Update the JPI Oceans Early gap analisys

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1. INTRODUCTION

Europe can surely be characterized as «blue». It contains vast coastlines along two oceans and four seas: The Atlantic and Arctic oceans, the Baltic, the North Sea, the Mediterranean and the Black Sea, to which we should add immense overseas territories as well as connections with inland waterways. This fact leaves a clear mark on its activities, its citizens, its economy and its climate.

In this context JPI Oceans proposes *three large and interdependent programmatic areas for Horizon 2020*;

Climate changing the oceans

Healthy oceans, seas and coasts

A sustainable blue economy

Finally these areas need to be complemented by suitable *Multipurpose Infrastructures* to address long term challenges on oceans, as well as *Human Capacity Building*

The Joint Programming Initiative on Healthy and Productive Seas and Oceans has been put in place by Member States (MS) and Associated Countries (AC) to solve the grand challenges related to the interaction between *climate and the marine environment and the blue economy*. Due to their dimension, these challenges cannot be solved by individual actions of MS or AC. A concerted pan-European approach and long-term strategic effort is required to tackle them.

In the current European Framework Programme for Research (FP7) healthy and productive seas and oceans has not been recognised as a societal challenge as such. Due to this fact, marine and maritime research has been spread across all the Specific Programmes of FP7 and across different thematic areas and priority lines of these Programmes in a rather fragmentary manner. Only recently, seas and oceans have been recognised in FP7 as a priority through the Oceans of Tomorrow. The calls have been launched on an annual basis by the European Commission since 2010. The calls are an important recognition of the need for an integrated, interdisciplinary and cross-sectoral science based approach to respond to the complexity of our oceans system and the effect of climate change and anthropogenic activities on the functioning of marine systems.

However, the approach adopted through the Oceans of Tomorrow calls being a step in the right direction, lack a strategic long-term perspective and programming required to tackle these major challenges related to seas and oceans (i.e. climate change impact, ensure the GES of marine waters, boost, and manage the maritime economy in a sustainable way).

For the above reasons JPI Oceans wishes to draw the attention of the European Commission to the need to develop long-term programmatic and strategic areas at the intersection between *climate change*, the *marine environment* and the *blue economy*, to be taken into consideration in the planning and implementation of Horizon 2020. A long-term perspective is critically needed to tackle the grand challenges related to seas and oceans. Progress in the identified areas must build upon new scientific knowledge, innovation, optimised use of enabling technologies and infrastructures for research and observation, and on the building of human capacity.

JPI Oceans would like to recall that the funding support of the Commission impacts substantially in leveraging and enhancing cooperation between MS and AC. A stable long-term programmatic framework is thus also needed to facilitate the collaboration between the European Commission and JPI Oceans, the latter being a long-term process.

CHALLENGES AND OPPORTUNITIES

Seas and Oceans are the largest unexplored territory on Earth covering 71% of the Earth's surface. They contain large, untapped potential for growth and hold immense natural treasures, but are subject to substantial pressures from human activities and climate change. The EU's Marine Regions, with their strong connection to the sea, account for almost 40% of its GDP, tourism and leisure alone accounting for a 72 billion Euros annual revenue.

Despite the important implications that seas, oceans and coastal areas have on the life of European citizens and their potential for economic growth, there is still a clear lack of knowledge. Continued research is needed on the functioning of seas and oceans and the processes that regulate these, crucial interactions between oceans and climate, the effects of human activities on marine ecosystems (including cumulative pressures) and the spatial patterns and pressures affecting environmental resilience. Understanding the functioning of the marine and coastal ecosystems and their interactions with climate and human activities will allow us to respond to changes and threats to our seas, oceans and coastal areas with adequate, sustainable adaptive measures (including mitigation). It will also be necessary to develop cross-cutting and enabling technologies to improve the monitoring of seas and oceans in a cost efficient way as well as provide marine and maritime industries with the new technology and innovation to boost their growth in a sustainable way and adapt to climate change.

Researchers and technology providers in turn can only deliver the knowledge needed if they have the support of suitable capacities, infrastructures and observations. Improved knowledge and capacities are furthermore critical for the creation of a predictable and stable long-term framework for the sustainable development of our blue industries.

NEED FOR A LONG-TERM AND INTEGRATED APPROACH

The complexity of oceans, seas and coastal systems and the nature of the challenges they are facing cannot be addressed at individual level by countries. They require a long-term integrated approach across sectors at European level. They also demand an integrated scientific approach across the different sectors and disciplines and call for a strategic coordination of marine and maritime research and innovation activities between JPI Oceans and H2020. Only then can we enhance the synergies and the added value of national and EU investments, avoiding unnecessary duplication. This could be achieved by planning cross-cutting marine and maritime research in H2020 along the following programmatic areas, "*Climate changing the oceans", "Healthy oceans seas and coasts" and "A sustainable blue economy*".

2. CLIMATE CHANGING THE OCEANS

We depend upon Earth System Goods and Services for survival and yet, we have minimal understanding of how the oceans contribute to these goods and services and how they may change as consequence of climate change. The role of the oceans is critical for regulating the climate on Earth. However, due to the complex nature of the ocean system and its interaction with the climate, still a lot of fundamental questions remain to be answered (see Box 1).

BOX I : Climate changing the Ocean.

Open questions:

1. Which are the major mechanisms that connect climate and ocean processes?
2. How is climate change affecting ocean circulation patterns and water mass formation?
3. How will temperature changes affect marine biodiversity, food web dynamics, and the economic sectors relying on marine living resources?
4. What are the feedbacks to the climate system of the changes in ocean currents, seawater temperature, food web dynamics and marine biodiversity?
5. What are the effects of ocean acidification on marine ecosystems? What are the resulting feedbacks on climate?
6. Which are the combined effects of increased temperature and ocean acidification on the marine ecosystem, and the maritime economies? What are their feed-backs to the climate?
7. How does ocean acidification affect the capacity of the oceans to absorb CO_2 and how does this, in turn affect global warming?
8. How will climate change impact our coastal areas (e.g. sea level rise, submersion of coastal areas caused by storm surges, salt-wedge intrusion)?

