it in a cost efficient way in order to make feasible the monitoring of a wider range of biodiversity and ecosystem features at the geographic and temporal scales required. This needs of suitable 'business models' financially viable and develop integrated monitoring programmes taking into account the already existing programmes.

In the case of the impact of new/emerging human activities (e.g. deep sea mining) on deep sea ecosystem, more research is needed to study present and anticipate future impacts of increasing deep sea activities. Development of baselines and risk analyses may be necessary in the view of the potential risks from the exploration of new resources in subsea areas. In addition, identification of vulnerable areas is needed to prevent the damage of unknown vulnerable habitats and the loss of biodiversity. Research activities may also cause damage to deep sea ecosystem in order to minimise this impact it is necessary to develop less destructive methods to conduct research on benthic communities and geomorphological features. An interesting example about regards to monitoring marine biodiversity and microbial marine diversity is the application of image analysis to detect and analyze diversity through benthic imaging.

One of the major threats to biodiversity is the spread of invasive species, it is necessary to develop appropriate indices /indicators to measure and assess the risks and impact of invasive species (including impacts of aquaculture on the genetic diversity of wild populations caused by escapees). The problems associated with introduced species are expected to worsen over the next decades due to climate change, increased trade and aquaculture. It is necessary to conduct studies to assess the spreading and impact of invading species cause by climate change alone or in combination with human activities (e.g combined effects of maritime transport and climate change), including development of models. Studies of environmental genomics and approaches related to life history traits and adaptation must be strengthened so that eventually it becomes possible to adopt a rational strategy to deal with the problem of introduced species and provide effective mechanisms of action to minimize the impact or the introduction of exotic species.

Regional specificities

There are geographical areas where biodiversity can be more sensitive to climate change, due to the particular physiology of organisms inhabiting these areas and also due to regional oceanographic specificties. The marine and maritime research efforts may reveal general insights but these will show sea basin variations or have regional implications (e.g. the Mediterranean is a sea basin with very peculiar features and in addition it is a hotspot for biodiversity). Therefore understanding the impact on biodiversity requires a deeper knowledge of local pressures and this need to be addressed at regional or local level.

A realistic assessment of the local response of the climate change is important, in terms of some specific processes, including acidification and its impact on biodiversity. Thus threats to biodiversity are particularly imminent in the Arctic, with sea-ice loss profoundly affecting ice-associated marine life, and projected rates of acidification suggesting adverse ecosystem impacts within the next decade. Also biodiversity in the Southern Ocean can be affected by rapid changes caused by climate change in the context of rather pristine conditions. The Mediterranean is a hotspot for biodiversity and its specific features make this sea basin particularly suitable to study changes caused by climate change and human impacts, since those have trigger a rapid evolution of the basin. Also biodiversity in overseas territories can be particularly sensitive to climate change and acidification. Moreover, the differences in the impact of climate change between the northern and southern regions (e.g. between OSPAR areas) call for a better understanding of the potential climate change impacts at both the regional and local level.

AREA 2.2 ECOSYSTEM HEALTH AND HUMAN IMPACTS

TOPIC 2.2.1 DEVELOPMENT OF INDICATORS AND GUIDELINES TO ASSESS ECOSYSTEM HEALTH AND HUMAN IMPACTS AND HARMONIZE MONITORING PROGRAMMES FOR THE IMPLEMENTATION OF THE MSFD.

Research needs to achieve a good environmental status (GES)

One of the biggest areas to create synergies across Europe relates to the implementation of the Marine Strategy Framework Directive (MSFD), including research on indicators of good environmental status (GES) and their optimization and standardization for monitoring. In that regard there are important gaps on GES and its indicators, including the need for better conceptual and practical understanding of the meaning of GES and how it should be measured. Currenty these gaps are a major barrier to comply with legal requirements of the MSFD.

The definition of GES requires a profound and detailed understanding of the human interactions with marine environment (processes and effects) including coastal areas (such as estuaries, the littoral zone, and near-shore waters) and margins, where most of the population interacts with the marine environment, where economic activity takes place, and where biodiversity loss and environmental damage are most apparent.

Moreover, some components of the marine environment are not properly considered in the definition of GES. There are important knowledge gaps regarding the processes and structures of marine and coastal ecosystems that need to be addressed to be able to provide a sound definition of GES. For instance the current definition of GES does not include microbial component of the ecosystem or indicators specific for boundary layer-related processes. Moreover, the state of art for many of these indicators is not sufficiently known or understood. This requires a major effort in research, including methodology, which would certainly benefit from the pan-European approach.

We need quantitative information on the present ecological status of different marine ecosystems, with wide geographic coverage and high spatio-temporal resolution, characterization of ecological properties of marine habitats, current human impacts and potential uses with the objective of evaluating the GES according to the to different features of environment and its use. It will be necessary to set priorities and detect major risk of not achieving GES and to strengthen the expertise needed to foresee, select and assess the efficiency of management measures. Likewise, it is necessary to identify information needs to enable a move from expert judgement to a more evidence-based assessment and facilitate the access to all marine data to support this. There is also a need for the information generated from monitoring systems to be effectively communicated to policy makers, including uncertainty, and it is also necessary to make data available.

Some criteria may need further development and indicators of GES should be sensitive enough to measure the health of the ecosystems and the changes caused by human activities. It is necessary to implement research actions to assess the current indicators and, if proven necessary, develop more suitable indicators of GES and methodological standards to monitor efficiently and accurately the status of the marine environment and the impact of human activities. It is also necessary to optimize the number of indicators by identifying the key ones. These indicators should cover the main ecosystem components, the range of relevant pressures and should be suitable for assessing ecosystem functioning and cumulative effects. Research is also needed to build integrated models to develop and test indicators.

More research is needed to further develop and operationalise the descriptors of GES. In particular, the state of art for many of the indicators of GES it is still not sufficiently and more research is also needed to define target values for indicators and reference values at an appropriate scale in space and time, based on sound evidence (effect relationships in the oceanographic, biological, chemical processes in ecosystems), to keep human activities within the sustainability (carrying capacity conditions). In order to be able to set realistic targets more research is needed to better understand the functioning of the ecosystems and environmental sensitivities to natural and anthropogenic change, and define environmental thresholds in undisturbed areas to separate inherent natural variability from anthropogenic signals of change.

In addition to human activities, climate change may impact the marine environment and affect the GES. It is necessary to better understand the effects on climate change on the descriptors of GES by conducting focussed research taking into account the different ways through which climate change may affect GES. This may lead to the need for a regular review of assessment criteria used for targets and indicators. In order to adopt suitable management measures more research is needed to disentangle the impacts of climate change from those caused by human activities.

In 2020 the MSFD process will need to be updated and research must be able to deliver a lot of conceptually new approaches to monitoring by then; new tools (e.g chemical and biological sensors), new methods and monitoring strategies. Policy decisions regarding the use of marine space need to take into account the scientific knowledge and support the development of the new generation of indicators.

Specific research needs for some descriptors

Many of the specific research needs on descriptors and indicators relate to marine biodiversity and the effects of human activities on it. There is a need for research in order to decide on the best indicators of biodiversity and there are large data gaps on the proposed indicators of GES for biodiversity. It is also necessary to conduct further research to develop a scheme for assessing and monitoring biodiversity status at the ecosystem scale and to extend the development of ecosystem assessment methodologies, which brings together and build upon existing approaches for thematic assessments conducted in the framework of Regional Conventions. This should include a consideration of appropriate ecosystem components and their interactions as part of ecosystem functioning. Also aggregation and integration techniques need to be developed. There is also a need for assessment criteria (especially for species) that take into account regional differences and for agreement on the most appropriate geographic divisions. Another reseach priority is to enhance the knowledge on trait diversity and develop more research about different species sensitivity..

There is also a lack of data and understanding of several indicators (e.g. marine habitats, biodiversity, invasive species, seafloor integrity, marine food webs, emerging pollutants, marine litter and microplastics, marine noise and electromagnetic radiation) which requires further research on these pressures and on the impacts caused by them. Research is also needed to understand biological changes that cannot presently be explained (e.g. declines in seabird populations).

Need for coordination and harmonization at EU level: a common monitoring strategy

The MSFD has a predominant national approach, rather than being developed from an integrated vision at EU level. Currently there is a lack of harmonization of indicators of GES and in addition there is no interoperability of the platforms for data collection. The procedure and protocols are not homogenized to assess the GES in a coherent manner across Europe. As there is no legal obligation to harmonize the indicators or do intercalibrations between Members States, each country has developed its own set of indicators of GES. The methods and protocols for monitoring are also different between European countries, increasing the fragmentation. The indicators and monitoring protocols should be harmonized at EU level, taking into account the regional specificities.

This fragmentation across Europe is a major barrier and there is a need for wide cooperation and agreements at regional and EU level on harmonization and standardization of indicators and procedures at pan-European level. Research efforts should be intensified to achieve harmonised monitoring and comprehensive assessment of human activities as a basis for implementation of the MSFD. A common monitoring strategy at European level is needed to respond to the challenges of the MSFD, taking into account the regional particularities. Monitoring is costly and the lack of a strategy causes unnecessary duplication. Currently there is enough room to improve the efficiency of monitoring by enhancing the coordination in the use of infrastructures, for instance through the coordination of interdisciplinary data collection at regional level, as well as by developing coherent and compatible observations in support of implementation of European directives and policies.

It is necessary to maintain and increase temporal series on biological and physico-chemical parameters in marine ecosystems, and measure/assess the GES, including biodiversity, of the seas through a long-term monitoring system. This can only be achieved by securing a long term financial commitment to monitoring programmes set apart from research funding. One of the limitations to a coordinated monitoring programme is that, according stakeholders, Member States want to be in control of their monitoring systems.

In addition, in order to be able to make an efficient use of the data collected by industry, harmonization and coordination between industries, authorities and research would be necessary to ensure that data are intercomparable to respond to the need of “collect data once and use it many times, no matter what the source” (i.e. data from industry, science, research and operational oceanography needs to be brought together).

Regional sea basins specificities and transboundary cooperation

The challenges faced by different regions should be taken into account. This also concern to the cooperation with neighbouring countries and international organizations. In that regard, one of the main issues raised by several stakeholders relates to the way Member States interact with non-members in certain regions. It is recognised that the timeline of the MSFD is ambitious but that there is an interest from neighbouring African countries to comply with the requirements. However, many of these states lack the required resources and it would be useful if funding availability is mapped. In addition there is a lack of coordination and harmonization between the requirements of the MSFD and the requirements of the Regional Conventions (e.g. Black Sea), which leads to unnecessary duplication.

At sea basin level it is necessary to continue cooperation and harmonisation of GES indicators between countries (e.g. the indicator on acoustics is different between some neighbouring countries) by making a better use of the current knowledge, from research groups and national institutes within and between member states, to define indicators and target values. Transboundary and cross-sectoral cooperation needs strengthening in view of the increased demand for the use of available space and resources.

Information from environmental impact assessments and related monitoring programmes is often inaccessible to the public and its use is also hampered by limited comparability of the data. Regarding specific needs within the scope of regional conventions, stakeholders raised the need to developed practical guidelines for the application of the OSPAR common MSFD indicators and also the need to ensure that the monitoring of these indicators is synchronised among the OSPAR countries and harmonised with other regional seas.

TOPIC 2.2.1 ASSESSING THE IMPACT OF MARINE POLLUTION (INCLUDING LITTER, MICROPLASTICS) AND NOISE ON MARINE ECOSYSTEMS AND RISKS FOR HUMAN HEALTH

Understanding marine pollution and its effects on marine ecosystems

Marine pollution, as a consequence of multiple human activities on-land and at sea, is one the main human pressures on the marine environment. A steep increase of pollution is expected over the next decades as a consequence of the increase of world population. The increase of global chemical pollution has been estimated in 3% per year, which is much more higher that the expected rate of increase of the world population.

Marine pollution can lead to a loss of biodiversity and have harmful effects on marine ecosystems at different organizations levels, including habitats, populations and organisms, causing also effects at physiological and cellular level on marine organisms. Depending on the concentration and the exposure time, chemical pollutants can cause different effects including the death of marine organisms, but more frequently due to their sublethal concentrations they cause adverse at physiological level, (such as impairment of the reproductive, alteration of hormone and immune systems and reduction of growth , among many others), and also at cellular and molecular level (e.g. stability of cellular membranes, DNA strands break, enzymes regulation, etc).

Classical pollutants remain high in the list of concern since there are still important knowledge gaps regarding the long term ecological and biological effects of these micro-pollutants on the marine environment, biodiversity and organisms (e.g. recent data suggest potential long-term adverse effects of classical pollutant on marine biota). In addition over the last decade the concern on emerging pollutants, such as new chemicals substances (e.g. pharmaceuticals, antibiotics, new pesticides, flame retardants, endocrine disrupters, personal care products, nanoparticles, etc), litter (including microplastics), has increased notably. We do not know much about their distribution, behavior and impacts on the marine environment. These large knowledge gaps need to be covered in order to quantify these pollutants and their distribution, elucidate their routes and assess their consequences on marina fauna and flora through coordinated observations and monitoring on test-areas. In particular, more research on methology is also needed on emerging chemical pollutants, litter and microplastics in order to standardize methods to quantify these pollutants in the marine environment, including water column, sediments and biota, and assess the risk to the marine ecosystems.

In relation to the harmful effects of pollution to marine ecosystems, it is necessary to improved dose-response assessment methodologies, in particular for emerging pressures in the marine environment that are insufficiently understood, (e.g. new pollutants, noise, microplastics, litter, electromagnetic radiation). The effects of these pollutants are hard to assess as there is a lack of understanding of the severity of impacts and hence the level of acceptable pressure is difficult to determine. Understanding resilience and ecosystem responses to pollution is needed to improve the management of human activities to reduce the inputs of chemicals and other harmful substances to the global water body, including the impact of pollution from marine and land-off (e.g. non-treated waste water pollution effects). The development and use of (effect-based) ecotoxicological tests at ecosystem (or at least community) level is needed to increase the understanding of altered ecosystem function as a measure of the effect of single or combinations of hazardous substances. On the other hand, increased stress of organisms due to environmental changes (e.g. rise of seawater temperature, acidification) may turn marine organisms more vulnerable to chemical contamination, though there is substantial lack of knowledge on the combined effect of climate change and pollution on marine organisms.

Dynamic of pollutants in the marine environment

There are large knowledge gaps in relation to the dynamic of emerging pollutants and materials in the marine environment, including their entrance routes and pathways in the marine environment, the bioaccumulation of toxic substances, the trophic transfer and also the degradation processes (including litter, microplastics and nanoparticles) and the interaction of the emerging chemicals and materials and effects on biodiversity, food-webs and populations. At the same time, there is a need for better linking sources, pathways and environmental status. Monitoring programmes should be able to trace back chemicals from the environment via their pathways to their sources in order to allow the appropriate development of programmes of measures to achieve good environmental status and assess progress being made.

A concern about some of the new emeging pollutants, such plastics, is that these can absorb other contaminants present in the marine environment on their surface, behaving as vectors for the transport of chemical pollutants, including emerging and classical pollutants (e.g. persistent organic pollutants such us PCBs, PAHs, PCDD, etc). On the other hand, the absorption of chemicals on the surface of these materials may also increase the bioability of the absorbed pollutants to marine biota. However, in general the knowledge on how these materials can modify the routes of transport, bioability of harmful properties of other pollutants present in the marine environment is very scarce and more research is needed to better understand dynamic of pollution in the marine environment and assess the environmental status and risks on the marine environment.

On the other hand, warming of the atmosphere in response to climate change may increase the tendency for atmospheric transport of certain substances and facilitate the spread of pollutants. On the other hand, in certain areas more frequent heavy rain events and floods can result in enhanced run-off and increased inputs of pollutants to the sea. Also an increase frequency of extreme storms may lead to remobilisation of contaminants from marine sediments (e.g. from historical pollution sites of coastal communities and dumping areas). Targeted research of the most relevant phenomena within the spectrum of possible climate change –related impact routes is needed. This may lead to the need for a regular review of assessment criteria used for targets and indicators of GES.

Underwater noise

In addition to chemical pollution and litter, the concern on the potential effects of marine underwater noise on the marine fauna, as a consequence of the increased number of maritime activities (e.g. shipping, offshore wind farms, military activities, etc), has increased notably over the last years. Currently there is a lack of data on underwater noise and there is also a lack of understating of its effects on the marine environment. More coordinated research and monitoring is needed to characterize the status of marine ecosystems regarding underwater noise, its propagation and its impact on the marine fauna in order to provide scientific support for the implementation of the MSFD. Currently the level of acceptable pressure is difficult to determine, which requires improved dose-response assessment methodologies. Research is also needed to develop effective methods for ambient underwater noise characterization and sound modelling tools, including evaluation of data sources (e.g. shipping data).

Ocean and human health

Ocean and human health research is a novel approach that put together in a cross-sectorial way the benefits and risks of the marine environment and their resources on human health. In particular, seafood safety has been highlighted as one of the most pressing issues to be addressed. Pollution of seafood represents a major risk to human health, due to exposure of humans to marine pollutants through seafood consumption. Most pollutants are bioacumulated by marine organisms and subsequently transferred to upper trophic levels through food-web interactions and eventually they can reach marine organisms used for human consumption with the consequent risk. Tracing contaminants in the food webs it is an issue of high importance to understand how the pollutants can reach seafood.