The answers to such questions can only be achieved through long-term and interdisciplinary efforts, including the socio-economic dimension and the use of suitable tools, to deliver the knowledge needed:

OCEANS AND CLIMATE –

There is a need to improve our understanding of ocean processes (e.g. thermohaline circulation, water mass formation, surface circulation, etc.). We need to enhance our knowledge on the role of oceans on the climate, the interaction mechanisms between oceans, atmosphere and climate and the feedbacks that modulate the climate on Earth and the consequences of those feedbacks on oceans processes. Oceanographic paleo-records can provide baselines to study the current changes in the oceans and bring relevant information to learn from past climate events.

We need to improve our knowledge on the effects of climate change on marine ecosystems (including coastal, pelagic and benthic ecosystems): how marine biogeochemical cycles, food webs and marine biodiversity are being affected. Further research needs to be performed on ecosystem regime shifts caused by climate change, define tipping points and follow trends. Science is also needed to enhance our knowledge on the link between natural biological hazards and climate change, such us outbreaks of jellyfish, harmful algal blooms, cyanobacteria, and mucilage events that pose a risk for coastal tourism, leisure and related businesses. Deep seas, Polar Regions and the Southern European Sea basins, due to their exceptional oceanographic and ecological features, are particularly sensitive to climate change.

We do not know yet how ocean acidification will affect the capacity of oceans to absorb CO_2, which calls for more efforts in this field. Moreover very little is still known on the effect of ocean acidification on marine ecosystems (including coastal and deep sea ecosystems), on their functioning, their productivity, the biogeochemical cycles, species interactions, food web dynamics, marine biodiversity and the physiology of marine organisms.

> **WHY:** Only through long-term observation programmes we will be able to monitor oceans and its interaction with climate and develop the basic knowledge needed for devising adaptation and mitigation plans to the benefit of a number of maritime sectors and services.

MARINE OBSERVING SYSTEMS AND FORECASTING TO IMPROVE SAFETY AND SECURITY AT SEA –

Climate change is a major challenge for the maritime sectors. Maritime industries will have to face more frequent extreme ocean weather conditions, and consequently higher risks to the operations and the economic impact on these activities. This calls for improving the monitoring and forecasting of ocean weather systems, by establishing sustained observing systems and developing ocean-climate models downscaled to regional and local level. New sensors and upgraded infrastructures can provide large data sets in quasi real time. Optimising weather forecasts will be a cost-efficient way to assess and mitigate impacts on our economically important industries; tourism, maritime transport, fishing fleets, aquaculture farms, offshore platforms, ocean energy deployments and mineral extraction as they face more frequent extreme ocean weather conditions.

> **WHY:** A reliable monitoring and forecast system will contribute to the safety of maritime operations and security at sea, and will contribute to set up adequate maritime spatial plans and management measures.

CLIMATE CHANGE IMPACT ON FISHERIES –

Climate change is already affecting fish populations and their distribution in European waters, thus calling for new management regimes. The mechanisms underlying these changes are not well understood nor are the feedbacks since the impact of fishing on marine ecosystems can make fish populations less resilient to climate change. Likewise, very little is known on the impact of ocean acidification on fish and fish stock dynamics, particularly at early stages of development, and the possible combined effects with other stressors. It is also necessary to forecast the socio-economic effects on the sector and the economy of coastal areas to allow them to adapt to those changes.

> **WHY:** Climate change effects on fisheries need to be investigated and considered in modelling fish stocks dynamics to forecast the socio-economic effects of the changes, as well as take necessary measures towards management informed by an ecosystem based approach.

EFFECTS OF CLIMATE CHANGE ON AQUACULTURE –

There is already evidence of some selective effect of climate change on the species of interest for aquaculture. The increase of seawater temperature will favour the growth of species better adapted to warm waters while the opposite will occur to cold waters species. On the other hand, ocean acidification will particularly affect shellfish. Climate change can also affect aquaculture in other ways. Climate change can increase the incidences of harmful algal blooms (HABs), spreading of invasive species, diseases and parasites and cause shortage of aquaculture feed supply. The higher occurrence of storms can damage aquaculture cages and increase the escapees, impacting both the environment and the economic sector.

> **WHY:** Climate change is a major challenge for aquaculture, but can also provide opportunities for new species and marketing areas. Research in this field is essential to support strategies to adapt to climate change.

IMPACT OF CLIMATE CHANGE ON COASTAL AREAS –

Coastal areas are threatened by sea level rise, a higher frequency of extreme weather events and changes in coastal circulation and sedimentation patterns as consequences of climate change. These events and processes may have devastating effects on coastal ecosystems and may have major harmful socio-economic impacts on coastal cities, industrial hubs, naval facilities, maritime transport of freight and passengers, energy infrastructures, other coastal infrastructures and business, including tourism and leisure, and in general on the population of coastal areas. In order to face such great challenges, more efforts should be dedicated to gathering reliable environmental information and to develop models to predict the sea level rise, the changes in coastal dynamics. In addition, we should be able to better understand the dynamic of extreme weather events and assess the risks and impact of these pressures on coastal areas, including the economic, social and environmental impact.

> **WHY:** Scientific knowledge is needed to devise adaptation measures and minimise the risks and the socio-economic and environmental cost of climate change impacts on coastal areas. This requires early warning strategies and management plans informed by scientific knowledge.

LONGTERM OCEAN OBSERVATION PROGRAMMES –

Reliable hypotheses on the patterns and trends characterizing complex ocean phenomena such as ocean circulation and ocean ecosystem dynamics, air ocean exchanges, climate variability, seafloor processes, and their links with climate change can only be developed based on long (25-30 years) time series. It is important to be forward looking, identify today the data we need to collect and monitor, to answer the critical issues in 25 to 30 years.