On the other hand, the potential risks of pollution for human health through seafood consumption are still completely or not well understood. Research that relies on robust design, combining observations, data assimilation and statistical / epidemiological modelling is needed. This also calls for the development of coordinated European and global surveillance programs for analysing undesirable[1] in seafood. In some areas baseline studies on undesirables in seafood has been conducted which could be used as models.

Geographical and regional aspects

Though marine pollution is a global threat some areas or regions may be more exposed than others to pollution, for instance semi-enclosed seas like the Baltic Sea and the Mediterranean are highly influenced by the intense coastal pollution. Therefore, it is necessary to better understand marine pollution within a geographic-causal perspective and within wider range of changing pressures. Moreover the impact of pollution may differ between areas, thus coastal areas and continental margins (the most productive areas of seas and oceans and where most of the human activities at sea take place) are the most affected by pollution from different sources, both from land (e.g. inputs from industrial and domestic effluents, agricultural inputs) and marine sources (e.g. shipping, aquaculture, oil and gas platforms, accidents, leakage from shipwrecks, etc).

Due to the expansion of human activities and the development of new activities, remote areas such as deep sea and the arctic are also under the increasing pressure of pollution. However, the knowledge about deep sea ecosystems, the largest area of the ocean, and also on Arctic ecosystems is very limited. We know very little on the distribution of pollution, including litter and microplastics, in these remote areas and the resilience of these ecosystems to pollution. In order to address the effect of pollution on deep sea environments and remote areas it is necessary to develop data baselines from unpolluted areas and improve the understanding of ecosystems process to assess the impact of pollution on these ecosystems. In particular, regarding deep sea risk analysis may be

[1] *The term undesirable makes reference to dioxins, PCBs, heavy metals, in the case of farmed fish it also makes reference to therapeutic agents, illegal substances , etc*

necessary in relation to the exploration of new resources under the seabed, since even todays exploration of oil and gas can cause significant impacts (e.g. Deepwater Horizon).

Monitoring pollution and emerging issues

Addressing the issue of marine pollution in an effective way requires a concerted efforts at EU level and particularly between neighbouring countries. Marine pollution does not have frontiers and to tackle the problem improved cooperation between countries is needed (e.g. the source of pollution may be located outside the frontiers of the country affected).

Geographical integration (sea basin strategies towards the consolidation of an EU strategy) is indeed needed to avoid fragmentation and/or duplication of means (infrastructures, programs etc.). A management strategy is needed to best address the fragmentation of decision making processes across sectors and ecosystem components and to develop integrated and harmonize monitoring programmes across physical, chemical and biological systems, which take into account current monitoring efforts being undertaken at regional sea basin level (e.g. OSPAR). Special attention should be paid to support monitoring activities and equipment in regions where there is insufficient data at present.

Some relevant emerging issues in the marine environment require new and effective approaches for actions and solutions to address the problem of pollution from land (e.g. industrial and urban inputs on the coast) and from maritime activities (e.g. pollution from shipping activities, ballast water, tank washings, engine room effluent discharges; accidents such as oil spill and the leakage of different contaminants from shipwrecks and dumping areas, aquaculture activities, etc). Intervention plans in highly polluted areas are needed.

One of the emerging issues raised by some of the stakeholders in the consultation is the need to monitor and tackled pollution from ship wrecks. Hundreds of wrecks are spread over the different Europe's sea basins (some of them from War World II). These wrecks contain oil and in addition some of them may also contain other hazardous substances than can be released to the marine environment at any moment. Addressing the threat of pollution from shipwrecks will require to develop sound scientific approaches to monitoring pollution leaking from the wrecks and develop model for risk assessment, incorporating real time data (e.g. through chemical sensors). This knowledge is necessary to facilitate decision making process to implement management measures for cost efficient remediation actions.

Pollution due to maritime accidents and oil spills is still a major cause of concern. In order to improve management of spills caused by accidents and minimize their impact it is necessary the development of enhanced models to forecast the spill behavior to undertake effective containment and remediation measures.

There is a need for technology development to improve the efficiency of marine pollution monitoring through the development of new sensors and biosensors (e.g. through the use of organisms or new biological probes) for in situ data collection. Also new technology advances are needed to integrate these sensors on underwater autonomous platforms to provide real time data acquisition at different locations and depths. Also technologies are needed to increase the detection capabilities of the current systems employed to monitor pollution.

TOPIC 2.2.3. EUTROPHICATION AND HARMFUL BLOOMS

Addressing the effects of eutrophication and HABs on human activities

Eutrophication and harmful algal blooms (HABs) is a major concern in coastal areas due to their impacts, not only on the marine environment but also on human activities particularly on some sectors of the maritime economy (e.g. fisheries, aquaculture, tourism) and also due to the harmful effects on human health. The consequences of increasing nutrients and organic matter inputs into the sea has been an issue for decades in Europe. The stimulation of phytoplankton growth by nutrients can eventually lead to eutrophication and processes such as changes in species composition, loss of biodiversity, ecosystem degradation, hypoxia, anoxia and harmful algal blooms, among others. Thus eutrophication and HABs caused from nutrient inputs from diffuse sources (mainly from agiculture use of fertilizers) and non-treated waste water inputs, continues being a major problem in many places along the European coastal waters. We do not have a complete knowledge of factors triggering HABs and this requieres further research and monitoring efforts in this field.

As to the impact of HABs on human activities, one of the sectors more affected by HABs is aquaculture, though at the same time pollution (nutrients and organic intpus) from aquaculture can lead itself to eutrophication in aquaculture sites and may also promote toxic algal blooms (e.g. proliferation of fish killing and/or toxic microalgae). It is necessary to better characterize the impacts of aquaculture on coastal areas and ecosystems an also to evaluate risks associated with HABs events, including socio-economic risks, that could affect the sustainability of aquaculture and other activities that can be potentally affected by phytoplankton toxic events (e.g. fisheries and tourism). This requires continous monitoring of phytoplankton assemblages, nutrient supply and oceanographic dynamics in aquaculture sites and other areas (such as tourist and fisheries areas) potentially affected by eutrophication and HABs.

Fish killing microalgal blooms are a threat for aquaculture and there is a need to investigate the ocurrence of these blooms especially in aquaculture sites, including the potential influence of climate change in the proliferation of this type of events. The information collected through monitoring can be complemented by measures to foster integration of the already available information on HABs and fish killing events in European waters, facilitate communication with related international research and promote the engagement of end users to draw prevention and mitigation plans

Harmful Algal Blooms (HABs) and human health

Understanding ocean health and human health needs to come higher up on the agenda. In addition to the environmental and economic damage caused by HABs, these harmful blooms are a serious risk for human health due to the toxins produced by the phytoplankton species involved in the blooms. The ingestion of seafood containing toxins is the main route of exposure of humans to HABs toxins, and the current EU legislation (EU Food Safety and Marine Environment Legislation) focuses on the need for improving knowledge of marine-related biohazards – e.g. harmful algal blooms and the bioaccumulation of toxins.

There are some emerging issues in relation to HABs and human health that requiere further research efforts, including a better undestanding of risks. This includes potential emergence of ciguatera fish poisoning outbreaks (already detected in Macaronesia) in temperate European waters, associated to the expansion of *Gambierdiscus* spp. (already detected in Greece), a tropical benthic dinoflagellate, due to climate change and globalized seafood trade. It is also necessary to track the presence, possible expansion and increased frequency of blooms of the benthic microalgae *Ostreopsis spp.*, whose outbreaks cause respiratory problems and cutaneous irritation in beaches and recreational areas. Another emergin issue that needs to be address is the risk for human health caused by the occurrence of new toxins in seafood imported from tropical areas. Therefore minimising the risks for human health implies tracing toxins in the food chains including imported seafood.

Monitoring and data needs on eutrophication and HABs in the context of climate change

It has been suggested that the warming of the oceans due to climate change may increase the frequency of HABs in European coastal waters. However we do not know yet the real consequences of climate change and acidification on the occurrence of HABs and it is necessary to improve the current understanding of the processes implied in HABs. In order to assess the link between HABs, climate change and human impacts it is necessary to determine the combined effect of short-term decadal-scale climate variation and anthropogenic pressures on the occurrence of HABs in general.

It will require to integrate the available long term databases on HAB events over the last decades with environmental and climate related environmental variables and with IPCC (International Panel on Climate Change) prediction models in European waters. It also requires implementation of biological monitoring in key sites, both in areas negatively affected by HABs and in areas particularly sensitive to climate change, with a high spatial and temporal resolution, including real time observation. In addition the development of common data sets, including microalgal and climate indicators (temperature, pH, oxygen), to track the impact of climate change on the expansion and/or intensification of different HABs is needed.

In particular, regarding toxic benthic dinoflagellates data series from temperate European latitudes are needed to track the real distribution of those benthic dinoflagellates (currently in apparent expansion related to climate change). In this context, it is necessary to maintain and expand the available coastal data series to include monitoring of benthic dinoflagellates, especially in hot spots (currently located in the Northern and Central Mediterranean Sea and Macaronesia Islands). The monitoring should integrate multidisciplinary environmental information in real time (when possible), including complementary biological, physical and atmospheric information.

European monitoring data sets on HABs are fragmented and should be harmonised. Adequate and coordinated monitoring of targeted biological organisms (e.g. harmful phytoplankton and others such as jellyfish) and processes (e.g. growth rates, encystment and excystment rates of toxic microalgae) is needed in European waters. This requires to maintain and/or establish regular monitoring programs (particularly in aquaculture and tourisc areas) and develop standard methods at EU level to also monitor benthic HABs, including the improvement current analytical methods for determination of toxins and the develop new detection procedures. In that regard a network of monitoring sites and the development of a common data base, starting for instance from the already collaborating centres under the ICES-IOC WGHABD, or through the integration of the network of EU National Reference Laboratories for Marine Biotoxins with new research initatives, would be needed.

It is necessary also to improve the current modelling tools to increase the reliability of toxic algal bloom forecast in order to adopt suitable management measures to minimised the impact on sectors such as fisheries, aquaculture and tourism and also to reduce the risk for human health . The improvement of scale resolution of IPCC models can also help to better understand the links between climate change and HABs.

On the other hand, classic monitoring techniques for HABs should be complemented with the development of molecular biology techniques and biosensors to detect harmful species and toxins more rapidly and conduct monitoring in a more cost efficient way. Coordinate data sharing and preservation should be strengthened, including the establishment of appropriate data management policies. In order to indentify strengths and weaknesses with a view to overcome the deficiencies and improve the methodological approaches it would be necessary to review ongoing monitoring protocols and projects.

TOPIC 2.2.4. INDIVIDUAL AND COMBINED IMPACTS OF HUMAN ACTIVITIES AND DRIVERS ON THE MARINE ENVIRONMENT AND SYNERGIES WITH CLIMATE CHANGE

Combined impacts of human activities

One of the most pressing issues in a 20-30 years perspective is to ensure that all human activities that can have an impact on the marine environment are carried out and managed in a sustainable way. Understanding how the different human activities or the combination of different drivers (like eutrophication, fishing, chemicals/pollutants, climate change, etc) affects the marine environment is of utmost importance to develop management practices that can handle human activities and their impacts to ensure a sustainable and economically viable use of the coasts and oceans and their resources.

The knowledge on the sum of environmental impacts caused by maritime activities and combination of human drivers needs is not sufficient and needs to be expanded. It is necessary to better understand the ecosystem functioning and their natural variability, improve our knowledge on pressures, and understand anthropogenic changes and environmental sensitivities to cumulative impacts and multiple stressors on spatial scales and over longer timeframes.

The main gap to assess the impact of human activities on the marine environment, including single and multiple stressors, is to define ecosystem health, which is a prerequisite for any assessment of the ecosystem status, taking into account the inherent environmental variability of ecosystems. We need to enhance our knowledge on the impact of human activities on the environmental status of marine ecosystems and how to measure these impacts. Currently there are many knowledge gaps and barriers to assess the environmental status of marine ecosystems. The main shortcomings and needs that research funding agencies and stakeholders have found on the assessment of good environmental status (GES) have been detailed in topic 2.2.1.

In addition to the issues highlighted in topic 2.2.1 other additional barriers and knowledge gaps need to be overcome to assess the combined effect of multiple stressors on the marine environment.

The current knowledge gaps on ecosystems and pressures make difficult to develop comprehensive assessment of the environment. In spite of progress made in scientific research and the development of more comprehensive assessment and monitoring programmes, some of the gaps in knowledge on the effects of human activities still remain to be covered (e.g. some gaps identified in OSPAR QSR 2000 still remain in the OSPAR QSR 2010). Thus much effort has been put into developing approaches for assessing cumulative effects, but standard methods have yet to be agreed and only very few data on cumulative effects of human activities are available. Thus, it is necessary to establish accurate and reliable criteria and indicators for cumulative human impacts and develop a coherent, pan-European approach to study the combined impacts of human activities on the marine environment through the coordination of national and regional activities in the implementation of MSFD.

On the other hand, data on spatial and temporal trends of some human activities and their effects on the marine environment are incomplete or lacking. There is also limited transboundary and cross-sectoral cooperation, e.g. in the light of a more integrated view on use of available space and resources. Another major shortcoming is that the information from monitoring programmes and impact assessment is not usually accessible. Moreover the potential use of such information it is usually hampered by limited comparability of the data. The efforts should be intensified to achieve harmonised, comprehensive assessment and monitoring of human activities, as a basis for implementation of the EU Marine Strategy Framework Directive (MSFD) and its concept of good environmental status (GES) by EU Member States, and explore the synergies of human impacts with climate change.

Synergies between human activities and climate change

There is a lack of knowledge on the combined effect of climate and human drivers and their impacts on the marine environment. However, the MSFD does not address the issue of how the different human and climate impacts act together. Therefore is an urgent need to understand and characterize the combined effects of these pressures on marine and coastal ecosystems functioning, habitats, biodiversity, food webs and marine organisms. This knowledge will enhance the current capacity to forecast future changes and tipping points at sub-regional and local scale and it will also provide support to the design of mitigation and adaptation plans. JPI Oceans could play a role in bringing together countries to address the problem of quantifying the multiple stressors on the environment and their impacts.

One of the major causes of concern of the combine impact of human activities and climate change it is the impact of invasive species on marine ecosystems. Due to the warming of the oceans and the increased maritime traffic the spread of invasive species is expected to increase over the next decades. In order to devise suitable measure to minimise the impact cause by invasive species it is necessary to develop predictive models for assessing the interactive effects of climate change and increased global shipping and transport on the distribution of native and non-indigenous species.

The combined effect of climate change and human pressures may increase the occurrence of harmful algal blooms (HABs) and jellyfish outbreaks. It is necessary to better understand the processes involved in triggering these blooms and outbreaks in order to improve the predictive capacity of models. Likewise the increasing pressure of fishing on fish stocks combined with the effects of climate change may lead to changes in fish stock distribution and abundance

Fundamental research, based on the extensive monitoring and long-term datasets is needed to identify single, synergistic and cumulative impacts of climate and human drivers on marine ecosystems and its sub-components. In particular it is necessary to increase understanding and quantifying the synergies between cumulative impact of multiple human activities and climate change in coastal margins (estuaries, the littoral zone, and near-shore waters), since most of the maritime economic activities are conducted in the coastal areas and continental shelf.

In addition to extensive field studies it are also necessary to conduct multi-stressor experiments, to get a deeper insight of the effect of multiple pressures on the ecosystems. Experimental research should be combine with the development of models to predict the synergies between climate change and human induced impacts. This will also help disentangle the impact of climate change from other pressures on ecosystems functioning.

It is necessary to develop models or frameworks, that include key processes, to quantify cumulative impacts according to habitat sensitivity. This requires a multidisciplinary approach and it may include the development of a matrix of combinations of human activities against habitat types (according to sensitivity) and the likely cumulative impact. On the other hand, gaps in knowledge should be filled, particularly concerning cumulative effects on biodiversity by improving the understanding of the response of marine biodiversity to human pressures and climate change. JPI Oceans could support the development of frameworks to quantify cumulative impacts on different types of habitats according to their sensitivity and bring information needed together.

The development of integrated approach to deal with multiple stressors at various levels should include regulation and planning of activities (MSP, MPAs, ICZM, etc), monitoring of cumulative impacts and development and implementation of robust and reliable management strategies for human activities. It should also include the development of methodologies to analyse cumulative impacts and to analyse the relation between pressures and environmental indicators, as well as to consider the integration of marine monitoring and maritime surveillance and the development of a common information sharing environment, enabling access to information in the different contexts and promoting effective decision making.

Current models need to be improved in order to enhance the predictive capability and reduce uncertainty linked to anthropogenic-induced changes and to develop scenarios that better inform policy-makers and society on the impact of multiple stressors. Models can also be very helpful to identify and separate individual effects from cumulative effects. Therefore, further effort is needed in the development of regional scale Earth ecosystem models by integrating marine research and modelling community from the beginning of new initiatives. Regional models need to be validated and calibrated with reference datasets and the model predictive capacity and the uncertainty need to be communicated to decision-makers.