Extra efforts should be undertaken in sectors with large economic importance and in those sectors, which are considered to be strategic and particularly vulnerable to climate change. Likewise additional effort will be needed in regions particularly sensitive to climate change, and which are sentinel sites for shifts in climate-related processes to increase our understanding and tracking of trends.

> **WHY:** Only through long-term observation programmes and improvement of predictive capabilities over long time spans (50-100 years) will we be able to improve our understanding of ocean processes, their inter-linkage with climate and finally the impact on our communities, economies, and ecosystems. With such information, policy makers will be able to adopt the most suitable mitigation and adaptation measures.

3. HEALTHY OCEANS, SEAS AND COASTS

Oceans, seas and coasts host huge biological resources. Their health, from coasts to deep seas, relies on our knowledge about marine ecosystems and their functioning (physical, biological, chemical and geological processes)

BOX II : Healthy Oceans, Seas and Coasts.

Open questions:

1. How can we improve our ability to measure, assess and remediate the impact caused by pressures and human activities?
2. How can we ensure that all these activities are managed sustainably?
3. Is it sufficient to do this through a sectoral and disciplinary approach?
4. What is the accumulated effect of human pressures (including pressures from land activities and riverine inputs), on the health of marine ecosystems?
5. How the health of an ecosystem can affect the maritime economy and what might be the socio-economic consequences?

Solving complex issues such as those listed above (see Box II) requires an interdisciplinary and cross-sectoral approach, which will allow the development and application of the ecosystem-based approach to the management of human activities at sea, as the Marine Strategy Framework Directive (MSFD) requires. In order to keep seas and oceans healthy and safe and preserve their biodiversity and good and services, it is also necessary to pay attention to the general public's behaviour and perception of the sea, and identify incentives to change adverse behaviour.

RESEARCH AND TECHNOLOGY IN SUPPORT OF THE MSFD –

In order to protect and preserve the marine environment, we need to improve our understanding of the functioning of marine ecosystems and the goods and services they provide to the biosphere, the economy, human wellbeing, health and society. The resilience of, and future prospects of, coastal natural environments are inextricably coupled with the social, economic and cultural systems that lead to people living, depending on or influencing the coasts. Marine environmental research has been developed more along a science-based than a societal-based approach. As a consequence there are knowledge gaps and needs, including the need for baselines and further elaboration of indicators related to the MSFD (e.g. GES indicators of biodiversity and habitats, seabed integrity, present and emerging pollutants, nuclear waste, litter, noise, etc.), which need to be addressed urgently.

Some research gaps are due to the lack of technologies. Some disciplines still invest big efforts in collecting data in situ with out-dated methods. New and targeted devices can more efficiently monitor the environment and assess the impact of human pressures. In situ, mobile and remote technologies can rely on a set of new technologies such as ICT, nanomaterial's, molecular biology and omics that allow high throughput data collection. They should be integrated with the development of bioinformatics and e-science tools, to monitor the marine environment and integrate the information into conventional data streams. This multidisciplinary approach offers huge opportunities for use in next generation cost-efficient marine monitoring programs in support of the MSFD.

> **WHY:** There are still large knowledge gaps on the functioning of marine ecosystem that need to be addressed and also more efforts are urgently needed for developing base lines and indicators related to the MSFD to achieve the GES of European marine waters by 2020 being a legal obligation to EU member states. The development of new in situ sensors and use of new technologies, like nanomaterial's, omics and ICT technologies, will be important in order to reduce the costs of environmental monitoring.

COMBINED EFFECT OF MULTIPLE STRESSORS –

In addition to human pressures, marine ecosystems are exposed to other multiple stress-factors (e.g. climate change, ocean acidification, UV radiation, etc.). However, the cumulative effects of the numerous and different stressors impacting our marine systems are rarely considered and our knowledge is very scarce. There is a need to obtain further insights by developing holistic models that can help predict future changes, provide early warnings and inform on potential tipping points. This knowledge is crucial, to design and prioritize adaptation and mitigation policies and restore ecosystem functioning and health, particularly in areas such as coastal zones which are subject to the impact of multiple pressures. The impact of multiple stressors must be considered in the development of more integrated policies, since up to now management measures have been adopted through sectoral policies.

> **WHY:** Integrated research on multiple stressors will help us understand the complex interactions between pressures and their effect on marine ecosystems and to produce more reliable models to forecast with accuracy future scenarios to better inform policy makers in setting up integrated mitigation strategies.

UNVEILING AND PROTECTING MARINE BIODIVERSITY –

We need to have better understanding of the distribution patterns and the dynamics, from the surface to the seabed, of marine biodiversity in the ocean and understand its role (functionality) in the ecosystem. Estimations point out that 90% of marine biodiversity remains undiscovered. The consequence is that we lack baselines on the number of species as well as their role in the ecosystem. Most of the seabed remains to be mapped and explored to uncover, understand and preserve its habitats and biodiversity. Meanwhile, human pressures, climate change, pathogens and invasive species are leading to the loss of habitats and biodiversity in many areas, including coastal areas. We also need to enhance our knowledge to understand the functioning of vulnerable marine ecosystems (including marine protected areas MPAs).

> **WHY:** Improving our knowledge on seabed features and characteristics is essential to map deep-sea biodiversity hotspots, set up adequate plans for their management (MPAs) as well as assess the impact of human activities in particular fisheries to adopt suitable management measures and to know how these measures affect the natural processes and human activities (e.g. fisheries) in the nearby areas.

MARINE ECOSYSTEMS HEALTH AND HUMAN HEALTH –

The relationships between human health and the health of marine ecosystems are still relatively unexplored and require further research. The degradation of the marine environment by biological (e.g. pathogens, bio-toxins from microalgae, etc.) and non-biological pollutants (heavy metals, chemicals, micro plastics, emerging pollutants, radioactive material, etc.) may affect human health through direct contact with polluted bathwaters or consumption of contaminated seafood. However, very little is known about the pathways and dynamics of many pollutants and pathogens in the marine environment and the effects on human health, marine organisms, ecosystems and maritime activities (e.g. aquaculture, fisheries, tourism). On the other hand, seafood and sea products have important benefits for human health, providing a healthy source of proteins, fatty-acids and other essential nutrients, but then again, trans-disciplinary research on seafood and human health is scarce.