Monitoring needs

More data with higher resolution in time and space will be needed to improve current models. The acquisition of more data at higher temporal frequency and spatial resolution requires adequate and coordinated monitoring schemes of ecological indicators of climate change and human impacts, particularly in especially sensitive areas in different European seas. Currently there is a lack of base and monitoring information (in some cases data) available under a coherent, comprehensive and public facility. In addition data collected through these monitoring efforts should be made available to the scientific community to maximise their use together with information from monitoring.

The impact of human activities and climate change can vary between sea basins and therefore regional specificities must be taken into account in the development of monitoring programmes and assessment of impacts. In particular, it is necessary to increase the monitoring capacities in those areas or regions where there is insufficient data coverage at present. An enhanced cooperation, coordination and sharing of the existing research infrastructures at regional and sea basin level is needed to develop long term programs at regional level to monitor changes in the marine environment caused by climate change and human activities.

JPI Oceans could take an overview of activities occurring regionally, particularly in regard to neighbouring Member States with open boundaries. The perspective of national programs should be change so they are conceived in the context of a broader data collection framework, with a view to develop regional infrastructures to conduct joint surveys programs on the functioning of marine ecosystems, the effects of climate change, the impacts of human activities and the state of fish stocks.

Currently there is a lack of a pan-European monitoring strategy covering human impacts and climate change impacts, taking into account the regional specificities. JPI Oceans could develop such a strategy and play a role in coordinating the cooperation between Member States at regional and pan-European level to address research and also to long term monitoring needs of the MSFD, including the development of suitable indicators, harmonization of indicator, harmonization of monitoring methods and tools on data collection and analysis for climate change and human impact indicators. JPI Oceans could also facilitate the coordination of existing efforts/networks that work at national or regional levels on these issues.

Individual impacts of specific human activities

In addition to the necessity of a comprehensive assessment of the impact of multiple stressors on the marine environment, many RFAs and stakeholders have also supported the necessity to conduct further research on the environmental impacts of a range of specific human activities. This necessity it is justified by the existing knowledge gaps on the effects of different traditional human activities on the environment and by the development of new activities which impact is no well or completely unknown (e.g. deep sea mining).

According to the responses of stakeholders to the consultation, the specific human activities which impacts require further research for assessment or actions for solutions are: marine renewable energy, offshore wind energy, aquaculture, fisheries, discharges from land sources (e.g petrochemical plants, nuclear plants, agricultural inputs, untreated waste waters), coastal modification (e.g. harbours), coastal tourism and leisure, maritime transport, deep sea mining, carbon capture and storage, military activity, and in general the impact of the increased number of installations on the sea shore, on the sea floor and on the continental shelf on the seafloor. The research and monitoring activities are needed to better understand impact of these human activities on the marine environment in order to develop targeted management measures to ensure their sustainability and the compliance with the current environmental legislation and international agreements. This is also a requisite to support the development of a blue growth based economy.

Geographical specificities on multiple stressors

Due to the climate change and the development of human activities, great changes are expected in several seas and European countries should be directly involved in initiatives to address these major changes. This is of particular importance for the Mediterranean Sea as well as for Arctic and Southern Ocean. Such challenges will require coordinated approaches, and should be tackled at EU level to develop the knowledge needed for using the resources without jeopardizing the environment. Due to these imminent changes, particularly in the Arctic, it is necessary to conduct a comprehensive assessment of the current status of the marine environment in order to develop baselines for future assessments and development of management measures.

The same situation pertains to the deep sea – even at a larger scale than EU – because deep sea areas are now under increasing pressures of pollution, fisheries, exploitation of mineral and energy resources. This is all the more critical since relatively few is known deep sea, particularly regarding the potential resilience of the deep ecosystems, despite it is the largest area of the ocean

Response to emerging issues

JPI Oceans represents the ideal integrated “environment” to implement a new, sound knowledge-based and successful system to create effective lines to assail a large number of emerging issues in the marine system. JPI Oceans could provide an answer respond to any major disaster inside and outside the EU by coordinating requests and offers for assistance between 30 participating states: the EU 27 and the three European Economic Area (EEA) countries. This could be done through the establishment of an international board composed by experts, coordinated by JPI Oceans, that should provide sound knowledge for timely and successful decision-making and risk management assessment for emerging issues at sea.

AREA 2.3. RESEARCH TO SUPPORT THE SUSTAINABLE MANAGEMENT OF HUMAN ACTIVITIES AND MINIMISE THEIR IMPACT ON COASTAL AND MARINE ECOSYSTEMS

TOPIC: 2.3.1 VALUATION OF ECOSYSTEMS GOOD AND SERVICES, ASSESSMENT OF SOCIOECONOMIC IMPACT OF HUMAN ACTIVITIES ON THE MARINE ENVIRONMENT AND DEVELOPMENT OF MEASURES TO SUPPORT A SUSTAINABLE MANAGEMENT

Identifying and valuating ecosystem good and services

Research on marine ecosystems good and services is poorly developed in Europe. Getting a real understanding of these goods and services and their environmental, economic and social value is fundamental to integrate these concepts into management , advance towards the ecosystems-based approach and develop a sustainable maritime economy, while ensuring the good environmental status of the marine environment (GES).

Therefore more research is needed to understand and ensure the delivery of ecosystem goods and services (e.g. services provided by marine biodiversity) and the impacts caused by human activities on them to assess the consequences of ecosystem changes for the economy and the society. Research activities in this area should pay especial attention to the coastal areas and vulnerable areas. This knowledge will also support the marine planning and protection of marine resources and biodiversity (e.g. through the designation and management of marine protected areas including protection of coastal sites), and it is the basis for a comprehensive valuation of marine ecosystem good and services. The development of case studies on particular areas and activities should be considered. One of the major barriers to assess impacts is the uncertainty related to human impacts due to the existence of important knowledge gaps. This call for putting in place a framework to deal with uncertainty of impacts related to human activities.

In general there is insufficient knowledge of the social and economic value of ecosystems and biodiversity. We need to know qualitativelyand quantitatively the marine and coastal ecosystem services in a context of global change. With this aim we need to develop methods of economical valuation of biodiversity good and services and other coastal and marine good and services to provide tools for a proper preservation and protection measures. Mechanisms for pricing environmental issues and define common sustainability criteria need to be developed.

Developing knowledge to support of policies and management measures[2]

One of the most pressing issues over the next decades will be to ensure that all human activities are carried out (managed) in a sustainable way. More multidisciplinary and cross-sectoral research involving science, technology, service providers, industries, policy makers and society is needed to develop sound knowledge to understand the risks and environmental impacts of different economic uses of the sea (e.g. shipping, fisheries, aquaculture, tourism, marine structures, energy production, exploitation of minerals, etc) and other pressures (e.g. pollution from land sources) on the marine environment. This should include the development of models to assess impacts of different technological methods of fishing, shipping or exploitation. Also the development of methods for sustainable use of marine resources will be needed to design and implement appropriate marine and maritime governances, including the development reliable mitigation and remediation plans at local/regional scale and the implementation of marine environment protection directives. The objective is to make compatible the use of marine services and resources with a good environmental status of the marine environment. Appropriate governance system will need to integrate scientific, socio-economic and political actions towards the sustainable use of the coastal and marine ecosystem good and services, including marine biodiversity. We also need to assess the economic cost of increasing ecosystems vulnerability. For instance, in the case of fisheries we need to integrate available knowledge concerning the impact of fishery activities on fish stocks and on the loss of biodiversity in European seas, and their socio- and bio-economic cost/benefit.

It is necessary to develop ecosystem metrics and indicator frameworks to support management through the development of new knowledge and also to develop decision support systems to sustain and increase ecosystem benefits. More research is also needed to develop new management framework that incorporates new principles in the utilisation of resources to measure and mitigate

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[2] MSP and ICZM are essential tools for the implementation of the ecosystem based approach and to minimise the impacts on the marine environment, thereby these tools are particularly relevant for this topic. Nevertheless, the needs related to MSP and ICZM have already been addressed through topic 2.3.2 , thereby they have not been considered in the present topic. Likewise the designation of marine protected areas (MPAs) as a tool to protect marine biodiversity and habitats has been addressed through topic 2.1.2 Nevertheless some management aspects of MPAs that are considered within the present topic. In the same way, the issues on fisheries management that have been considered under topic 2.3.3 , though some aspects are also considered within this topic.

impacts on ecosystem (e.g. result-based management to maximise output of product and services and ensure internalisation of costs in production).

The products and activities that cause the least negative environmental impact should be promote through policies, regulations and market prices. But currently there is not enough knowledge to consider environmental performance of maritime activities a parameter for profitability and further. Moreover, there is no mechanisms in the market economy to ensure that the maritime products and activities with the lowest environmental impacts are preferred by consumers. Targeted research to understand key ecological and biological processes that can be used to establish indicators for economical sustainability should be developed. In the case of marine bioresources, research for a sound based estimation of maximum sustainable yield of biological resource, both for fisheries and bioresources with potential use at genetic level, is needed. Nevertheless, in the case of fisheries there still knowledge gaps in order to apply the MSY concept in some cases (e.g. mixed fisheries) (see topic 2.3.3). Development of materials and technologies with reduced environmental impact will be needed, together with the diffusion of practices/technologies to ensure sustainability of human activities (e.g. in fisheries, maritime transport, etc).

On the other hand, the management of human activities is currently based on administrative borders and local coastal management is often limited to narrow administrative borders, causing duplication and fragmentation within the same ecosystem. It is necessary to change this approach and define geographical borders for ecosystems and develop optimal knowledge based management strategies to enable efficient resources. The development of more holistic ecosystem based management systems, focussed on maintaining the bearing capacity of marine resources, is a priority, This holistic approach is also needed when addressing local or sectoral issues. For instance in the decommissioning of oil and gas platforms environmental aspects such as impacts on habitats, MPAs, etc should be considered.

As to management, one of the problems in many countries is that the marine environmental remits are spread between different ministries – In relation this JPI Oceans could help facilitate national integration.by bringing national authorities together by creating a forum for them to provide input and feedback to JPI activities.

The network architecture of marine protected areas requires the development new knowledge on connectivity of marine systems and integrate this knowledge in the implementation of management measures. In addition there are several questions related to management of MPAs that need to be answered, such as: What will be the effect of fisheries measures in marine protected areas at the EU scale? What is the impact of MPAs on fisheries resources? or What is the full impact of marine renewable infrastructure on protected areas.? Marine landscape ecology should be develop to address how the spatial organization of habitat (size, diversity, degree of fragmentation, etc.) influences the dynamics of marine communities and meta-communities.

Ecosystem approach and marine-socieconomic modeling as a basis for sustainale management

In order to optimise operations and minimise its environmental impact in a long term perspective it is necessary to understand the ecosystem and the human activities as part of the ecosystems , taking into account environmental effects on a local, regional and global scale, The ecosystem approach to the management of marine activities, including the development of technological innovative approaches, is fundamental to support the sustainable use of resources. However many knowledge gaps on ecosystem functioning, human activities and their impacts need to be overcome to improve our understanding to apply this holistic approach to management, keeping also in mind that we need to consider diversity and complexity of marine habitats (including benthic and open sea habitats) and biodiversity good and services when applying the ecosystem approach. More research is also needed to understand human pressures and their impacts on the marine environment, including the cumulative impacts of multiple stressors.

It is necessary to develop fully coupled ecosystem and resource utilisation models with realistic environmental and human forcings, accommodating natural and human feedback and enhanced modelling by applying state of the art data assimilation techniques. These models are needed to assess the effects of different management options. Such models can be used to increase general knowledge of the systems, and serve as tools in ecosystem based approach to resource management and mitigation efforts. More data (including effective use and management) and new tools for visualisation and pathway analysis are needed to enhance models.

Further research is also needed to assess the socio-economic and environmental effects of policies and management options, through the development of scenarios and forecasting. Environmental optimisation models need to be connected to economical models, where long term scenarios are the basis for the development of decision criteria. Models should be able to evaluate in an space base approach, different scenarios from using or managing marine resources, taking into account the socioeconomic and environmental aspects. There is also a need of multi-disciplinary knowledge and models to evaluate risks, opportunities, costs and benefits linked to adaptation and mitigation pathways Foresight and scenario development should be focused on key marine areas, with bio-physical drivers and pressures, and socio-economical and societal/behavioural impacts and choices.

The development of marine socio-economic models need to be interlinked and bring in policy needs boundary areas, sensitivities, and they also need more data. They require a multidisciplinary approach bringing together marine scientist from different disciplines and socioeconomist in a joint research area to break the "cultural" gap between natural and human sciences by defining a common language and combining environmental and socioeconomic date. JPI Oceans could take the initiative to instigate mechanisms that would facilitate communication on a semi-formal basis; i.e. the development of a communication plan and framework. Improving the linkages between different scientific disciplines (natural sciences and socio/economical sciences) will contribute to develop suitable tools for integrated policy evaluation which will improve the ability of decision-making to take account of the important interactions between humans and marine ecosystems. On the other hand, there is a need for a new generation of inter-disciplinary scientists with deep knowledge on both natural and socio-economic sciences.

Data and monitoring needs

A major barrier for socioeconomic assessment and the development of models is the lack of socioeconomic data and the difficulty to access to the existing data which prevents the development of socioeconomic scenarios. Moreover, there is no system in place to map and collect socio-economic data at EU level. Putting in place suitable monitoring and observation systems to get the environmental, biological and socio-economic data needed for the implementation of EU policies and the sustainable management of human activities is a priority.

In relation to monitoring, it is important to decide on common socio-economic and environmental challenges which impact the oceans and coastal areas and how they should be monitored; the key parameters to be measured,;how they should be measured; and how to store and disseminate the data. More effort is needed to develop baseline data (physical, biological and socioeconomic) in order to monitor changes and understand the delivery of ecosystem goods and services, More data are also needed in the deep sea, particularly in areas than can be impacted by human activities in order to developed a sound management for the use of deep sea resources. Also stronger automation and new techniques, a more integrated approach towards the understanding and management of the marine environment can are necessary to improve current baselines and fill the gaps.

Compilation of ”big data” from monitoring efforts can lead to advanced model developments for ecosystems and resource uses (living resources, energy and transport). But access to data is currently a major barrier to improve models and knowedge. This also concerns the regulations governing data holders which are different across different countries. Effective use of existing data and rationalisation of future data collection must be promoted.

One the barriers to protect the environment is the insufficient involvement of "industry" in the concerns and practices of preserving ecosystems and marine resources. The development of Knowledge base cooperative management requires the contribution of different sectors. The involvement of industry in joint monitoring actions with authorities and research institutes needs to be promoted to build an industry, academia and government cross sector vision of a shared data collection, management and information infrastructure.

In addition, to improve the stewardship of natural resources it is necessary to proactively translate knowledge, based on an ecosystem approach. JPI Oceans could outreach to industry the outcomes of research to ensure that marine resources are exploited sustainably.

Regional aspects of management and specificities

The Marine Strategy Framework Directive (MSFD) and the Commom Fisheries Policy (CFP) require sea basin/regional management. Also human and climate change impacts on ecosystems vary between sea basins. Resource exploitation needs the best available evidence and information on the natural living and non-living resources at a regional scale so that economic gains can be maximised and environmental impact minimised. For this purpose data (regional scale data) need to be made available and information must be shared (physical, biological, chemical, hydrological, social and economic).

On the other hand to implement the ecosystem approach to the management of maritime activities on regional scales it is necessary to improve the structures for adaptive governance and management. These require suitable and effective information-providing mechanisms which largely depend on adequate monitoring tools and assessments. Also interactions between top-down and bottom-up governance and management systems should be better understood. Research into development of predictive and adaptive ecosystem and socioeconomic models ,together with new governance structures based on decentralized results based management principles may improve an increased yet ecologically, economically and socially sustainable use of resources.

There is a need for regional adaptation concept and the development of regional vulnerability analysis. For instance in the Arctic the economic planning is progressing faster than our scientific knowledge on ecosystems and impacts and decisions are taken without a sound knowledge base for management. It is necessary to develop baselines for the environment and scenarios of maritime economy in the Arctic , but also in the Southern Ocean, supported by research programmes, targeted to investigate critical issues for sustainable economic development . It is also necessary a closer cooperation between science and maritime economies to minimise the impact human activities in the Arctic Ocean. On the other hand, the status of Mediterranean Sea should also be regarded as a top priority due to the rapid changes that this basin is suffering due to combined environmental pressures (resources exploitation, natural hazards, impacts of climate change etc.) which require a coordinated multidisciplinary research effort.

As to fisheries, management is particularly difficult in some sea basins. This is the case of the Mediterranean where due to the scarcity of data available for many stocks and also to the fact that many fisheries in the Mediterranean are mixed fisheries, thereby the maximum sustainable yield (MSY) concept can not be applied directly and needs of additional considerations. In the field of aquaculture there are regional specificities to support the growth and environmental sustainability of aquaculture due to the differences in species and in environmental conditions and pressures between basins.

TOPIC 2.3.2. MARINE SPATIAL PLANNING (MSP) AND INTEGRATED COASTAL ZONE MANAGEMENT (ICZM)

Frameworks and tools to handle increasing demand of space

There is an increased demand and competition for the use of the maritime space and marine resources between the many stakeholders that use the ocean for commercial purposes. This calls for the implementation of innovative approach to management to align the interests of economic development and protect the environment, so as to avoid the environmental degradation and conflicts of interest between the different sectors. It is necessary to set up new frameworks for management that can couple the ecosystem and the resource utilisation models in order to assess the effects of the different management choices. This requires the development of tools to implement marine spatial planning (MSP) to make compatible the use of space and resources with the protection of the environment. These maritime spatial planning tools need to consider mobility of human activities as a part of the management system and should have threefold flexibility to be effective: flexibility in time, space and policy.

On the other hand the consequences of climate change for the planning of maritime activities are unknown. It is necessary to assess the risks and the potential climate change induced losses/gains, and generate strategies and adaptation options.

Planning and sustainable management of coastal regions

Coastal areas are increasingly confronted with challenges linked to urbanization, economic development, tourism, maritime activities, climate change and subsidence. Sustainable management of the coastal areas and resources requires and integrated ecosystem-based management. One goal for coastal science is to contribute to a shift from a precaution approach to a more knowledge based management of the coastal zone, linking marine research with the land-use research and the urbanization research.

Sustainable management of the coastal areas and coastal resources needs the development of cross-disciplinary research and practical management tools. It also requires the development of a common framework and reality model (architecture) and the use of MSP methodology for integrated coastal zone development and management. In addition, understanding short and longer-term environmental changes and impacts caused by intense coastal and maritime industrial development is needed to develop mitigation and remediation strategies.

To avoid complexity and delays in the planning processes and management of the marine and maritime areas it will be necessary to develop and implement a more articulate governance model by integrating sectoral policies on coastal and marine areas and provide a legal framework for planning and practical management tools. The coordination of existing existing plans (e.g. civil protection and coastal marine contingency) will also be necessary.

One of the challenges is to integrate and make widely accessible the scientific results and knowledge, disseminate good practices and analyse socio-cultural hindrances for utilizing this knowledge. The engagement and the dialogue with stakeholders from different sectors and coastal communities, including local authorities is needed. Tools are also necessary to bridge the gap between science and policy making in order to develop a common language to be used by scientist and politicians involved in ICZM and MSP and also users. The development platforms and sharing of technological resources are also important tools to this end.

Enhancing our understanding of pressures to improve spatial planning and coastal management

In order to develop integrated management measures in the coastal zone and the planning of the maritime space it is necessary improve our understanding of the interactions at the interface between marine ecosystems and human activities. In particular it is necessary to address the impact of human activities on coastal areas (including estuaries, the littoral zone, and near-shore waters), such as physical degradation of coastal areas due to climate changes and increased human pressures from different maritime activities (e.g tourism, aquaculture, fishing, shipping etc), industrialisation (e.g. infrastructures and installations on the sea shore, on the sea floor and on the continental shelf-including potential impacts from accidents) and urbanization. In addition we need to better understand the pressures and impacts from land sources on the coastal environment (e.g. chemical pollution, eutrophication, litter, coastal infrastructures, etc). Research is also needed to better integrate sectoral activities and address the impact of different activities from a holistic perspective.

This also requires better knowledge of the ecosystems and their dynamic in the coastal zone, including marine habitats structuration, biodiversity, land-sea interactions and coastal-open sea exchanges and proceses. It is also necessary to assess the ecological risks and consequences of industrial and economic development in a long time perspective as well as the consequences of the impacts on the economy, jobs and nearby coastal societies and the implications for management.

In order to ensure the sustainable use of marine good and services and develop mitigation measures we need a profound and detailed understanding the individual and combined effects of climate change and human pressures on the marine and coastal ecosystems functioning and biodiversity, at sub-regional and local scale in order to devise mitigation and adaptation plans.

Monitoring, data needs and modelling to support coastal management and planning of activities

A concerted effort between Member States is needed to be developed a maritime spatial planning (MSP) strategy and spatial planning tools for the management of the increasing number of marine activities and the increasing pressures on the marine environment. This will also provide support to the implementation of the Marine Strategy Framework Directive (MSFD). Due to the important differences between sea basins in their environmental features and the pressures and impacts, such a strategy should be supported by a coherent regional (sea-basin) and local monitoring programmes under a pan-European framework.

The sound management of coastal areas and the planning of the marine space require suitable environmental and socioeconomic data. However, currently there are important data gaps that need to be covered, including processes and interactions in the coastal zone. Likewise there is insufficient knowledge of bathymetry, since most existing data have been collected to meet the requirements of navigation; the coverage and the quality is insufficient for proper MSP and ICZM. To this end more data from coastal observatories and measures to promote access to marine and maritime research platforms in coastal areas and off-shore (e.g. ships and associated equipment, aquaculture test facilities, ROVs, AUVs and other high-end deployable equipment) are needed. In addition to environmental data, socio-economic on human activities as well as the valuation of the coastal zones and their uses, and the value of ecosystem good and services that are going to be impacted are needed to support a sound planning and management of activities. In general, it is necessary to ensure that data cover the spatial and temporal needs to improve advice in relation to management, planning and carrying capacity, bringing the spatial and temporal resolution to meet user needs.

In order to assess the effect of the planning and management measures, models that are able to evaluate in a space base approach the social, economic and environmental effects of different scenarios of using marine resources are needed. To get the data to feed the models a permanent monitoring of development plans needs also to be developed together with the assessment of the effects on the coastal and marine environment. To this end it will be necessary to conduct monitoring of the targeted areas and develop improved and innovative observation and data management systems, including tools and methodologies to support marine information needs.

Another need is to gather the necessary information for the elaboration of a comprehensive and EU-wide database for ICZM and MSP (sharing environment integrated supporting system) founded on the outcomes of national studies, with detailed stocktaking of actors, drivers, environmental features, processes and likely outcomes. Scientific information should be summarize in indicators for ICZM (e.g. coastal atlas) and be also targeted to local policy makers and the public to address local problems..

It is necessary to build an EU-wide coastal mapping (joining the land and the sea) and develop precise mapping of habitats, pressures, impacts, environmental features, species distribution, including elements on ecosystem-anthropogenic interactions. The development of digital coastal models would be very useful to this end. This could be supported by promoting an ecology of marine landscapes and integrated modelisation of biotic and abiotic parameters and interdisciplinary studies of the new biome "littoral".

TOPIC: 2.3.3. RESEARCH TO SUPPORT THE SUSTAINABLE MANAGEMENT OF FISHERIES

Impacts of fisheries and management measures

Fisheries impacts on ecosystems remain as one of most relevant concerns within human pressures. The most pressing issues related to fisheries is to provide sound scientific knowledge for the management of fish stocks to ensure the long term sustainability of this activity, minimise the impact on the environment and allow the recovery of depleted fish stocks. The reform of the Common Fisheries Policy (CFP) aims to make fisheries more sustainable by adopting measures to avoid overfishing and minimising the impact of fisheries activities on the marine environment, by implementing an ecosystem based approach to the management of fisheries activities and fish stocks.

The effect of fisheries on the status of marine ecosystems, marine biodiversity and the dynamics of pelagic and demersal food webs needs to be better understood to provide scientific advice to support the CFP. On the other hand, the role of different biotic components of the marine ecosystem in sustaining fisheries is not well known. More research and development of models are needed to advance further on this field.

There are still important knowledge gaps on how fishing activities interact with and impact on marine ecosystems, from physical damage to biodiversity changes, and this requires to develop a knowledge grid of fishing impacts on ecosystems, including mapping of large scale habitat destruction (e.g. caused by trawling) and also to get information on the effects of different types of fishing gears on the environment and the living resources. Likewise it is important to improve the knowledge of the role of different exploited species in the ecosystem and also to know how fishing activities affect the connectivity between ecosystems (including vulnerable deep-sea ecosystems), and how impacts on a particular area may affect neighbouring ecosystems. This knowledge on impacts is also needed to develop of new approaches, technologies and devices to reduce the impact of fishing activities on the marine environment including by catches.

Evaluations of fisheries impacts do not usually consider negative effects of fishing on marine ecosystems and it is necessary to develop assessment models, monitoring programs and management framework that explicitly consider these impacts on marine habitats and communities, by integrating available knowledge concerning the impact on fish stocks and on the environment (e.g. on the loss of biodiversity and other environmental effects), and their socio- and bio-economic cost and benefit. We need also to consider spatial aspects in assessment and management procedures, for instance by considering spatial distribution of vital phases of commercial species and the spatial pattern of fishing effort in assessments. This should be supported by new models based on repartition of habitats, fishery resources and fishing impacts in space.

Policies and management measures have social, economic and environmental consequences, which need to be further investigated. The discard ban proposed by the new CFP might have important consequences on marine food webs and the behaviour of fishermen. Currently we do not understand well the effects of by-catch and discards on marine ecosystems and research will be needed to elucidate the effects of implementation of the discard band, including the socioeconomic consequences. In relation to the impact of management measures, it is also important to better assess the effect of fisheries management measures on marine protected area (MPAs), including the abundance of species and also evaluate the benefits for neighbouring areas and the economic impacts for the sector.

New models and data needs to support fisheries management

One of the objectives of the CFP is to achieve a maximum sustainable yield (MSY) of the exploited fish stocks. However, there are still important data and knowledge gaps to apply the MSY concept to the management of mixed fisheries, which is an important shortcoming for managing these fisheries in a sustainable way. Therefore, new knowledge and models to support the application of the concept of MSY are needed. On the other hand, scientific advice is currently provided on a stock-by-stock basis. Modelling to provide advice on multi-species on a sea-basin scale would be of greater use to fisheries managers, particularly in relation to data poor stocks. It is also necessary to assess alternative management strategies, such as balanced harvesting.

The ecosystem approach to management of fisheries needs to consider the social, economic and environmental factors equally, by integrating biological, economic and social knowledge to support advice for fisheries. This implies the development of management strategies that use environmental, social, and economic scientific advice and it will require the development of bio-economic and socio-economic fishery models.

A holistic understanding of the functioning of marine ecosystems is needed to apply the ecosystem based approach, which includes ecology, physiology and dynamics of commercial fish populations, as well as the integration of data and information on fish stocks with data and information on ecosystems (including food webs, species, physical features, etc). New and more reliable models integrating all these data need to be developed. However, there is not enough environmental data available to improve models, including data on species interaction and food webs, as well as additional data on other species that currently are not considered in fisheries modelling (e.g. jellyfish abundance and distribution). More data and improved knowledge need to be obtained to support the development of adaptive management systems based on ecosystem modelling at fishery appropriate scales.

Knowledge and data available on fish stock is often limited and in many cases data are very poor. The status of more than 65% of stocks is unknown, which makes fish stock assessment and fisheries management difficult. These data and knowledge gaps are more marked in some regions, such as the Mediterranean. Therefore, biological data on pelagic and demersal fish stocks needs to be improved, particularly for poor data stocks and regions where data are scarce. This requires increasing the frequency and geographical coverage of the current fishing surveys to obtain more information (such as biological parameters, abundance indices for commercial species and species composition of catches and by-catches) and to reduce the uncertainty in stock assessments, particularly for data poor stocks and also in regions where there are large data gaps.

In order to respond to the goals of the CFP and the MSFD there is a need for more environmental data. This could be achieved by collecting more relevant environmental data relevant through fisheries research surveys and also through fishing vessels. This is an area where there are substantial opportunities to do things more efficiently, both to collect and use the data. One of the most urgent needs is to provide access to and share data, in a coherent and transparent form, to advance in the development of knowledge and the improvement of models on which fisheries management decisions are based.

Currently the socioeconomic data are very scarce and patchy and there is no a system in place to collect , harmonize and manage these data. This information is needed to support the development of bioeconomic and socio-economic fishery models to provide scientific advice. In order to take into account the socioeconomic aspects of fisheries, it is necessary to compile information on fisheries activities and the related socio economic aspects and impacts. Compliance devices (CCTV, e-logbooks and VMS , provide technologies which give real-time data and have the potential to be much more revealing as to what is caught where and when.

The effect of regime shifts and environmental variability on fish stocks

There is a great uncertainty on the possible effects of climate change on fisheries and the economic impact on coastal populations depending on this sector. Climate change can trigger regime changes that could affect the dynamics of fish stocks. However, currently there is not enough knowledge to discern between the effect of climate change and the effect of human activities on the fluctuations of fish stocks. These knowledge gaps need to be overcome in order to implement sound fisheries management measures. It has already been observed that some stocks have moved northwards and this has created political tension between some countries and the EU relating to catch quotas. Changes in fish stocks distribution and abundance as a consequence of climate change will require expanded knowledge to establish new systems of allocation for widely distributed stocks under changing distribution and develop models to assess the consequences of alternative fisheries management objectives and strategies. JPI Oceans may have a role in providing support to develop new knowledge in this area. Moreover, this knowledge will allow a move from passive fishery management to an adaptive one. This should be based on real time monitoring of physical drivers, as well as on information on resource abundances and human pressures in order to adequately assess fishery catches, stock sizes and population structures.

In addtion, it is necessary to conduct research on the consequences of regime shifts for species abundance and food web interactions and map these changes, including the development of ecosystem models to disentangle the effects of climate change from those due to fisheries exploitation, and to assess the economic impact of climate change on the fisheries sector. Long term research is needed in this field to elucidate the direct and indirect effects of climate change on fish ecology, physiology and population's dynamics.

Environmental data are key to develop accurate modelling of fish stocks. Therefore it is extremely important to ensure that data collected capture the dynamics of ecosystems at the appropriate spatial and temporal scales needed. In relation to this, the strong interannual variability of highly dynamic ecosystems, such as up-welling systems largely influence by climate conditions, may add difficulties and uncertainty to models predictions and consequently to fisheries management.

Regional specificities on fisheries research in support of management

Adaptive management systems based on ecosystem modelling at fishery appropriate scales have to be develop to support the regionalization of fisheries management. A regional approach to policies, such as fisheries, means a wider variety of management approaches; it is therefore important that scientists and stakeholders understand these policies.

The management of fisheries is difficult in some sea basins, such as the Mediterranean, mainly due to the scarcity of data on many fish stocks (e.g. biology and population dynamics, abundance and distribution of species). Moreover many fisheries in the Mediterranean are mixed, thereby the MSY concept is difficult to apply. It is also necessary to consider the structure of spawning stock in the existing models and management approaches applied in the Mediterranean in order to estimate renewal capability of exploited stocks. Research should be conducted to support management measures to enhance the diversity of the age class structure of spawners in order to increase the stock capability to buffer unfavourable climatic conditions. This requires improved knowledge on distribution, size class spatial structure of spawners and habitats where mature and highly productive spawners are concentrated.

The importance of small scale fisheries for the coastal economies has not been duly considered by the research projects conducted under the framework programme. Likewise data on artisanal fisheries and sports fishing are scarce, including biological data, effort, catch by species and gear, and by-catches. Artisanal and small-scale fisheries are particularly important in Europe for coastal communities and play an important role in the society, especially in some sea basins. It is necessary to strengthen the research in this field to cover knowledge gaps and assess the biological, economic and social situation of locally dependent fisheries, providing options for local management measures to ensure the sustainable use of stocks, while contributing to the good environmental status (GES) of the marine environment

Moreover, enhanced cooperation is needed at regional level to improve the coordination and planning of fisheries surveys in order to avoid duplication and conduct fisheries monitoring more cost efficiently. There is also a need for calibration and standardization of methods used in regional fisheries surveys (e.g. calibration of trawling gears between research vessels).

3.3 GOAL 3: CLIMATE CHANGE IMPACTS ON THE MARINE ENVIRONMENT

AREA 3.1 IMPACTS OF CLIMATE CHANGE AND OCEAN ACIDIFICATION ON THE MARINE ENVIRONMENT

TOPIC 3.1.1. IMPACT OF CLIMATE CHANGE ON THE FUNCTIONING OF MARINE ECOSYSTEMS, BIODIVERSITY AND ORGANISMS: PAST, PRESENT AND FUTURE PERSPECTIVES

Better understanding the role climate change in changing ecosystems

Global warming and sea level rise are expected to be the hot spots for the next 20-30 years. The current knowledge on the effects of climate change on marine ecosystems is insufficient and there still are also important knowledge gaps on the impacts on the carbon cycle, other biogeochemical cycles, pelagic food webs and on the ecology, biology and population dynamics of pelagic marine organisms and ecosystems. The global nature of climate change calls for strengthening the cooperation with international partners (such as ICES and IOC).

Climate change has the potential to impact ecosystems at all levels. From a scientific perspective we need to improve the current knowledge on climate change and how it will affect marine ecosystems, this fundamental knowledge will also serve as a basis to develop adaptation measures to minimise the impacts. Small natural changes caused by climate change are basically unknown and the cumulative effect of these small changes (like recruitment period, effects on bacterial populations, etc.) might be catastrophic. To this end it is necessary to advance in the research of the impact of climate change on biogeochemical processes, pelagic food webs interactions and on the ecology, biology and population dynamics of pelagic marine organisms, including changes in productivity. In addition it is necessary to assess the effects of climate change on complex biological interactions in the marine environment, such the interactions between parasite/pathogens with their host and also the effects on symbiosis phenomena in order to match/mismatch productivity issues and symbiosis in a climate change.