> **WHY:** Addressing the complex nature of factors affecting environmental health and the relationships between human health and the health of marine ecosystems is critical to understand the benefits from the sea and minimise the risks of adverse effects on marine ecosystems and human health.

INTEGRATED GOVERNANCE OF COASTAL AREAS AND MARITIME ACTIVITIES -

The oceans, seas and coasts, from the surface to the seabed, are subject to an increasing demand of space from all sectors, increasing also the number and impact of human pressures on the marine environment. Moreover, coastal areas are the marine systems, which are most affected by human pressures, such as pollution, urban development, tourism, maritime activities and land industrial development. These pressures lead to the destabilization, erosion and destruction of the coastline and its habitats. The resilience of coastal and marine ecosystems (including coasts' structural features) to human pressures is highly uncertain which call for a precautionary approach and research to build knowledge about nature and ecological resilience, and to plan and manage human activities in an integrated way. Thus, further research efforts are needed to improve our understanding of the functioning of our marine and coastal ecosystems (including lagoons, deltas, salt marshes, estuary, fjords, estuaries, and beaches), their highly complex interactions with the ocean ecosystems, and the effects of human pressures.

Coastal areas and maritime activities are also threatened by risks linked to marine geological hazards (including fault movement, submarine volcanic activity, sediment failure and coastal subsidence), and impact of retrogressive failure or the generation of tsunami waves. These marine geological hazards call for monitoring strategies on geodynamics and the development of models to assess their risks and adequate management measures to minimise their impact on coastal areas, the maritime economy and ensure security of citizens.

The integrated management of human activities requires the implementation of maritime spatial plans (MSP) in conjunction with the adoption of integrated coastal zone management (ICZM) measures, which will also avoid conflicts of interest between sectors for the use of our coast and seas.

> **WHY:** Exploring the connections and synergies between and ICZM and MSP, including tools and models will enhance our knowledge to support policies (IMP, MSFD, CFP, etc.) for the integrated governance of human activities at sea and in coastal areas, with due attention to regional specificities (*e.g.*. cultural heritage, which is one of the key attractiveness of the tourist and leisure industries). Only with such knowledge will we be able to guarantee the security and sustainability of the coastal developments and their maritime activities.

4. A SUSTAINABLE BLUE ECONOMY

The oceans, seas and coasts, from the surface to the seabed, are crowding up with increasing demand of space from all sectors. Moreover maritime activities are facing major environmental and climate related challenges. Thus, environmental sustainability of maritime activities is essential to ensure that maritime growth and the blue economy are in compliance with the current EU environmental policy framework, while climate change effects (including the increasing incidence of extreme weather events) pose a risk for maritime operations and may hamper the growth of the maritime sectors. New technologies and innovative measures, as well as integrated approaches across sectors and disciplines are needed to boost an environmentally sustainable and climate change resilient blue economy. They are also needed to promote the sustainable growth of coastal activities and the economy of maritime regions, ensure the supply of seafood, raw materials and energy to Europe, as well as to generate jobs and improve the welfare of European citizens.

BOX III : A Sustainable Blue Economy.

Open questions:

1. How can we minimise the impact of the blue economy on the marine environment?

2. What impacts will climate change have on our present and future blue economy?

3. Which cross-sectoral and enabling technologies do we need to meet these challenges?

Answering such issues requires the development of a knowledge baseline on all uses of the sea, their needs to ensure sectoral growth, their existing or possible interactions, and their impact on the natural environment (BOX 3).

CROSS-SECTORAL, INNOVATIVE TECHNOLOGY –

Maritime sectors face common challenges for operations at sea to ensure the safety and to avoid damaging the marine environment. This needs to be solved through the development of a common technology base. Cross-cutting enabling technologies (e.g. ICT, electronics, robotics, sensors, nanomaterial's, biotechnologies, technologies for extreme weather conditions, deep sea environments, observing systems, surveillance, ROVs, etc.), and simulation models are key to assess the environmental impact of maritime activities, ensure the resilience of the maritime industries to climate change and to enable growth across all disciplines and sectors. Cross-cutting technologies are also essential for research and monitoring in order to ensure the sustainability of the maritime industries and support EU marine and maritime policies (e.g. MSFD, IMP, CFP, ICZM) and other policies with a marine component (e.g. Energy Policy).

Innovations in maritime industries (e.g. design of multipurpose offshore platforms, offshore energy devices; green ships, multipurpose vessels, greening of coastal activities, etc.), and in particular eco-innovation, represent major opportunities to boost competitiveness and job creation. The eco-innovation concept must be embedded in the design and planning of all future maritime activities, including coastal activities. It calls for an integrated and interdisciplinary approach as well as enhanced interaction between science, technology and innovation

> **WHY:** Investments in RTD to develop new technologies and innovative measures, through an integrated approach across sectors and disciplines will contribute to boost an environmentally sustainable and climate change resilient blue economy, and thereby generate growth and jobs and improve the welfare of European citizens.

RENEWABLE ENERGY –

A number of initiatives have been developed to generate energy from large offshore installations (e.g. wind power platforms, wave energy, tidal energy, inter alia). An integrated effort is required to strengthen Europe's competitiveness in this global market, while creating secure, minimum impact, cost efficient technological solutions. They must rely on an interdisciplinary approach as well as enhanced interaction between science, technology and innovation. Multi-purpose, environmental friendly platforms provide optimised solutions for different sectors, which need to occupy the maritime space to share costs and benefits associated with such investments. Such solutions would also contribute to minimize the demand for space for infrastructures at sea.

> **WHY:** Investing in integrated RTD towards eco-innovative technological solutions, i.e. large scale multi-purpose off-shore platforms, is a step to preserve the marine environment for future generations and promote the growth of industry.