We do not have sufficient knowledge about the vulnerability and capacity for adaptation of marine species to climate change at all levels of biological organisation, from cells to ecosystems. It is necessary to advance in the understanding of resilience and vulnerability of ecosystem components to climate change and improve the knowledge about the vulnerability of species, habitats and ecological processes. Likewise, research is needed to understand changes in migration of organisms due to global warming (including reduced ice sheet, ocean acidification, circulation and seasonality changes), and the spreading of non-indigenous species by examining the relationship between climate change and invasive species.

On the other hand, the current knowledge on the genetic and epigenetic consequences of climate changes for economically important species is very limited. In particular, epigenetic mechanisms, and later biological functioning, can be affected by changes in the environment. We must integrate fundamental regulatory ecophysiology with climate change research to understand how organisms adapt to climate change. This will require experimentation within expected thresholds for future climate change scenarios, the use genetic tools, and the combined use of numerical models with experimental and field research.

Coastal areas, including continental margins, are the most productive areas of the ocean being extremely important to the feeding, reproduction and spawning of many marine species. They also hold a rich biodiversity and provide vary valuable good and services to humankind. However, these areas are among the most threatened by the possible effects of climate change, such as sea level rise, increasing incidence of floods and storm surges, saltwater intrusion, etc Thus we need to develop extensive research to better understand the impact of climate change on coastal and marine ecosystems, their components, and the biodiversity sensitivity, at sub-regional and local scale in order to assess impacts, quantify the risk and develop early warning systems to implement mitigation and adaptation plans.

Field research on climate change and its effects on marin ecosystems needs to be completemented with agreed experimental approaches that address the multifactorial nature of climate change, so as to improve the understanding of effects on ecosystems. This knowledgee will also serve as basis for the sustainable management of resources.

Base lines and models to disentangle the effects of climate change from other drivers

A basic requirement to understand, assess and predict with better accuracy the impact of climate changes on marine ecosystems is to develop the capacity to separate the inherent natural variability of the system from anthropogenic signals. More coordinated research efforts are needed in this field to disentangle the impact of climate change from other drivers, both natural and anthropogenic, on ecosystem structure and functioning. To this end it will be necessary to establish a rigorous baselines of natural variability for ecological indicators of climate change in selected European coastal and open sea areas. Define “essential environmental ocean variables” (EEOV) and associated intercalibration and standardization procedures

It will also be necessary to improve the knowledge on climate change/impact and interactions with other ecosystem drivers. In particular a meta-analysis of long-term ecosystem variability and its relationship to climate and anthropogenic forcing will be needes, as well as targeted studies to understand if species composition, migrations of fish or other organisms is a consequence of climate, more local pressures (such as exploitation) or both. This will also serve as fundamental knowledge for the management of resources.

New models of the biogeochemical state of the ocean are also needed in order to understand the impact of climate change on biogeochemical cycles and processes such as ocean deoxygenation in the context of climate change. This will require concerted analyses of long-term physico-chemical and biological ecosystem variability using all available time-series data across Europe. The use of models for the analysis of climate related effects upon marine life, based on best available scenarios for climate change, will be an important starting point.

Development of models are also needed to understand better the synergies between climate change and human pressures and the combined impacts. For instance in the case of invasive species predictive models are needed to assess the interactive effects of climate change and increased global shipping and transport on the distribution of native and non-indigenous species.

Understanding past environmental changes in conection to climate variability

The lack of long records of background variability in the marine environment preceding the use of instrumental measurement makes difficult to determine whether changes are the result of human activity or are consistent with natural variability. The use of real world data from periods before the widespread availability of instrumental records will help to constrain the range of model predictions by excluding 'impossible' trajectories from the ensemble. It will also help to distinguish the natural background level of marine environmental variability, enabling a robust assessment of the degree of human impact. This will require to map written records on climate variability, interpreting the archaeological register and look into geophysical evidence.

Understanding of how and why climate has changed throughout Earth's history, on timescales ranging from decades to millions of years, will help understand future scenarios of climate change. In order to understand how periods of past warming have influenced ocean productivity and predict how climate change will affect the marine environment in longer time scales, it is necessary the development of multidisciplinary scientific studies about past climate, oceanography and marine ecology , integrating historical and paleo data, ocean observing and forecasting systems to provide better indicators of past, current and future environmental status. This needs to be supported by increased observational capacity of the present and the past oceans including long sediment coring and alternative platforms (e.g. shells) are necessary to cover key gaps in our knowledge of ocean response to climate change and its environmental impacts.

Regional dimension of climate change and monitoring needs

Although climate change is global process, the responses of seas and oceans to climate change are regional and therefore its impacts on ecosystems may differ between regions. Thus some geographical areas are more sensitive than others to climate change. In particular the polar oceans and semi-enclosed sea basins, such as the Mediterranean Sea, appear to be more sensitive to climate change than other regions. Climate change effects also present different across the OSPAR areas, with higher increase in temperature and acidification occurring in northern areas (Regions I and II) in comparison to the southern areas (Regions IV and V). The differences in climate change impacts between regions imply a need to understand better the potential climate change impacts at both the regional and local level, as well as the risk of so-called 'tipping points' being reached in different regions.

In fact polar seas and other vulnerable regions are unravelling rapid changes triggered by climate change. The Arctic and Southern Ocean represent an opportunity to study, under rather pristine conditions, changes that can be considered as "geological" by nature despite occurring at a "human" temporal scale. In order to understand and quantify these changes a coordinated effort is needed to map the marine environment in the Arctic and other vulnerable European seas, such as the Mediterranean, where important impacts are expected in the coming decades, to assess the current status, identify emerging problems and develop baselines for future studies. Thus in these areas it is necessary to support more research to understand and quantify their oceanographic characteristics (including currents and water mass formation), sea ice cover (extend and thickness), ecosystems functioning (including seabed) and biodiversity (including species shifts and species richness) under rather pristine conditions.

We also need to better understand and predict the physical, biogeochemical and biological response at subregional or local level, for instance it the changes in the European Eastern Atlantic Margin caused by global environmental change should be moniored. Likewise impact of climate change on biodiversity and habitats (i.e. coral reefs) in the overseas territories need to be further understood.

This requires coordinate regional cooperation between Member States and the development of regional monitoring strategies. Also cooperation in monitoring with third countries and partner organizations is needed to address climate change sea related issues at basin level (e.g. cooperation with USA and Canada in the observation of the North Atlantic).The great achievement to be made by JPI Oceans would be to ensure geographical integration from sea basin strategies towards the consolidation of an EU strategy, address long-term monitoring needs and implement tools in place properly chosen around Europe for the long-think .

Monitoring efforts need to be strengthened in sensitive and under-sampled areas/regions to cover current data gaps and to track relevant climate change related processes. This is the case for the Arctic, the Mediterranean and the Black Sea where development of new knowledge and information services is hampered by the lack of systematic and comprehensive in-situ observations. There is a need to establish long-term monitoring programs and observing systems to be integrated in a global European monitoring network to observe changes in essential climate and biological variables. The aim is to ascertain the impact of climate change in the marine ecosystems with high spatio-temporal resolution, at sub regional and local scales, in a variety of European coastal, open sea waters and straits. Monitoring of straits (e.g. Gibraltar) is also key to understand exchanges at sea basin level in salt and water balance and changes produce by climate change in these basins.

But today we lack a budget line to fund monitoring activities and equipment. This call for improving the coordination of existing monitoring infrastructures and programmes at regional level and developing joint databases. We also need to identify selected locations to establish reference monitoring sites to track relevant climate change related processes, define the suitable ecological indicators of climate change at regional level as well as to check specific objectives and protocols for monitoring.

TOPIC 3.1.2. EFFECTS OF OCEAN ACIDIFICATION ON MARINE ECOSYSTEMS: SYNERGIES WITH GLOBAL WARMING AND OTHER STRESSORS

Impacts of ocean acidification on marine ecosystems

The health of marine ecosystems, their habitats, the marine biodiversity and the populations of marine organisms are seriously threaten by climate change, ocean acidification and the pressures of human activities. In particular ocean acidification is considered one of the most pressing issues in a 20-30 years perspective.

The accelerated increase of greenhouse gas emissions in the atmosphere is causing changes (with unknown effects) in the chemical composition of the seas and oceans. The extent and effects of ocean acidification (both CO_2 and on regional scale SOx and NO_X) are unknown. The pressures and impacts of acidification on marine ecosystems will increase in the future, since CO_2 emissions into the atmosphere are expected to continue.

It is necessary to develop further research to understand the possible impact of negative emissions on the chemistry of the marine environment and on the different components of marine ecosystems. Currently there are important knowledge gaps on the consequences of ocean acidification on the functioning of ecosystems, on marine organisms and processes (e.g primary production and food webs). It is necessary to conduct field and experimental research to know how species, particularly phytoplankton and other species from low trophic levels, react to increased acidification. A pH decrease could affect the survival of calcifying organisms and reduce their competitive advantage over non-calcifying species.

The changes observed in ocean acidification over the last decades have no precedents on Earth's history, therefore we do not have historical tracks to predict changes in ecosystems caused by such rapid changes in the pH of seawater. It is necessary to increase research efforts to assess ocean acidification on the whole ecosystem, including the resilience of ecosystems and feedbacks. To conduct such ecosystem assessment requires multidisciplinary efforts among biologists, physicists, chemists, experimentalists and modellers. But at the same time we need to understand the effects of acidification on biodiversity and how the different organisms will adapt or acclimate to these changes. To respond to these questions it is necessary to conduct research on the sensitivity and tolerance of species to acidification and assess the impacts, including the potential effects on the distribution of marine organisms in response of changes in pH.

It is important to communicate to policy makers key issues and figures, such as CO_2 crossing the 400ppm threshold in the atmosphere, to ensure these issues are at the forefront of government decision making and increase the awareness for ocean-related climate change and ocean acidification in the general public. Encouraging information sharing and new ways of working internationally on common themes- e.g. ocean acidification is equally important.

Synergies with global warming and other stressors

The combined effects of warming of the ocean and acidification are completely unknown. More research are needed to ascertain the possible interactions between these pressures and the impacts on marine ecosystems (pelagic and benthic), including biogeochemical processes. This scientific knowledge is also needed to provide base knowledge to inform policy makers on management options to adapt to the impacts of climate change.

In order to assess the combined impact of climate change and acidification it is also necessary to understand natural variability and separate this variability from changes caused by climate change and ocean acidification (e.g. species composition, change in migrations patterns of fish or other organisms). It is also necessary to disentangle the impact caused by human activities from those caused by acidification and warming. This knowledge is essential for the adoption of management measures of human activities and adaptation acidification and climate change.

Oceans play a key role in regulating Earth's climate. However ocean acidification and warming may have major consequences on this role played by oceans, though we do not understand well the possible effects and feed backs. Therefore, it is necessary to enhance the knowledge on the role of the ocean acidification on ocean processes (physical, chemical and biological) in regulating the Earth's climate and its responses to a high CO_2 world (including the carbon cycle, deoxygenation and other biogeochemical cycles of key elements), with better knowledge of the associated consequences and uncertainties based on evidence from long-term, quality-controlled datasets and process-based understanding.

In particular further efforts are needed in research to understand changes in biogeochemical cycles, such as potential future dimethyl sulphide (DMS) changes as a results of ocean acidification and climate change and into gaining a consensus regarding the expected trends in DMS derived from marine organisms. This requires field and lab studies of DMS-producing organisms and the changes in behavior and population sizes that would most likely result from warming and acidification. Long-term monitoring programs and facilities, field assessments, as well as lab and mesocosms studies of species and assemblages under stress are needed to get deeper insights and make advances in this field.

Climate change and ocean acidification are also threatening deep sea vulnerable ecosystems and MPAs. However it is still not well understood how these pressures are affecting benthic ecosystems and their biodiversity. Thus it is necessary to assess the impact of climate change and ocean acidification on deep sea ecosystems, their biodiversity and the goods and services they provide in order to develop suitable management measures, including measures for MPAs.

To gain a greater understanding of the long-term impacts of ocean acidification and warming on marine species and ecosystems it is also necessary to look at the interactions with other stressors such as increased pollution. Specifically we need to know how pervasive exposure to the stressors affects individual species over the course of several generations, and the wider dynamics of marine ecosystems.

Currently there is a poor integration of monitoring and observational technology with experimental research on climate change and acidification effects. More research combining experimental work, field studies and modelling is needed to elucidate the potential synergies of acidification and ocean warming on marine ecosystems.

Modelling, forecasting and rising awareness on ocean acidification and its impacts

We do not have the necessary basic understanding on all processes and the effects of acidification and warming, nor modelling tolls to needed to respond to all the challenges pose by acidification and warming. This is a major problem to provide reliable forecast. In fact, scientists are still trying to understand the signal-to-noise relationship in ocean acidification, therefore data cannot be used to provide policy advice yet. On the other hand the current climate models are not able to make accurate predictions and there is a high degree of uncertainty. It is extremely important to improve methods and models to reduce the uncertainty of projections in regional seas on the carbon cycle (the efficiency of the biological and physical pump and the impact on the acidification).

We also need to better predict and understand the socio-economic impact of acidification on maritime activities and coastal areas in order to devise adaptation measures to minimise the risks and costs. For instance we do not understand how climate change and ocean acidification will affect the ecology, physiology and population dynamics of fish, and the consequent economic impact on the aquaculture and fisheries sector and on coastal economies depending on fisheries. There is a lack of knowledge about the effects of acidification of the oceans on species, especially on reproduction and early life stages. Increased experimental studies of the effects of acidification on key marine species can help advance in this field. Likewise, we do not really know which are going to be the impacts, costs and potential benefits of the combine effect of climate change and acidification on marine aquaculture (e.g. faster growth rates due to rising temperatures versus slower growth rates caused by acidification), . Therefore it is necessary to conduct research on the potential impact of climate change and ocean acidification on this sector and develop knowledge needed to support advice and management measures to adapt to changes caused by combined effects of acidification and and climate change.

Regional specifities

Ocean acidification is a global process, but there are differences in the impacts at regional or local level and some regions are more sensitive than others The nature, rate and impacts of acidification and climate change differ across regions. For instance the increase in temperature and acidification will be higher in northern areas of OSPAR than in the southern ones. In the case of the Arctic threats to biodiversity are imminent with sea-ice loss profoundly affecting ice-associated marine life, and projected rates of acidification suggesting adverse ecosystem impacts within the next decade. We need to understand impacts of ocean acidification at regional level and make a realistic assessment of the local response, the impact on biodiversity and enhance knowledge about the vulnerability of species, habitats and ecological processes and their interaction with pressures from human activities, as well as assess the risk of so-called ‘tipping points’ being reached. A coordinated effort is needed to assess the current status of the Arctic and other vulnerable regional European seas (e.g Mediterranean) in relation to acidification in order to understand the processes and how organisms and populations adapt to changes, and get predictions in combination with past records. This assessment will serve as a basis for future studies and anticipate potential emerging impacts.

It is necessary to ensure adequate observing capabilities to monitor the relevant phenomena. At regional level it is necessary to give priority to the monitoring and assessment of ocean acidification and its effects on marine ecosystems and work with relevant organisations (e.g. ICES, IOC, operational oceanography networks) and conventions to put in place systems for assessing effects of acidification and climate change. This should include scenarios of potential impacts, development of methods and indicators to monitor and assess the progression of acidification and also other climate change impacts at regional scales. Better links between science and the development of local policy on risk assessment are essential.

To advance in the understanding on ocean acidification it is necessary to maintaining at regional level the long-time climate series that already exist on essential variables (e.g. temperature, pH and oxygen), including also atmospheric CO_2 time series in key sites. It is also necessary to define “essential environmental ocean variables” (EEOV) and associated intercalibration and standardization procedures, and establish rigorous baselines on ecological indicators of climate change and acidification in selected European coastal and open sea areas, identifying “sentinel” observatories on representative areas sensitive to climate change, and in particular to acidification.

TOPIC 3.1.3. OCEAN – ATMOSPHERE INTERACTIONS: THE ROLE OF OCEANS ON EARTH'S CLIMATE

The role of oceans in regulating climate on Earth and feed backs

The effect of climate change on the environment and humanity has many facets. The issues range from a long-term reduction of sea ice coverage and thickness in the Arctic, to changes in ocean circulation and sea level rise, to name a few. These changes have the potential to cause impacts on a global scale on the environment, the economy and the wellbeing of humankind and can therefore be seen as grand societal challenges, which will require a global approach to respond to them.

Oceans play a key role in regulating the Earth's climate through exchange of momentum, heat, carbon and other key elements. However, due to the complexity of this topic there are still many knowledge gaps that need to be overcome to understand these interactions. Knowledge on the role of the ocean processes (physical, chemical and biological) in regulating the Earth's climate and the impacts of climate on oceans caused by increasing temperatures and atmospheric concentrations of CO_2 world is still limited. This call for more research to better understand the role of the oceans, including sea ice, as part of the global climate system over varying timescales. There is also an urgent need to explain the role of the oceans sub-surface to policy-makers, especially deep-ocean and its role as a heat and carbon sink.