DEEP-SEA MINING, OIL & GAS –

The global need for raw materials is ever increasing and we witness increased interest in exploring resources from the deep sea. Deep-sea mining constitutes a completely new area of possibilities. Seas and oceans still hold under the seabed significant reservoirs of oil and gas yet to be found. Harvesting from these resources requires careful exploration prior to exploitation based on the precautionary principal. Recently gas hydrates have also become a focus of interest due to their enormous untapped potential to secure the energy supply to Europe. These resources are often found in pristine areas with vulnerable, unique habitats and species, such as cold areas with slow recovery rates. Sound scientific knowledge, suitable deep-sea technologies, and multidisciplinary and precautionary approaches are necessary to guarantee that valuable mineral-, oil and gas resources are extracted with minimal environmental damage and risk of accidents and display high operational safety. In order to achieve optimal results, technology must be developed and carefully tested on performance. In order to assess impacts, environmental (including ecological) data must be registered to feed as input to baselines and trends in environmental monitoring programmes.

> **WHY:** The exploitation of marine mineral, oil and gas resources must be conducted based on sound scientific knowledge and suitable technologies to ensure safety and minimise risks and impacts on the marine environment. This requires that baselines be embedded from the beginning of the exploration throughout the exploitation phase.

FISHERIES –

Fisheries has recently moved towards an ecosystem based approach to management which requires the integration, in a holistic way, interactions between fishing activities, the dynamics of fish stocks, the marine ecosystem and the socio-economic aspects. The goal is to make fisheries more sustainable while keeping the profitability of the sector, for which we must improve our knowledge on ecosystems, develop end-to-end models for fish stock assessment, develop technologies to minimise the impact of fishing on marine ecosystems (e.g. development of more efficient and selective fishing gears and reduce the impact on the seabed) and analyse the socio-economic impact of management measures. Also, more reliable data are needed to support management. This calls for new sensors and systems to monitor the marine environment and the fishing fleet activities. Research is also needed to develop new products from bycatches to increase the added value of these unwanted captures.

WHY: Such research and innovation can contribute in developing new knowledge, technologies and approaches to promote the development of sustainable fishing practices and support managers to make more informed decisions.

SEAFOOD AQUACULTURE –

Research in aquaculture needs to be more integrated with the environmental research and ecosystem, to generate new systems, technologies and approaches minimising its impact on the marine environment (e.g. alternative feeds, new devices for avoiding escapees, etc.) and maximise its benefits (e.g. replenish of threatened wild stocks). The potential role of integrated multi-trophic aquaculture (IMTA) as a more sustainable, profitable and less risky solution for the sector should be investigated. Progress can be made in many cross-cutting issues such as animal health and healthy production of seafood and the interaction and synergies with other human activities. The benefits for offshore aquaculture from sharing infrastructures with other offshore activities needs to be further investigated. On the policy side, a scientifically integrated approach should be taken to spatial planning.

WHY: Research and technological developments are necessary to ensure the production of healthy and safe seafood, promote the sustainable development of the European aquaculture, including offshore and IMTA. This will then improve our ability to tackle the environmental and spatial management challenges relating to this sector.

MARINE BIOTECHNOLOGY –

Marine biodiversity offers a vast potential to develop new products with a wide range of applications (e.g. pharmaceuticals, nutraceuticals, enzymes, dyes, cosmetics, biopolymers, feeds for aquaculture, etc.), and inspire the development of biomimetic materials. Bio prospecting should be further supported to advance the discovery and development of new substances. Aquaculture of microalgae can provide biofuels and other products with a wide range of applications. The development of culture techniques for new organisms is crucial to ensure the supply of products and safeguard the preservation of the source organisms and their habitats. This would require a multidisciplinary approach across the technology providers and biomass producers supported by marine science. Research and technology are necessary at all stages, from bioprospecting to characterization of products and development of methods to provide the supply needed to scale-up production at commercial level.

WHY: Marine biodiversity offers a vast source for new bioproducts and bio-mimetic materials with potential applications in a wide range of sectors. Marine biotechnology and bio-mimetic provides great commercial opportunities and solutions, with a huge range of applications ranging from health (e.g. antibiotics, anticancer, drugs, etc.) to marine sensors (e.g. nanomaterials, adhesives, antibiofouling coatings, etc.). These opportunities will also benefit non-maritime industries.

MARITIME TRANSPORT –

Maritime transport is expected to increase in volume and importance and should be promoted as a climate friendly alternative compared to road-based transport. Maritime transport both impacts and is impacted by the marine environment and climate change. The sector needs to meet EU and international targets for greenhouse gas emissions and cope with climate change impacts. To do so development and deployment of sustainable and effective non-technological and technological solutions is critical.

Moreover, technology breakthroughs for surveillance of present and emerging shipping routes and vessel-traffic-systems and constructions of ships that withstand harsh climatic conditions are important for maritime safety. Further development of models to simulate spills and their impact on the environment would be a cost-efficient way to assess risks. Due attention is to be paid to logistic processes, maintenance, repair, retrofitting and recycling to ensure environmental sustainability. We need a sound oceans science and technology base to stimulate eco innovations and models to make maritime transport more sustainable to reduce its impact on the marine environment and overcome issues such as sound disturbance, pollution, vessel/platform recycling, ballast water and invasive species, collisions with marine mammals and other species. In this field, the maritime transport can benefit from an interdisciplinary approach, technology synergies and cooperation with other sectors like fishing, aquaculture, tourism and ocean energy and substantial advance can come through scientific cooperation. Particularly, new sensors and simulation models are required for calibrating and optimising intervention (in terms of speediness and cost/benefit remediation efficiency) after accidental oil spill events or illegal discharges.

> **WHY***:* Maritime transport can make important technological advances towards a more sustainable sector from synergies coming from cross-sectoral, scientific collaboration between disciplines.

DATA SHARING –

Maritime industries, scientists and policy makers share a common interest in marine data. Monitoring networks, common use of infrastructures for collection, standardization and sharing of data would provide benefits to all of them calling for a collective effort in planning, gathering and managing of data. In this field maritime industries can also contribute significantly to the common interest by providing new platforms to monitor the marine environment (e.g. ferry box, sensors attached to fishing vessels, offshore platforms, etc.)

> **WHY:** Maritime industries can contribute significantly to the common interest, by providing new ways to monitor the environment. Joint efforts in gathering and sharing of marine data, between scientists, industry and policy makers, will maximise the benefits of investments in this field.

5. ENABLERS

MULTIPURPOSE INFRASTRUCTURES TO ADDRESS OCEANS' LONG TERM CHALLENGES

Policy-makers, service providers, industries and scientists are all in need of data, calling for multi-purpose use. H2020 activities should support the development of marine research infrastructures (MRI) as well as ICT infrastructures needed for gathering, managing, sharing and storing marine data and information. The Marine Strategy Framework Directive (MSFD) will be one of the most important policy drivers for MRI development at European scale in the coming decade(s). Besides the pressures on biodiversity that it addresses, attention will need to be paid to new pressures like emerging pollutants, noise and marine litter.

REAL TIME, AUTOMATIZED DATA COLLECTION –

Data collection should be more automated and thereby cost efficient and fit for purpose, as well as linked to a long term monitoring strategy. Satellite remote sensing provides unique opportunities. Still the development of new sensors and the improvement of technologies will be critical in this field to collect new data both from in situ sensors (such as to measure pollutants, biological or biogeochemical parameters for which we currently do not have reliable sensors) and also from remote sensors (e.g. SMOS mission of ESA which is still in development including activities to check and validate remote sensing measures of salinity).

BRIDGING THE GAP –

There is a strong trend in marine research centres towards inter-disciplinary research based on integration between physical, biogeochemical, biological (including genetic) and ecological data to develop holistic models that allow to better understand the functioning of marine ecosystems and their services, and also to respond to the requirements of EU policies to move towards an ecosystem approach to the management of human activities. These efforts should also be supported by infrastructure to bridge the gap between all disciplines.

WITHIN THE SCOPE OF HORIZON 2020, IT IS IMPORTANT TO:

Identify, prioritise, streamline, optimise and support the development and maintenance of sustainable research infrastructures of pan-European interest such as the ESFRI Research Infrastructures of relevance to cover the current gaps of societal challenge of the oceans and the scientific needs to support these.

Achieve the goal of opening 1000 Research Infrastructures through the Transnational Access ("Performance Indicators" - Annex II of COM (2011) 811/3) with a significant rate close to 20%.

Promote the development of synergies between the various financing tools (e.g. H2020, Structural Funds, National and Regional Funds).

> **WHY:** The objective is to underpin the generation and use of new knowledge with a view to achieve major advances in the different fields of marine and maritime research (e.g. ocean observation, monitoring of pollution, seabed mapping, marine biodiversity, aquaculture, marine biotechnologies, risk assessments, ocean weather forecasting, etc.). It will also enable

growth in maritime industries in need of data both for deploying their activities and assessing the impact (e.g. offshore wind energy, aquaculture, fisheries, oil and gas, ocean energy, leisure, tourism, etc.). Finally, data is fundamental to provide support to the implementation of EU policies (e.g. IMP, MSFD; CFP, WFD, Birds and Habitats Directive).

CAPACITY BUILDING

A lot has been done in Europe to stimulate cooperation across scientific institutions, to a large degree through project funding. These networks can be challenging to sustain without funding in place.

There is also still potential for stimulating further the cooperation between institutions across sea basins and at Pan-European level to allow for improved human capacity building, exchanges of experiences, development of common strategies and sharing of data and infrastructure to develop new knowledge and to provide science in support of EU policies. This would also increase the critical mass in new research areas which are relatively small and still somewhat fragmented.

Capacity building cannot be seen in separation from the infrastructure capabilities we hold in Europe. Assessing these capacities through a social science perspective and comparing the modes of cooperation with other regions such as the US could provide useful input to the further development of our human capacities and investments in skills.

WHY: Lack of human capacities are critical bottlenecks to boost the growth of a sustainable blue economy and to support policy implementation. Careful planning is needed to ensure sufficient critical mass of workforce with adequate skills and competence to face the new needs of sectors and policy to deal with the complexity of marine systems.

JPI Healthy and Productive Seas and Oceans

Updated gap analysis

Including Infrastructure and Human resources

Interface "Marine Environment / Climate"
Research areas
The role of the ocean in past times as climate regulator, and the impact of a changing climate on this function
Understanding the effect of climate change effect on ocean circulation patterns, water masses formation and water exchanges through straits and the feedbacks on the climate
Downscaling of global climate models to predict the climate change impact at regional, sub-regional seas and local areas
Modelling extreme events impacts on coastal areas and shelf processes, including floods, coastal-erosion events and sediment dynamics
Understanding changes in oceanographic coastal and shelf processes induced by climate change (e.g. shelf currents, upwelling, stratification, primary production, river discharges, etc)
Understanding and quantifying changes, and assessing opportunities and risks in the Arctic due to the opening of the area as a consequence of climate change and melting of ice.
Developing holistic models including the integration of sparse in situ data, to better understand the interlinks between marine ecosystems dynamics and climate change to improve predictions: hindcast/re-analysis of variability of ecosystems evolutions in response to climate change
Understanding the relation between climate change and the spreading of invasive species, jellyfish outbreaks, HABs and mucilague events

Climate change and ocean acidification effects on coastal and shallow marine ecosystems
Climate change and ocean acidification effects on pelagic food webs dynamics and biogeochemical processes.
Climate change and ocean acidification impacts on the status and functioning of benthic marine ecosystems, including deep sea ecosystems and their biological diversity: defining tipping points
Effect of climate change and ocean acidification on the ecology, distribution and population dynamics of commercially exploited fish and shellfish species
Effect of climate change and ocean acidification on the ecology, distribution and populations dynamics of key, threaten and endangered species in marine ecosystems, including forage fish
Impact of climate change and ocean acidification on the biogeochemical and geochemical processes in the seabed and the bentho-pelagic coupling
Understanding the impact of climate change on biodiversity and the value of ecosystem good and services
Interface "Marine Environment / Marine – Maritime/Human activities"
Development of ecosystem models to improve predictions of ecosystems evolutions in response to anthropogenic and climate pressures
Development of knowledge to understand and model the effects of multiple stressors, including climate change, on the marine ecosystem functioning, habitats and biodiversity
Research to further develop indicators of GES to provide support to the implementation of the MSFD
Development of knowledge to minimize the impact of maritime activities related with coastal infrastructures, building and dredging (e.g. technologies for “greening” marine - maritime activities, including port expansion on land and in waters, building and dredging with nature among others)