We need to increase our understanding and ability to predict interactions and feedback mechanisms between ocean and climate. It is necessary to deepen the knowledge on changes in ocean circulation due to major changes in climate and ocean-climate processes, both at global scale (teleconnections) but also at regional – local scale. This includes a greater understanding of the role of the large-scale ocean circulation and mixing processes on climate and improve the current knowledge on the heat transfer between oceans –atmosphere. We also need to better understand the role play by the global ocean circulation pattern in driving the climate through the development of climate instabilities or long-term state changes. In that regard it is also necessary to get deeper insights on how climate change is affecting deep water formation processes and the possible impacts on the termohaline circulation on the long term, with better knowledge of the associated consequences and uncertainties. Further multidisciplinary scientific studies about past climate and oceanography changes are also needed to improve the understanding on ocean-climate interaction and changes.

It is also necessary to understand the role play by marine biogeochemical cycles in the fluxes and exchanges of matter between ocean and atmosphere and the global biogeochemical cycles, in particular on the carbon sequestration pathways and other key elements. In that regard, we need enhanced understanding of the matter exchanges between ocean and atmosphere and the linkages with climate change and acidification. For example there is a need to invest in research to understand the expected trends in dimethyl sulphide (DMS) from marine organisms, which is thought to have a significant role in radiative forcing.

On the other hand, oceanographic processes in the continental margin have a high importance in relation to the sink and sequestration of carbon, but we do not know well how physical processes (such as continental margin currents and upwelling systems) and also biological and biogeochemical processes in the continental margins are being affected by climate change, which is due in part to the high variability of these areas and also to the gaps in data and knowledge. Also water circulation and biogeochemical fluxes through straits are key to maintaining the physical and biogeochemical balance in sea basins and changes, and they can be used to provide early warning systems of climate change effects in sea basins. Understanding ocean circulation increases our ability to predict the impacts of climate change and ocean acidification. However, there is little support on European infrastructure to monitor changes in the main marine currents of the different sea basins and the exchanges through the European straits.

To make a comprehensive assessment of the role of oceans on climate and global cycles it also is neccesary to understand and quantifying interactions and driving forces between the Earth's interior and the oceans (particularly geochemical flux and energy/momentum). Deeper monitoring of oceanic heat content would help us gain a better understanding of the Earth's heat budget, the relative uptake of oceans and atmosphere, and the timescales on which they operate.

Data and modelling needs to understand ocean-climate interactions

To address all the gaps identified above there is a need for continous monitoring and surveying to understand the processes and feedback mechanisms between the ocean and atmospheric systems, both on a global and also at regional scales, and provide evidence from long-term, quality-controlled datasets and process-based understanding.

Currently climate models lack of constrain. More data with enhanced geographic coverage, including also deep sea waters, and higher temporal frequency are needed to reduce the uncertainty of projections and predictions of climate change and its impact on the oceans. This requires coordinated efforts on climate related research and a need for a permanent infrastructure and support for sustained long-term observations and predictions of ocean changes through an integrated approach. Financial support for this permament infrastructure should not depend on normal grant funding, which is usually short term and therefore it does not secure the long term support needed to observe climate change related changes. Moreover long term support is also needed to separate natural variability from climate change effects. Natural multiannual and decadal variability is often very high which makes it difficult to detect real signals of climate change without a long term commitment to sustain these observations.

The biological and biogeochemical systems in the oceans, which are responsible of the uptake of CO_2 from atmosphere, are poorly represented in climate models. There is a need to develop new knowledge for the state, forcing and evolution of ecosystems by modelling the Earth system through coupled ocean-atmosphere models, tested on short to medium range predictions and extended to long-term climatic scales. Numerical models exist, but often the uncertainty of projections are high and they are not sufficiently understood. To overcome this problems models needs to be improved with new and more data and knowledge. The access to the use of high performance computing facilities can produce better reproduction parameters for key processes at global and regional level (e.g. Atlantic, Mediterranean, etc). Currently there are significant opportunities to exploit high performance computing for modelling.

There is a need for a continuous data collection, including year round data from cruises (which usually are limited to the summer months, leading to low data coverage for the winter months) and also automated and autonomous observation platforms which could improve the spatial and temporal coverage of data needs.

Climate change –ocean interacions at regional scale

Oceanographic models do not integrate eventual scenarios of climate change on sub regional and local scales. We need to develop high-resolution oceanic models in sub-regional and local areas, supported by high-resolution datasets and use downscaling of regional climate model output as forcing in three dimensional ecosystem models.

The Mediterranean Sea is a sensitive region to climate change and undersampled area. To gain understanding on the hydrography, ocean-atmosphere interactions and biogeochemistry of the Mediterranean Sea a joint programme of trans-Mediterranean hydrographic and biogeochemical sections should be implemented, thus counteracting the lack of data derived from the WOCE (World Ocean Circulation Experiment) programme. This data set will contribute to the implementation of circulation and biogeochemical models for the Mediterranean Sea. Furthermore oceanographic models do not integrate eventual scenarios of climate change on sub regional and local scales. We need to develop high-resolution oceanic models in sub-regional and local areas, supported by high-resolution datasets. .

The circulation of water masses in the Atlantic Ocean has a major role on global circulation processes and plays a key role on the climate, with likely feed backs on the global climate. Understanding circulation processes and changes in the Atlantic Ocean and the interaction with climate is key to understand climate regulation at global level. Monitoring and modelling of the "Atlantic Meridional Overturning Circulation" (AMOC) should be expanded and couple to atmospheric models and ecosystem models. Moreover, modelling of currents on the continental margin, such as the Iberian Current System (ICS) and the Eastern Boundary Upwelling System (EBUS) needs to be improved through the development of coupled models ocean-atmosphere models dowscaled at regional level.

AREA 3.2. INTERACTIONS BETWEEN CLIMATE CHANGE, HUMAN ACTIVITIES AND THE MARITIME ECONOMY

TOPIC 3.2.1. IMPACT OF CLIMATE CHANGE ON COASTAL AREAS

Risks of climate change to coastal areas and communities

The coastal areas and their ecosystems remain under the threats of climate change related hydrological hazards, such as sea level rise, flooding by storm surges, extreme weather events, increased coastal erosion along the littoral, etc. We need to deepen the knowledge about the potential effects of climate changes on particular coastal ecosystems, territories and economic activities of coastal communities. Despite sea level rise represents a major threat for coastal areas and communities, there is a lack of complete evaluation of the extension of the coastal areas than can be possibly submerged by sea-level rise and the environmental and socio-economic impact. Therefore, there is a need for a complete coastal mapping where inhabitants are at risk of sea level rise and understand other enhanced climate change hazards for higher scenarios on coastal communities.

Furthermore we lack a profound and detailed understanding of climate change impacts (e.g. sea level rise, flooding and storms surge) on harbours and coastal infrastructures and these should be better assessed and understood. We need to understand climate change hazards for the foreseen higher coastal communities, improving knowledge of marine-related risks and hazards.

Climate change impacts on coastal ecosystems

Coastal ecosystems and their biodiversity are particularly vulnerable to climate change. Sea level rise, erosion, flooding and surge storms can also cause the deterioration and eventually the loss of coastal habitats and also biodiversity and it is necessary to assess the local response of coastal ecosystems to these climate change impacts. It is also necessary to better understand the effect of global warming and ocean acidification on coastal ecosystems functioning, habitats structure, food-webs and species composition. It is also necessary to better understand the interactions at the coast-land interface (e.g. increased erosion and floods)) as well as the interactions between continental shelf processes and coastal areas in order to anticipate evolution in the coastal zone.

In addition to climate change, littoral areas are under extreme human pressures (e.g. urbanization, pollution, tourism, etc), which may increase the vulnerability of ecosystems, habitats, biodiversity and organisms to impacts of climate change. It is necessary to characterize the interaction and possible synergies of climate change with human pressures at sub-regional and local scale (including areas under increasing human pressures such as estuaries, deltas, lagoons, etc) in order to design mitigation and adaptation plans. For instance, climate change in combination with human activities may be responsible for the increased frequency of harmful algal blooms, with the consequent negative effects for ecosystems, maritime economy and human health. The role of climate change on the expansion and intensification of these processes need to be tracked and further clarified. To this end it would be necessary the integration of existing data bases on harmful algal blooms and climate change.

Approach to the management of climate change impacts on coastal areas

In order to adapt to climate change we need to develop knowledge on how to manage more effectively the effects of climate change on coastal zones. Implementing the existing polices can act as drivers, but new polices and management tools that go across the traditional sectoral division of management boundaries are also required.

The littoral is more and more fragile due to the combination of climate change and different human impacts and its needs to be preserved from these pressures, particularly those areas that are more exposed and vulnerable to the impact of sea level rise. It is necessary to identify ongoing impacts of climate change and prioritize urgent adaptation and mitigation actions and develop models and sustain regional early warning systems to monitor and assess the risks related to climate change. These early warning systems will allow to anticipate evolution of the coastal zone and major system changes to feed into mitigation and adaptation strategies. The development of adaptive management must provide measures of preparedness for and reduction of risk from coastal hazards, such as storm surges and extreme events, to politically acceptable levels.

Effects of climate change in coastal areas need to be addressed from a holistic point of view since they are not the only impacts on coastal areas. The combined effect of climate change and human pressures need to be address from the perspective of integrated coastal zone management. In that regards it is necessary to develop conduct a pan-EU integrated coastal zone management (ICZM) stocktaking, including not only human pressures but also climate variability (e.g. North Atlantic Oscillation variability), climate change impacts and land processes (such as trans-boundary pollution discharge through river systems).

Taking into account the current level of uncertainty on climate change and its impacts, it is necessary to strengthen immediate incorporation of the principle of precaution and prevention in developing strategies, policies and public and private initiatives to adpat and protect against climate change, particularly in terms of location and infrastructure public facilities and economic activities. For instance, large harbours are usually well protected against potential effects of climate change, whilst small structures, which are focused on the day-to-day constraints, are far from adapting to climate change. This requires an increased ability to assess and predict impacts of climate change at local level from the continental shelf to land-sea interface..

It is also necessary to raise awareness on climate change impact on coastal areas and engage decision makers, organizations and citizens. Measures to promote greater public awareness need to be taken. Likewise, we should deepen our understanding on how inhabitants want their coastal zone to be managed. To this end it is necessary to improve the dialogue with stakeholders and engage with coastal communities. Coastal zone inhabitants are the ones who have to cope with climate change impacts, such as rising sea level. Actually people living in those coastal zones do already have small scale adaptations. We should also look at sharing experiences and knowledge with coastal communities to learn on small scale local adaptation measures and how these could be scaled up. In order to better understand the perception of coastal communities on climate change and how they adapt to climate change we need to gather information on their current use of the coastal zone, what they value, their perception on how climate change is affecting them, the local responses adopted in response to climate change, how they think climate change may affect them in the future and the possible options to adapt to climate change.

In order to communicate knowledge on climate change related issues to stakeholders it will be necessary to develop tools for actors that are involved in coastal development so they can digest, accumulate and use "state-of-art" knowledge from political, social, economic and natural science in their daily work and bridge the gap between advanced science and local coastal zone management

Socio-economic impacts of climate change on coastal areas

Many of the most important maritime economic activities, such as tourism, are develop in coastal areas and archipelagos, but we do not know well the socio-economic impact that climate change will have on coastal areas and archipelagos and how it may affect the good and services provided by coastal areas.

This will require a detailed valuation of coastal zones, their uses and services and also an assessment of the impact of climate change on ecosystems in terms of economic value under different climate scenarios. The advancement in valuation of coastal and ecosystem services and the impact on climate change on these will provide necessary knowledge for proper preservation and protection of these services through the adoption of mitigation options and strategies to minimise the risks and costs of climate change. Also the socioeconomic impacts of climate change on coastal activities (such as sea level rise, floods and extreme weather events) need to be assessed under different scenarios in order to determine the potential induced losses/gains for different sector. Models need to be developed to improve the predictions and reduce costs of adaptation. Assessment should be done at local/regional level to take into account the geographical specificities of climate change impacts.

Assessing the socioeconomic impact of climate change on coastal areas requires interdisciplinary research (from physics to socioeconomics) and the development of marine socio-economic holistic models, as well scenarios development and forecasting techniques. These need to incorporate knowledge that comes from different sectors to ensure a holistic approach. One of the major barriers to address socio-economic implications of climate change is the scarce socio-economic data and also the lack of an established system for monitoring and collecting economic data.

There is a need to identify and agree on common socio-economic and environmental challenges which impact the coastal areas and how they should be monitored, measured and stored. In addition, there are poor links between 'natural' sciences and socio-economic sciences, with both communities working at different scales. It is also necessary to overcome the language barrier between natural sciences and economics through promoting a new generation of inter-disciplinary scientists with knowledge of natural and socio-economic science.

Modelling climate change impacts on coastal areas

Research to characterize the individual and combined effects of climate change and human pressures on the different habitats at sub-regional and local scale is needed to design appropriate mitigation and adaptation plans.

In order to predict impacts of climate change on coastal areas we need to develop models downscaled to local and coastal scales, with improved robustness and resolution to improve reliability of predictions of sea level rise, extreme events and other environmental impacts. The current oceanographic models do not integrate eventual scenarios of climate change with sub regional and local resolution and it is necessary to develop high resolution models using high resolution data series, so as to improve predictions on ecosystems and related effects upon marine life in response to climate pressures, based on best available scenarios for climate change. Climate – ecosystems models should also take into account the impacts of the various activities on the environment and interactions between pressures and cumulative impacts. This requires detailed understanding of the human interactions with the coastal environment (processes and effects), as well as of the complex effects of climate change on the coastal environment.

More sampling data are needed to improve predictions and better understand impacts of climate change on coastal areas, bringing the spatial resolution to meet user needs. In order to cover this data need from coastal areas it is necessary to develop an integrated European monitoring strategy to conduct monitoring in a more cost efficient way, including monitoring of coastal areas, based on today's and future societal and policy needs and science priorities. It is necessary to define essential climate and environmental variables that need to be measured and agree on intercalibration and standardization procedures. Rigorous baselines for ecological indicators of climate change in selected European coastal areas are also needed. Monitoring should be supported by a network of observatories in areas sensitive to climate change. That network should provide access to marine and maritime research platforms in coastal areas. In order to manage, store and disseminate coastal data, a robust, integrated and coordinated database available to multidisciplinary research teams will be needed.

TOPIC 3.2.2. IMPACT OF CLIMATE CHANGE ON MARINE AND MARITIME ACTIVITIES

Climate change and the maritime economy

Marine ecosystems provide a huge source of goods and services to the society, but we do not know how these are going to be affected by climate change and the consequences of these effects on the maritime economy. Climate change pose both opportunities (e.g. new shipping routes, access to new resources, aquaculture of new species, etc) and threats (e.g. sea level rise, extreme events, warming of oceans, acidification, loss of biodiversity, etc), which need to be better understood. But currently there is a lack of knowledge on the socio-economic consequences of climate change impacts on the marine and maritime economy.

Current production sites are not adapted to consequences of climate change and we do not know the cost of adaptation, including aspects of engineering of coastal and off-shore infrastructures. More frequent storms, with higher waves and stronger winds, lead to more wear and tear of sea-based installations. Due to increased temperatures, problems of biofouling and proliferation of invasive species is becoming more and more relevant and it is expected to grow in the coming decades. Therefore, it is necessary to assess the impact that climate change is currently having on the maritime economy and develop adaptation measures. In addition, it is also necessary to develop models in order to improve predictive capacities to anticipate future impacts and major risks for the development of marine and maritime activities, taking also into account worst case scenarios. The big driver here would be to improve risk management, increase resilience to climate change and variability, enhance safety at sea and increase the efficiency and effectiveness of all ocean-based activities through scientifically founded services and the development of appropriate adaptation and mitigation strategies. One of the major barriers is to deal with the current level of uncertainty in climate change predictions, which requires improvements of current models. The current uncertainty levels call for an immediate incorporation of the principle of precaution and prevention in developing new activities and strategies, policies and public and private initiatives. This issue is addressed in further detail in topic 3.2.3.

In addtion, to assess the impact of climate change on the maritime economy we need proper socioeconomic research and also socio-economic data of maritime activities. However there are no systems in place to collect and manage economic information on maritime industries and their activities. The socio-economic research in this field must include the development of models, combining marine ecosystem and economic dynamics, as well as scenarios development and forecasting techniques. Research should also be developed to deepen the knowledge on the potential effects of climate change on particular economic activities. All this knowledge will contribute to provide suitable tools for integrated policy evaluation which will improve the ability of decision-making to take account of the important interactions between humans and marine ecosystems.

A holistic and integrated approach involving stakeholders (e.g. natural scientists, socio-economist and decision makers) is needed for the development of adaptive policy tools and to evaluate best practices. It will also be necessary to raise awareness and engage civil organizations and citizens.

However a major barrier in this field is that there are poor links between 'natural' sciences and socio-economic sciences, with scientist from both communities working at different scales and using different languages. In that regard, there is also a need for a new generation of inter-disciplinary scientists with knowledge of natural and socio-economic science.