Subseabed carbon storage and sequestration, risks and impacts on the marine environment
Identify, monitor and mitigate the impact of radioactive pollution in the marine environment
Identification of sources, pathways and fates of marine litter (from macro aggregates to microparticles) and assessing its impact on the marine environment
Production of biofuels from marine algae
Development of knowledge to implementation of the EBA to fisheries management for the sustainable development of fisheries
Innovative developments to minimize the physical damage of fishing to the marine environment and increase the cost efficiency and the selectivity of fishing activities to avoid by-catches and their impact non-targeted and endangered fish species
Automatic systems to improve the quantity and quality of data to monitor fishing and aquaculture activities and their impacts on the marine environment
Mitigating the impact of aquaculture on the marine environment (e.g. development of sustainable feeds, preventing escapees, preventing diseases and parasites, etc.)
Aquaculture of new marine organisms and algae to provide a secure source of organisms and raw materials for biotechnology applications
Investigate the potential of multitrophic aquaculture to make the aquaculture more sustainable and resilient to risks.
Aquaculture in benefit of the environment: restocking of threaten and endangered wild fish population
Valuation of ecosystem good and services and the impact of human activities
Design of vessels to minimize the impact of shipping activities on the marine environment (e.g. Ballast free ship, Low ballast exchange ship; etc.)
Development to new methods, approaches and technologies to prevent, fight against and remediate/bioremediate the impact of marine pollution (e.g. oil and HNS spills, heavy metals, organic chemicals, emerging pollutants and microplastics)

Improving models to simulate the dynamic of spills, their potential effects on the marine environment and the risks on the economy
Development of technologies to improve competitiveness of the maritime transport by reducing its carbon foot print (reduction of fuel consumption and CO_2, NOx, SOx emissions) including green shipping
Impacts of noise on marine environment and marine organisms : tools and technologies for noise reduction and noise monitoring
Monitoring, assessing and preventing risks from geohazards (earthquakes, volcanoes, landslides, sediment methane release and tsunamis) on the economy and population
Effects of atmospheric inputs on the functioning of the marine ecosystems: assessment of trends and future projections connected to industrialization and desertification.
Sources, distribution, dynamic and fate of pollutants in the marine environment, including microplastics and new emerging pollutants, and their effects on marine organisms and ecosystems
Dynamics of pathogens and parasites in seafood and assessment of risks to human health
Impact of pollution on seafood quality and safety: effects on human health
Eutrophication in coastal areas: drivers and impacts on coastal economies
Assessing the impacts and benefits of offshore wind farms and ocean energy on marine ecosystems
Ecological effects of deep sea mining and development of technologies to minimize its impact
Development of technologies to minimize the impact of oil and gas extraction (including gas hydrates) on marine ecosystems
Relationships between marine ecosystem health and human health
Development of tools and innovative measures to make the maritime tourism industry more sustainable

Development of technology, tools and approaches to build with nature and ecological resilience (e.g. dredging, coastal and urban development, etc.)
Development of technology, methods, approaches and strategies to recover marine litter
Interface " Marine – Maritime activities / Climate Change"
Climate change impacts on the economy of coastal areas (e.g. sea level rise, coastal erosion, extreme events, *salt-wedge intrusion*) and design of strategies for early warning systems and adaptation measures (e.g. coastal defences, ports, offshore structures, cultural heritage, etc)
Evaluating the consequences of climate change on the governance (MSP and ICZM) of coastal and maritime activities and the economic impact of management measures on sectors (e.g. maritime tourism, maritime transport, aquaculture, etc.):
Climate change impact on the production and location of offshore wind and ocean energy
Effects of climate change on the exploitation and harvesting of marine biodiversity
Climate change versus fisheries impact on fish stocks and the sustainability and performance of the fisheries sector
Risks and benefits of climate change for the aquaculture sector: adaptation strategies and measures
Impacts of climate change on maritime transport : opportunities and risks (sea level rise, Artic ice sheet melting, extreme events)
Design of vessels, including fishing vessels, with improved stability and sea keeping (including coastal vessels) and offshore structures to meet the challenge of extreme conditions.
Impact of climate change on maritime operations and development of technologies and measures to improve the safety (e.g. offshore platforms for oil and gas extraction, offshore wind farms, dredging, mining, etc.)

New technologies and approaches to monitor, in real time, the ocean and the effects of climate change on the marine environment through industry platforms (e.g. use of ferryboxes and other ships of opportunity, fishing vessels, offshore fix or deriving platforms, autonomous vehicles)
Improving ocean weather forecasting and warning systems and other related socio-economic services derived from marine monitoring and metocean data (e.g. tools and services for safer and more efficient shipping, maritime surveillance, tourism, warning on HABs risks, jellyfish invasions, etc)

Generic cross-cutting technologies
Research areas
Development of sensors and bio-sensors (and related IT systems) for in situ observation of the marine environment including climate observation
Molecular biology, genetic and omic tools for developing new methods and approaches to monitor and assess the GES of marine waters
Sensors (and related IT systems) and robotics for autonomous platforms and monitoring stations (e.g. gliders, floating buoys, ship of opportunity)
Development of buoys, gliders Hybri ROV and other autonomous systems or 'in situ' observation of the marine environment
Improve transmission technologies on real and delayed time for autonomous vehicles on Operational Oceanography from instrument to Satellite.
Improve transmission technologies from sensors to datalog on marine instruments and vehicles.
Hyperbaric technologies and robotics to observe and research the deep sea and its seabed
Development of more efficient technology and environmentally friendly materials (e.g. new antifouling agents , tools to reduce fouling, degradable materials for nets)
Development of technologies across marine and maritime sectors to build large sustainable offshore installation to operate safely in harsh climatic conditions.
Development of new corrosion resistant and anti-fouling materials and improvement of current ones
Technologies for underwater mining and exploitation of minerals from deep sea.

Life at sea. Development of new concepts for factories at sea for energy / food / deep sea resources exploitation
New technologies to lower the impact of waste disposal and other discharges (e.g. desalinization plants) on the marine environment
Bioprospecting marine biodiversity and discovery of bioproducts and biopolymers with applications to a wide range of sectors (e.g. health, cosmetics, nutraceuticals, aquaculture, industrial processes, maritime industries, etc.)
Development of marine bio-mimetic science (e.g. concepts, designs and materials)
Development of cross-cutting technologies for application to coastal structures/ offshore platforms/ ports / marina /logistic interfaces development
Design of multipurpose ships to satisfy the demand of multiple sectors (e.g. offshore wind energy, marine renewable, off shore aquaculture, offshore oil and gas, deep-sea mining, etc.)
Development of Information and Communication Technologies (ICT) for data management, including assuring quality of data and products
Development of technologies that ensure gentle and resource efficient harvesting and processing of seafood.
Knowledge / technology transfer across the marine / maritime cluster/ other activities
Projects and actions to promote synergies/ knowledge / technology transfer across maritime sectors (e.g. shipbuilding / maritime transport (freight and passengers) / offshore energy / fisheries / aquaculture/oil and gas/carbon capture)
Projects and actions to promote synergies/ knowledge / technology transfer between marine science and maritime sectors (e.g. use of offshore platforms for scientific purposes, , use of marine deep sea technologies for subseabed carbon storage and resources exploitation)
Projects and actions to promote synergies/ knowledge / technology transfer between marine science and other non-maritime industry sectors (e.g. design and development of new processes, materials, etc.)

Actions to support policy making
New knowledge for development of indicators and definition of targets for the GES descriptors at regional and sub-regional level to support the implementation of the Marine Strategy Framework directive
Development of new knowledge for the implementation of the CFP
Knowledge, including ICT modeling and simulations to support marine spatial planning and integrated management of coastal zones
Development of integrated knowledge, tools, technologies and innovative measures to promote the sustainable growth of European aquaculture in Europe through species diversification and genetic improvements of traits
Use of new molecular biology and genetics tools to improve seafood quality, safety and traceability to European consumers
Understanding the dynamics of vulnerable marine ecosystems and essential habitats to support management measures to set up reserves and coherent networks of MPAs
Mechanism to secure transfer of knowledge from science to policy to provide sound advice to policy makers
Knowledge to support the management and ensure the sustainable use of marine biodiversity
Knowledge as basis to define a common legal framework regarding ownership of biotic and abiotic resources and IPRs for its exploitation and commercialization
Think tank and foresight to feed the continuous and long-term development of the JPI bringing it to the next ERA step as one of the framework conditions requested
Knowledge on how the legal framework in various countries affect the development of maritime and marine knowledge based (bio-) economies in order to help authorities facilitate development of the marine and maritime economy

Create taxonomic databases linked to genetics databases for European regional seas in support of the MSFD and to prevent grey taxonomy
Knowledge to preserve the maritime heritage and enhance cultural and societal benefits from seas and oceans

Marine Research Infrastructures
Research Areas
Establishing robust mechanisms to ensure and improve sharing of and access to marine data, including real-time data; coming from different sources and regions (particularly through the development of the European Marine Observation Data Network – EMODNET
An improved convergence between different marine research infrastructure projects, with a view to ensure that they respond better to societal and policy needs
MRIs to undertake over the long term a complete seabed mapping of all European basins (including identification and characterization of habitats).
Sustained Long-term European deep water transects including regional seas (GO-SHIP)
Enlargement of existing MRIs to widen their services or geographical scope to develop truly pan-European MRIs to respond to societal challenges
Sustained Consortium of European research vessels
Development of an European offshore ocean observatory of fixed stations.
Network of biodiversity observatories to study marine biodiversity changes and evolution in response to climate change.
Cabled sea-floor stations

Development of an European marine infrastructure to monitor marine pollution and conduct pollutant risk assessment
Large infrastructure to develop aquaculture research on key species (e.g. bluefin tuna)
MRIs to assess measure exchanges through straits in European sea basins
European HABs monitoring and warning observatory
European MRI to monitor slope and deep currents and sedimentary processes in European waters
Development of the regional dimension of research infrastructures for aquaculture to ensure they are tailored to respond to the regional needs so as to maximize the benefit for the industry
Network of calibration labs and hyperbaric tanks (for sensors and Instrumentation development)
Smart Ocean observatory programme

Human Resources and capacity building
Research Areas
Stimulate recruitment to marine and maritime research by promoting the attractiveness of marine and maritime careers among the youth.
Develop networks of research institutions at pan-European level to further promote the cooperation in research and the exchange and training of researchers and technicians
Develop actions to engage and retain the "best brains" to solve the crucial issues and guarantee the development and consolidation of a professional career for researchers and technicians and promote their careers opportunities through long-life training schemes

Increase gender equality
Develop marine and maritime hubs, involving research, academia and industry to improve the skills of young researchers to satisfy the demand of science and industry and promote jobs opportunities
Increase visibility of the marine issues and reach common understanding among researchers, business communities, politicians and the general public in order to rise our youth's interest to work in this field
Increase and improve the educational and training possibilities to cover the increasing demand of young researchers and technicians with interdisciplinary skills
Stimulate the urgent need to recruit scientist to work in some disciplines that are very little attractive to researchers but of great relevance in marine environmental research (e.g. phytoplankton and zooplankton taxonomy)
Increase the cooperation on education and specialization within marine and maritime RTD at pan-European level.