It will be necessary to assess climate change induced changes in the ice covered seas and utilise the scientific information on climate change to improve planning of activities in the Arctic, where the sea ice retreat makes the area more accessible to commercial interests, like the expansion of maritime transport, fishing, exploitation of energy and mineral resources. There is a need to react fast in order for maritime transport to adapt to these new opportunities, changes and more extreme weather conditions. Surveillance of shipping routes by vessel-traffic-systems is one way to take care of that. We also need to develop predictive models for assessing the interactive effects of climate change and increased global shipping and transport.

On the other hand, the consequences of climate change in the planning of marine activities (MSP) are not well understood. This will require new knowledge on the expected environmental impact for future planning. It is necessary to take further the climate and ecosystem data-modelling and data-simulations by including the impacts of the various activities on the environment and interactions between the various activities - as a planning tool for the industry and a basis for development of a legal framework, thus creating predictability for industries.

Climate change can also cause an increased frequency of harmful algal blooms (HABs) and this may have a negative impacts on the aquaculture and fisheries sector, as well as on the tourism. It is essential to maintain and coordinate already existing HABs monitoring programs in aquaculture and tourist areas in Europe to track the impact of climate change on the expansion and/or intensification of HABs. We need to understand processes implied in triggering HABs and the link with climate change. The issue of HABs is dealt in more detail in topic 2.2.3.

Climate change on effects on living resources

It is necessary to better understand and forecast the effect of climate change on living marine resources, including seafood production, through the development of models that link ecosystem models to climate models, and assess the socio-economic effects and their management through cross disciplinary research. Both more studies of natural stocks and also experimental biological research are needed. Experimental studies are key to investigate the effects of climate change on organisms through the manipulation of environmental conditions (single and multiple) to examine the biological responses (behavioral, physiological and immunological).

There is also little knowledge about the genetic and epigenetic consequences of climate changes for economically important species. In particular, epigenetic mechanisms, and later biological functioning, can be affected due to changes in the environment. We do not understand well how climate change and ocean acidification will affect the ecology, physiology and population dynamics of fish, the economic impact on the fisheries sector and on coastal economies depending on fisheries. It is necessary to support long term research to elucidate the direct and indirect effects of climate change on fish ecology, physiology and population's dynamics and the socioeconomic impact on the fisheries sector. The impact of climate change on fisheries is addressed in greater depth in topic 2.3.3.

In the case of aquaculture, we do not really know which are going to be the impacts, costs and potential benefits of climate change. But it seems clear that there would be ‘winners and losers’ in terms of species, though we do not know how particular species will be affected. Climate change will have negative effects on aquaculture, such as effects negative physiological effects for some species (e..g slower growth), increase frequency of storms may damage aquaculture cages, spread of diseases, invasive species, increase frequency of harmful algal blooms. So we need more research to prepare aquaculture to cope and adapt to these circumstances and develop management measures based on the ecosystem approach to overcome the negative effects of climate change and ocean acidification on the aquaculture sector. On the other hand, there is also a need to conduct research to understand the positive effects and opportunities of climate change for aquaculture, to help the sector to take advantage from these. Thus the increase of seawater temperature will lead to faster growth rates for some species and new areas may be open for growth/industrialization. But more research is needed to understand the whole range of climate change effects on the sector, including the negative and positive socio-economic impacts.

TOPIC 3.2.3. ADDRESSING THE UNCERTAINTY AND RISK OF CLIMATE CHANGE BY IMPROVING MODELLING AND FORECASTING TO SUPPORT EARLY WARNING AND ADAPTATION MEASURES

Addressing uncertainty and risks of climate change by improving models

One of the major current problems with climate projections is the high level of uncertainly of the current predictions. Current climate models lack of constrains and does not provide accurate results on climate change scenarios This needs to be overcome to provide sound scientific knowledge and advice in order to develop reliable forescasting tools to support early warming systems and develop proper adaptation or remediation measures. The uncertaninly is also a barrier to improve the knowledge and predict the effects of climate change on the marine environment, which is a major inconvenient for develop management measures for the sustainable use of marine ecosystems and bioresources. In addtion, uncertainly on climate change is also a barrier for industry to grow.

Currently it is not possible to provide robust enough projections to advice managers and support policy. Moreover, uncertainty is generally not taken into account in communicating data and assumptions produced by scientists to policy makers and this may cause misunderstanding. It is necessary to communicate better this uncertainty e.g. through information products on uncertainty Improvements of models will allow to reduce uncertainty and to optimize the response to climate change

It is necessary understand vulnerabilities and risks, including those related to global climate change and climate impacts, to develop uncertainty and risk analysis of stability and resilience in predictive models. We need to develop and sustain regional early warning systems and methodology to anticipate major system changes impacting on marine and maritime activities, reducing vulnerabilities and risks relating to global climate change and impacts. Improvement of forecasting capabilities and capacities is important for coastal regions, population, society, sustainability of maritime operations, as well as for the safety of operations.

The improvement of forecasting will allow us to develop scenarios to better inform and engage with policy-makers and society on climate change impacts, preparing them for adaptation and mitigation measures. Adaptation and mitigation of climate change measures in the marine and maritime realm requires a clear view of the most probable changes in the marine environment and indirect changes in order to be able to develop suitable adaptation measures at regional/local level. It also requires a dialogue between marine and maritime stakeholders.

In order to overcome the problem of uncertainty and optimize the response to climate change it is necessary to improve current models. This will allow to develop scenarios that better inform policy-makers and society on the future impacts. Currently there are no long-term scenarios for marine ecosystems under anthropogenic changes and we need reliable ocean climate modelling and forecasting at subannual to multidecadal timescales, including physical, biological and biogeochemical parameters and predict the future evolution of marine ecosystems under different climate change scenarios. This involves the generation of new knowledge for the state, forcing and evolution of ecosystems, as well as development of coupled models ocean-climate and use ensemble of models.

The uncertainty of climate models also prevents accurate outcomes of biogeochemical modelling, since the bulk of uncertainty lies in climate modelling. Moreover, the biological and biogeochemical processes in the ocean which are responsible for the uptake of CO_2 from atmosphere are poorly represented in the current models. It is necessary the development of new models of the biogeochemical state of the ocean to predict the effects of climate variability on biogeochemical cycles and ecosystems. These models will help us understand the impact of climate change on seas and oceans and also role of the ocean on the climate in the medium and long term. In order to increase the accuracy of climate models these should integrate key processes occurring in the oceans that are not being considering in the current models, such as geological gas release from the seafloor or exchange of heat between the Earth's interior and the oceans,

The improvement of modelling approaches calls for a multidisciplinary approach to ocean and climate change related issues. This requires to strengthen the cooperation and exchange of knowledge and information between scientists from different disciplines in the development of models, including scientists from different fields of marine sciences, climate sciences and modellers. According to inputs from stakeholders, JPI Oceans could play a role and becoming a home for modelling by bringing together experts from different disciplines to address current challenges and needs in modelling. It is also necessary to develop a new generation of scientist with multidisciplinary skills in marine sciences, including modelling.

Downscaling of models to regional and local level

Climate change is a global process but there are regional and local differences in the response of ecosystems. This requieres the development of management measures at local/regional level to adapt to these impacts. Therefore we need to develop more reliable and accurate models at a proper geographical scale to have better predictions at regional and local level. Also the interface between global and regional models needs to be examined in terms of accuracy, reliability, validity of assumptions and precision of results. The output of the downscaled regional model can be used as a forcing in three dimensional ecosystem models.

The current level of uncertainty from downscaled regional climate models (RCMs) is very high. So in order to improve the knowledge and to support implementation of regional and local adaptation strategies it is necessary to reduce the uncertainty of climate change in regional seas, and develop ocean climate-models to improve the reliability of predictions of dominant climate-sensitive processes (e.g. weakening of the Atlantic MOC [Meridional Overturning Circulation) and on the carbon cycle (the efficiency of the biological and physical pump and the impact on the acidification) under different climate change scenarios.

However, the current oceanographic models do not integrate eventual scenarios of climate change with sub regional and local resolution and it is necessary to develop high resolution oceanic/ecosystems models in sub-regional and local areas, using high resolution data series to improve predictions of impacts on ecosystems and marine based on best available climate change scenarios. It is also needed to validate, improve and adapt existing models to test for their applicability to other areas or regions (e.g. MENOR and WMOP developed for operational purposes in the Western Mediterranean).

Data and monitoring needs to improve models and reduce uncertainty

We cannot understand or mitigate or adapt to climate change if we don`t have the proper measurements. A key issue to reduce uncertainly is data quality and data availability. Data quality is critical to ensure the reliability of models and also the outcomes of predictions. In addtion we need more data to cover the spatial and the temporal gaps, including also data gaps in the deep ocean where the available data are scarce. We also need long monitoring time series from key sites and more data to improve the calibration and validation of models.

Another major problem to reduce the uncertainty of climate change and develop more reliable scenarios and projections is the difficulty to separate natural inherent variability from climate change signals. This requires of long term data series to develop baselines of natural variability, but there is not enough long-term (e.g. multidecadal) records of background variability to constrain decadal scale climate models and shelf sea biogeochemical models. In particular there are large data gaps and insufficient long term time series at regional level (e..g Mediterranean, Artic) and in the deep ocean.

Records of the full effect of climate change on the marine environment are limited to the period covered by instrumental measurements, but such long records are spatially rare and are mostly limited to sea surface temperatures. Records of sea bottom conditions are much more limited both spatially and temporally. The use of real world data from periods before the widespread availability of instrumental records will help to constrain the range of model predictions. It will also help distinguish the natural background level of marine environmental variability, enabling a robust assessment of the degree of human impact Suitable archives are now available using different approaches (e.gg annually-banded shells of very long-lived marine molluscs).

Data harmonization is critical to ensure intercomparability and interoperability of environmental data, so that those data can be used to feed models. We need long term reference data sets (including old data) for validating and calibrating the models. These long data sets can be used as a test the models in order to determine the accuracy and reliability of the models. This has been done in the past for the physical parameters but for chemical and biological parameters this is still an open question. This work is being doing in at EU level by EMODNET (European Marine Observation Data Network), but more efforts are needed at EU level in relation to data harmonization.

In order to improve the knowledge, data and reduce the uncertainly of climate projections in the ocean we need to improve the observational capacities (including spatial and temporal coverage) and develop a coherent and proper monitoring strategy and identify what kind of parameters (physical, biological, chemical) are needed as reference data set. This requires to optimize the use of e-infrastructures for management of increasing volumes of marine information products (from observations and models) based on internationally accepted standards. All this needs to be supported by a consolidate marine data and information management system at European level. There is room to improve the way that data are used. In that regard, it is necessary to promote the availability and access of the scientific community to data and deepen the exchange of data knowledge between different scientific fields.

4. MAPPING OF PAN-EUROPEAN AND REGIONAL STRATEGIC RESEARCH AGENDAS AND PRIORITIES

This section provides an list of the scientific strategic research agendas and strategic documents developed by relevant pan-European and regional scientific organizations (e.g. European Marine Board, EFARO, EUROMARINE), regional science organizations (e.g. ICES, CIESM) and regional or pan European initatives (e.g. SEAS-ERA, BONUS). This mapping of pan-European and regional marine science strategic research agendas and strategic documents does not try to provide an exhaustive list of all stategies developed and priorities identified by the different organizations and initatives, but it rather aims to provide a broad overview of the main research strategies and scientific priorities related to marine research at EU level over the last years. The list of research strategies and documents is given below in table 3.

In addition to the research strategies and priorities identified by relevant marine science organizations and initatives table 3 also includes the priorities identified by the CLAMER project (Climate Change and European Marine Ecosystem Research (http://www.clamer.eu/), since the outcomes of this project (which objective was to map and synthesise the research findings of recent and projected climate change impacts on marine ecosystems in Europe) are very relevant for Goal 3 of JPI Oceans.

All the information on priorities, needs and gaps provided by the different agendas and documents will be useful to complement , when necessary, the information gathered through the consultation process of CSA Oceans. That information will also be useful to examine how the topics that have emerged from the analysis of the stakeholder inputs to consultation conducted by CSA Oceans fit to the priorities of these agendas and strategic documents. This may help assess the overall relevance of the priority topics identified by WP3 based on the analysis of common denominators between research funding agencies and stakeholders.

Table 3. Pan-European and regional marine research strategic and strategic documents published by relevant pan-european and regional science organizations and initiatives publish since 2009.

ORGANIZATION/INITIATIVE	RESEARCH STRATEGY/STRATEGIC DOCUMENT/PRIORITIES	Date of publication
European Marine Board http://www.marineboard.eu	**LINKING OCEANS AND HUMAN HEALTH: A STRATEGIC RESEARCH PRIORITY FOR EUROPE** It is the last position paper published by the European Marine Board. It identifies key research needs and priorities to support the development of a holistic and coherent transnational oceans and human health research effort in Europe http://www.marineboard.eu/publications	**2013**
European Marine Board http://www.marineboard.eu	**NAVIGATING THE FUTURE IV** Navigating the Future IV, published in 2013, is last document of the series "Navitaing the Future" issued by the European Marine Board. It provides a blueprint for the next phase of seas and oceans research in Europe. Navigating the Future is a series of strategic documents produced periodically by the European Marine Board, where major gaps, needs and challenges in European marine research are identified. At difference from other Marine Board position papers which are usually focused on specific themes, Navigating the Future reports are intended to cover the full range of marine research and to address both applied science, which can contribute to Europe's blue growth agenda, and fundamental science which is crucial to provide an understanding of marine ecosystem functioning and the provision of marine ecosystem goods and services which benefit society. Navigating the Future IV is organized around the framework of key societal challenges in the areas of climate, human health, food security, energy and safe and sustainable use of marine space. http://www.marineboard.eu/publications	**2013**
European Marine Board http://www.marineboard.eu	**ACHIEVING ECOLOGICALLY COHERENT MPA NETWORK IN EUROPE: SCIENCE NEEDS AND PRIORITIES** It addresses science needs and priorities to inform, engage and empower stakeholders in planning networks of MPAs across Europe and beyond http://www.marineboard.eu/publications	**2013**
European Marine Board http://www.marineboard.eu	**MARINE BIODIVERSITY: A SCIENCE ROADMAP FOR EUROPE** This roadmap addresses knowledge gaps and research capacities needs, and it also examines the policy context and provides a roadmap for marine biodiversity research in Europe. http://www.marineboard.eu/publications	**2012**
European Marine Board http://www.marineboard.eu	**MARINE MICROBIAL DIVERSITY AND ITS ROLE IN ECOSYSTEM FUNCTIONING AND ENVIRONMENTAL CHANGE** This document highlights recent advances in marine microbial research and identifies key priorities and needs for future	**2012**

	European research. http://www.marineboard.eu/publications	
European Marine Board **http://www.marineboard.eu**	**MONITORING CHEMICAL POLLUTION IN EUROPE'S SEAS - PROGRAMMES, PRACTICES AND PRIORITIES FOR RESEARCH** This document provides a critical evaluation of current monitoring practices and assessment frameworks as well as mechanisms for including emerging chemicals of concern in monitoring programmes http://www.marineboard.eu/publications	**2011**
European Marine Board **http://www.marineboard.eu**	**MARINE BIOTECHNOLOGY: A VISION AND STRATEGY FOR EUROPE** It provides an overview on Marine biotechnology state of the art and its significant potential to contribute to scientific, societal and economic needs; and a concrete science policy strategy http://www.marineboard.eu/publications	**2010**
European Marine Board **http://www.marineboard.eu**	**MARINE RENEWABLE ENERGY** It gives an overview of how marine renewable energy can provide innovative solutions to tackle future energy challenges and to fully contribute to the EU 2020 vision http://www.marineboard.eu/publications	**2010**
European Marine Board **http://www.marineboard.eu**	**SCIENCE DIMENSIONS OF AN ECOSYSTEM APPROACH TO MANAGEMENT OF BIOTIC OCEAN RESOURCES** It establishes the research priorities and a work plan to achieve the objectives of the Marine Strategy Framework Directive. Joint EMB-ICES-EFARO publication http://www.marineboard.eu/publications	**2010**
EFARO (European Fisheries and Aquaculture Research Organizations) **http://www.efaro.eu/**	**STRATEGIC SCIENCE PRIORITIES FOR THE NEXT DECADE IN SUPPORT OF SUSTAINABLE LIVING MARINE RESOURCES AND A HEALTHY ENVIRONMENT: AN EFARO VIEW** This paper sets out EFARO's view on the developing science agenda that will inform the prioritisation of marine science within Europe in the coming decade, emphasizing the importance of involving existing scientific organisations and networks in implementing the strategy. **http://www.marineboard.eu/publications**	**2013**
EFARO (European Fisheries and Aquaculture Research Organizations) **http://www.efaro.eu/**	**CLIMATE CHANGE AND EUROPEAN FISHERIES: OBSERVED CHANGES AND FUTURE PROSPECTS** This EFARO position paper report considers the potential implications of climate change and ocean acidification for fisheries in the European Union. The document it is focussed on 'applied' topics that have a direct relevance to fleets, the	**2012**

	operation of fishing gears and fishery catches in the future. The document also provides an overview of the current knowledge on climate change and fisheries research. The report is the outcome of an EFARO fisheries workshop held in February 2011. http://www.efaro.eu/default.asp?ZNT=S0T1O-1P131	
EFARO (European Fisheries and Aquaculture Research Organizations) http://www.efaro.eu/	**KEY TOPICS FOR SCIENTIFIC SUPPORT TO THE EUROPEAN AQUACULTURE STRATEGY** This report produced by EFARO provides a list of research topics and priorities needed to support the European Aquaculture Strategy. The report is based on the outcomes of the EFARO Aquaculture Strategic Working Group set in 2008, which identified the 12 key topics in which gaps in R&D exist with respect to the EU Aquaculture Strategy ambitions towards sustainable development of the European aquaculture sector. The document scores the topics on the basis of urgency/immediacy and relevance. The research topics are also categorised according to perceived 'value for money' (VFM), and their match/relevance to the stated objectives and remit of EFARO (i.e. to promote scientific cooperation in the area of fisheries and aquaculture specifically). For each theme the main science priorities are identified. http://www.efaro.eu/default.asp?ZNT=S0T1O-1P159	**2013**
EFARO (European Fisheries and Aquaculture Research Organizations) http://www.efaro.eu/	**EFARO'S VIEW ON THE FUTURE OF EUROPEAN FISHERIES AND AQUACULTURE** This document presents the EFARO's view on the future of European fisheries and aquaculture research, based on the outcome of the FEUFAR project which established and analyzed five 'foresight' scenarios considering the potential development of the European fisheries and aquaculture sectors to about 2020. This future orientated research agenda comprises five main priority areas, and three cross-cutting support areas. http://www.efaro.eu/default.asp?ZNT=S0T1O-1P104	**2009**
EUROMARINE http://www.euromarineconsortium.eu/	**EUROMARINE STRATEGIC RESEARCH REPORT** It sets out a common vision on **research priorities** and a **research strategy** agreed by the EUROMARINE patners. Three main areas have been identified by EUROMARINE as key priorities and challenges for the future of marine sciences within Europe. In addition key emerging fields has also been identified. These are strategic issues common to the three Network of Excellence (NoE) that preceeded to EUROMARINE and their implementation require a multidisciplinary approach. http://www.euromarineconsortium.eu/downloads/key-documents?download=176:euromarine-research-strategy-report	**2013**

SEAS-ERA **http://www.seas-era.eu**	**TOWARDS A STRATEGIC RESEARCH AGENDA/MARINE RESEARCH PLAN FOR THE EUROPEAN ATLANTIC SEA BASIN** The document was published by SEAS-ERA in 2013 and it sets marine research priorities for the Atlantic region. The identification of the priorities was based on a consultation process involving stakeholders and several workshops. In addition the SEAS.ERA partners also took into account the marine and maritime research priorities set out by the Implementation Plan of the Atlantic Strategy. http://www.seas-era.eu/np4/%7B$clientServletPath%7D/?newsId=19&fileName=Seas_Era_6_1_1.pdf	**2013**
SEAS-ERA **http://www.seas-era.eu**	**SEAS-ERA STRATEGIC RESEARCH AGENDA FOR THE MEDITERRANEAN SEA** The SEAS-ERA strategic research agenda for the Mediterranean Sea has been developed by the Mediterranean partners of this ERA-NET The objective of this agenda is to define the main research priorities and challenges for the Mediterranena Sea in the coming years. http://www.seas-era.eu/np4/%7B$clientServletPath%7D/?newsId=149&fileName=SEAS_ERA_D.7.1.1_Med_SRA.pdf	**2012**
SEAS-ERA **http://www.seas-era.eu**	**BLACK SEA STRATEGIC RESEARCH AGENDA** The Black Sea Strategic Research Agenda set out the marine research priorities of SEAS-ERA for the Black sea basin and it is the result of a consultation process conducted by SEASERA partner and involving experts and strategic workshops http://www.seas-era.eu/np4/%7B$clientServletPath%7D/?newsId=19&fileName=SEAS_ERA_BS_SRA_Final.pdf	**2012**
BONUS (Joint Baltic Research and Development Programme) **http://www.bonusportal.org**	**BONUS STRATEGIC RESEARCH AGENDA 2011-2017** The BONUS agenda addresses the main challenges that the Baltic Sea is facing from a holistic perspective, which includes also the coastal areas and the land sea interactions, taking into account the interaction and influence of the catchment area on the status of the Baltic Sea marine ecosystems. The development of the agenda has involved a broad consultation process. http://www.bonusportal.org/files/2981/Publication_No._14.pdf	**2011**
CLAMER (Climate Change	**CLIMATE CHANGE RESEARCH RESULTS- SYNTHESIS OF**	**2011**

and European Marine Ecosystem Research http://www.clamer.eu/	**EUROPEAN RESEARCH ON THE EFFECTS OF CLIMATE CHANGE ON MARINE ENVIRONMENTS** The document was published as a Marine Board Special Report in 2011, aims to (i) highlight the key role of oceans in regulating the Earth's climate and the global biogeochemical cycles; (ii) provide a review of the current state of scientific knowledge on the impacts of climate change on European seas and oceans; and (iii) identify research gaps and priorities for future research. In this report, the analyses of progress and gaps in research on impacts of climate change on the marine environment are classified according to thematic (e.g. sea-level rise, coastal erosion, etc.) and regional (e.g. Baltic, Atlantic, etc.) categories. The document is the outcome of the mapping conducted under the project and the contribution of coordinators of relevant EU projects. http://www.marineboard.eu/images/publications/Climate%20Change%20Research%20Results-70.pdf	
ICES(International Council for the Exploration of the Sea) www.ices.dk	**ICES SCIENCE PLAN 2009-2013** The ICES Science Plan 2009-2013 is based on the analysis of national science plans of ICES members and identifies the key areas of collaboration where added value can be created and where advances in marine research is needed to provide advice in support of management measures and policies. The ICES Science Plan addresses two of the six strategic goals identified by the ICES Strategic Plan, which are focussed in research and in strengthening the cooperation between countries. http://www.ices.dk/community/Documents/SCICOM/ICES%20Science%20Plan%202009-2013%20formatted.pdf	**2009**
CIESM (Mediterranean Science Commission) http://www.clamer.eu/	**CIESM PRIORITIES FOR THE MEDITERRANEAN** CIESM has not develop a proper marine research strategy for the Mediterranena, but research priorities and emerging issues in the Mediterranean have been identified by experts through working groups and published as thematic CIESM Workshop Monographs. This collection of CIESM workshops was launched in 1997 and 45 volumes have been published so far. Each volume addresses a specific topic . The full list of CIESM Workshop Monographs is accessible through the CIESM website from where the full documents can be downloaded (http://www.ciesm.org/online/monographs/index.htm). In addition to the themes identified by the CIESM Workshop Monographs, research priorities are also reflected in the CIESM Programmes, which are drawn from key recommendations of experts in the CIESM research workshops. Currently there are 7	**N/A**

	ongoing Programs involving a large number of associated research institutes in CIESM Member States. These programmes are focussed on the observation and monitoring of key parameters Hydrochanges; JellyWatch; Marine Economics; MedGLOSS; Mediterranean Exotic Species; PartnerSHIPS; Tropical Signals: http://www.ciesm.org/marine/programs/index.htm	

5. ASSESSING THE RELEVANCE OF THE TOPICS DRAWN FROM THE CONSULTATION

The outcomes of the mapping conducted through the consultation process launched by CSA Oceans were further examined. The aim was to test the relevance of the topics against the mapped pan-European and regional strategies by looking at the common points between the topics found by and the priorities identified by other pan-European and regional research organizations and initiatives (e.g. European Marine Board, EFARO, EUROMARINE, ICES, CIESM, SEAS-ERA, BONUS Article 185, and priorities relevant project such as CLAMER).

Table 4 shows the list topics identified by WP3 for Goal 2 and Goal 3 of JPI Oceans. Those topics emerged as common denominators from the analysis of inputs from research funding agencies and stakeholders during the CSA Oceans consultation process. Table 4 provides qualitative information (YES/NO) on the concordance of these topics with the themes or priorities identified by relevant pan-European and regional marine science organizations and initiatives. Topics were lallebed with YES when they showed some degree of agreement or coincidence with the priorities identified in the research agendas and strategic documents listed under section 4,. In some cases the coincidence between topics identified by WP3 and those addressed by the agendas and documents listed under section 4 was very high, though sometimes the coincidence was only partial. On the other hand, topics that did not show any concordance with priority indentified by the agendas and documents listed under section 4 were labelled with NO.

Table 4 shows that the concordance was in general very good between most of the topics identified by WP3, based on the consultation inputs, and the priorities set out at pan European and regional level by relevant science institutions and initatives. This indicates clearly that the topics identified by WP3 from the consultation are priority issues for other relevant marine science agendas at EU and regional level, confirming that these are important challenges at pan-European level for which the alignment of national research agendas should be considered. This also opens the possibility for enhancing the cooperation between JPI Oceans and other initatives to create synergies around those topics on which there is common interest, which are relevant for JPI Oceans and for other pan-European initatives and organizations.

The outcomes of the mapping conducted by WP3 and the topics identified from inputs of stakeholders were presented to the Strategic Advisory Board (StAB) of JPI Oceans in a joint CSA Oceans – StAB meeting that tooks place in Madrid on 8 July 2014. The StAB was asked by CSA Oceans partners to assess the relevance of these topics for JPI Oceans. The StAB concluded that all the topics were relevant for JPI Oceans, which confirms the findings from the consultation process.

Table 4. Concordance between topics indentified by WP3 and research priorities and needs identified by relevant pan-european and regional organizations and initiatives

	Marine Board	ICES	EFARO	CIESM	EURO-MARINE	SEASERA Atlantic	SEASERA Med	SEASERA Black Sea	BONUS	CLAMER
GOAL 2 ENSURE THE GES OF THE MARINE ENVIRONMENT AND OPTIMISE THE PLANNING OF MARINE ACTIVITIES										
AREA1: UNDERSTANDING THE FUNCTIONING AND VARIABILITY OF MARINE ECOSYSTEMS										
Topic 1.1. Understanding the functioning of Marine and Coastal Ecosystems	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Topic 1.2 Understanding and protecting marine biodiversity and deep sea ecosystems	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
AREA2: ECOSYSTEM HEALTH AND HUMAN IMPACTS										
TOPIC: 2.1 Development of indicators and guidelines to assess ecosystem health and human impacts and harmonize monitoring programmes for the implementation of the MSFD	YES	YES	YES	NO	YES	YES	YES	YES	YES	NO
TOPIC: 2.2 Assessing the impact of marine pollution (including litter, micoplastics and noise	YES	YES	NO	YES	NO	YES	YES	YES	YES	NO
TOPIC: 2.3 Eutrophication and harmful blooms	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES
TOPIC: 2.4 Individual and cumulative impacts of human activities and drivers on the marine environment and synergies with climate change	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
AREA3: RESEARCH TO SUPPORT THE SUSTAINABLE MANAGEMENT OF HUMAN ACTIVITIES AND MINIMISE THEIR IMPACT ON COASTAL AND MARINE ECOSYSTEMS										
TOPIC: 3.1 Valuation of ecosystems good and services, assessment of socioeconomic impact of human activities on the marine environment and development of measures to support a sustainable management	YES	YES	YES	YES	YES	YES	YES	YES	YES	NO
TOPIC: 3.2. Research to support Marine Spatial Planning MSP and Integrated Coastal Zone Management ICZM	YES	YES	YES	YES	NO	YES	YES	YES	YES	NO
TOPIC: 3.3. Research to support the sustainable management of fisheries[3]	YES	YES	YES	YES	NO	YES	YES	YES	YES	YES
GOAL 3: CLIMATE CHANGE[4]										
AREA 1: Impacts of climate change and ocean acidification on the marine environment										
TOPIC 1.1. Impact of climate change on the functioning of marine ecosystems, biodiversity and organisms: past, present and future perspectives	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
TOPIC 1.2. Effects of ocean acidification on marine ecosystems: synergies with global warming	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES
TOPIC 1.3. Ocean – Atmosphere interactions: The role of Oceans on Earth's climate	YES	NO	YES	YES	NO	YES	YES	YES	NO	YES
AREA 2: Interactions between climate change, human activities and maritime economy										
TOPIC 2.1. Impact of climate change on coastal areas	YES	YES	NO	YES	YES	YES	YES	YES	YES	YES
TOPIC 2.2. Impact of climate change on marine and maritime activities[5]	NO	YES	YES	YES	NO	NO	NO	NO	YES	YES
TOPIC 2.3. Addressing the uncertainty and risk of climate change by improving modelling and forecasting to support early warning and adaptation measures	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

[3] Including impacts of climate change on fisheries.

[4] The issues related to the impact of human activities have been considered under Goal 2 of JPI Oceans, instead under Goal 3 to avoid overlapping .

[5] Excluding impact of climate change on fisheries which is addressed within Goal 2, Area 3, by topic 3.3.

6. ANNEX 1

List of participants in the stakeholders consultative workshops organized by CSA Oceans in May-June 2013.

WORKSHOP	Participant Name	Organisation/Initative/Project
European Technology Platforms (ETP) and Industry Associations and Initatives	Maribel Rodriguez Olmo	ARIEMA - EFTP
European Technology Platforms (ETP) and Industry Associations and Initatives	Francois Marie Duthoit	DCNS - WATERBORNE
European Technology Platforms (ETP) and Industry Associations and Initatives	Courtney Hough	EATiP
European Technology Platforms (ETP) and Industry Associations and Initatives	Paris Sansoglou	EuDA - WATERBORNE
European Technology Platforms (ETP) and Industry Associations and Initatives	Vilma Radvilaite	EWEA
European Technology Platforms (ETP) and Industry Associations and Initatives	Ralf Fiedler	MARTEC
European Technology Platforms (ETP) and Industry Associations and Initatives	Leif Magne Sunde	SINTEF - EATiP
European Technology Platforms (ETP) and Industry Associations and Initatives	Hanne Digre	SINTEF - EFTP
European Technology Platforms (ETP) and Industry Associations and Initatives	Patrick Sorgeloos	UGent - EATiP
Science Organizations	Adi Kellermann	ICES
Science Organizations	Alessandro Crise	European Marine Board
Science Organizations	Jo Foden	EMECO
Science Organizations	Robin Cook	EFARO
Science Organizations	Josien Steenbergen	EFARO
Science Organizations	Catherine Boyen	EuroMarine
Science Organizations	Mike Thorndyke	EuroMarine/MARS
Science Organizations	Michael Weeb	ECORD
ERANETs-Art. 185	Andris Kaisa	BONUS

ERANETs-Art. 185	Andrusaitis Kononen	BONUS
ERANETs-Art. 185	Dennis Steffen	COFASP
ERANETs-Art. 185	Lisbjerg Syberg Hansen	COFASP
ERANETs-Art. 185	Steinar Bergseth	Marine Biotech
ERANETs-Art. 185	Ralf Fiedler	MARTEC II
ERANETs-Art. 185	Kostas Nittis	SEAS-ERA
International Organizations and Programmes	Elisa Berdalet	GEOHAB - International programme of Harmful Algae
International Organizations and Programmes	Albert Fischer	IOC-UNESCO/GOOS
International Organizations and Programmes	Katherine Hill	GCOS - Global Climate Observing System
International Organizations and Programmes	Gyorgyi Gurban	UNEP/MAP/ Barcelona Convention
International Organizations and Programmes	Irena Makarenko	Black Sea Commission
International Organizations and Programmes	Gert Verreet	OSPAR
International Organizations and Programmes	Andrew Brown	SCARFISH
International Organizations and Programmes	Trevor Platt	POGO - Partnership for Observation of the Global Oceans
International Organizations and Programmes	Yves-Henri Renhas	SHOM - Service hydrographique et océanogra-phique de la marine
Infrastructures	Olivier Lefort	OFEG
Infrastructures	Kostas Nittis	EuroGOOS
Infrastructures	Helen Glaves	ODIP
Infrastructures	Paolo Favali	EMSO
Infrastructures	Wouter Los	Lifewatch
Infrastructures	Simone van Schijndel	HYDRALAB IV
Infrastructures	Peter Wellens	HYDRALAB IV
Infrastructures	Jacques Binot	EUROFLEETS II
Infrastructures	Herman Hummel	EuroMarine
Infrastructures	Henning Wehde	NOOS
Infrastructures	Patrick Farcy	JERICO I3
Infrastructures	Adelino Canario	EMBRC
Infrastructures	Donatella Castelli	I-MARINE
Infrastructures	Marc Vandeputte	AQUAEXCEL
Infrastructures	*MARIEKE REUVER*	AQUAEXCEL
FP7 projects	Ferdinando Boero	CoCoNet and VECTORS
FP7 projects	Øivind Bergh	COEXIST and STAGES
FP7 projects	Anthony Grehan	CoralFISH
FP7 projects	Tim O'Higgins	KnowSeas
FP7 projects	Wojciech	MARCOM+

	Wawrzynski	
FP7 projects	Paula Kiuru	MAREX
FP7 projects	David Murphy	MarineTT
FP7 projects	Detlef Quadfasel	NACLIM
FP7 projects	Nikoleta Bellou	PERSEUS