Acronym: COLUMBUS

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Deliverable 3.2: Assignation of Knowledge needs to Competence Nodes

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CONTENT

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Executive Summary

The research funding landscape in Europe and even worldwide is diverse and fragmented, but some key statements can be made with regard to European knowledge needs in marine and maritime research:

- There is an ongoing need for fundamental research to comprehensively understand processes and functions of our coasts, seas and oceans. There are knowledge and data gaps in relation to the state of our oceans, impacts relating to marine resource exploitation and the risk of pollution to habitats, ecosystems and human health.
- Policy requires a solid knowledge base for decision making. This knowledge base can be evidenced by intensified (automated) ocean observation by fundamental and applied research.
- The complex challenges of sustainable Blue Growth should be addressed by combining expertise from a range of scientific disciplines and stakeholders.
- Fragmented and non-coordinated research efforts in marine and maritime science hinder interdisciplinary learning and slow the progress of technological breakthroughs in key technologies and innovative business sectors.
- Frequent assessment of risks, impacts and vulnerabilities must be ensured, through high temporal and regional resolution monitoring, analysis and prediction.
- Access to existing databases and continuously securing availability of data (sustainable data management) is essential for proper policy decisions and governmental management.

Introduction & Approach

As part of the Work Package 3 (WP3) analysis, the COLUMBUS Competence Nodes (CNs) were asked to develop a profile of their CN. Each CN consists of a leader, a fellow and several Node partners from the COLUMBUS consortium which ensures a strong interaction and sharing of knowledge between the CNs.

These CN profiles were originally based on individually selected strategic documents out of the total list detailed in Annex 1 of Deliverable 3.1. These profiles contain two sections: 1) the CN vision, state of the art and relevant value chains; and, 2) the preliminary listing of knowledge challenges, gaps and needs for the specific sector. The profiles are living documents, to be adapted throughout the timeline of the project, based on the experiences of the project partners and input from stakeholders. The identification of knowledge needs, and a subsequent definition of keywords for each CN, was used to identify projects for the knowledge supply component of the project, WP4.

On 8th and 9th of July 2015, COLUMBUS partners met in Berlin for a partner progress meeting. Under WP3, a one-day group discussion and activity-based meeting took place, with the key objective of allowing each of the COLUMBUS CNs to brainstorm with project partners to review, and improve, the

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above mentioned competence profiles. The second part of these profiles covered the identification of the key challenges, bottlenecks and knowledge gaps in the sectors and sub sectors, identified through a literature review of sector relevant documents and reports. In the following, a short introduction on a specific CN will be given followed by a description of specific knowledge needs.

Allocating knowledge needs to Competence Nodes

The work within the CNs and the exchange between them is a key element of the COLUMBUS project. The COLUMBUS project will conduct three cycles of knowledge collection, analysis and transfer to ensure that case studies are developed during the project's lifetime. Fixed milestones will ensure that the project outcomes will meet the questions raised in the beginning. The content of this deliverable will provide guidance in identifying potential knowledge to carry through this cycle.

Table 1 shows the subsectors and subthemes of each CN, to provide an overview of the scope of each CN, as detailed in the project application (DoA). As shown in the table, the CNs are very different in scope and structure, which makes it difficult to compare the CNs using predefined categories or factors. The CN profiles have been created to recognise the disparity across the CNs, to allow each CN with the chance to emphasize its own characteristics. The collection and analysis of knowledge, however, will be completed using a common methodology and form, as provided by WP2.

Table 1: Subsector and subthemes of each Competence Node

Competence Node	Subsector/ Subtheme
Fisheries	Fisheries Management
	Gear/Technology
	Stock assessment
	Seafood value chain
Aquaculture	Biofouling
	Breeding and Husbandry
	Quality
	Health and Welfare
	Sustainable aquaculture
	Production
	Supply sector and full value chain
Monitoring & Observation	Marine data and information acquisition, storage and access systems
	Monitoring and observation technology and systems (e.g. sensors, biosensors, bioinformatics, seabed mapping, Ocean observing systems, etc.)
Marine Biological Resources	Biomass
	Biocompounds for applications in e.g. Aquaculture, food, feed, biomaterial, biotechnology
	Marine genomics
	Blue biotech
	Marine ecosystem

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Maritime Transport & Logistics	Shipbuilding
	Shipping and operations
	Maritime logistics infrastructures
	Operations and Port operations (incl. safety & security, surveillance)
	Marine engineering value chains
Marine Physical Resources	Marine & offshore renewable energy
	Offshore oil & gas
	Marine aggregates
	Deep Sea mining
Maritime Tourism	Cruise and Cruise supply chains
	Leisure marine activities
	Marine infrastructures
	Leisure boat-building
	Marine engineering value chains
	Coastal/arctic tourism
Marine Governance & Management	Coastal & ocean governance and management
	Finance modelling & prediction
	Socio-economics
	Environmental impact assessment
	Water resource management
	Marine spatial planning
Marine Environment & Futures	Oceanography – in situ long term automated observation
	Biodiversity
	Climate change and effects on marine environment
	Ecosystem services

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Fisheries

Description of Competence Node

The strategic vision of the EU fisheries sector is to ensure that fishing activities contribute to long-term environmental, economic, and social sustainability, thereby contributing to the Europe 2020 Strategy for smart, sustainable and inclusive growth (see CFP). This includes a range of aspects, such as the aim to ensure traceability, security and quality of products marketed in the Union, contribute to increased productivity, stable markets, availability of food supplies, reasonable consumer prices and a fair standard of living for the fisheries sector. This is in line with financial measures given in for European Maritime and Fisheries Fund (EMFF) that aim to promote competitive, environmental sustainable, economically viable and socially responsible fisheries. There is a need to improve the sustainability and competitiveness of aquaculture as well as to foster the cultivation of aquatic products.

Overall, the fisheries in EU are regulated by the Common Fisheries Policy (CFP). Since the 2002 reform of the CFP, there has been increasing focus in Europe towards implementing multi-annual or long-term management plans. Besides given more stable investment possibilities for the fishermen, the long term management plans have also been introduced to avoid political disputes on TAC setting. Additionally, there has been the generic trend during the last decade to move away from the Precautionary Approach and towards Maximum Sustainable Yield (MSY) as the overarching management objective. Besides that, the landings obligation, introduced in the recent CFP reform, is a major change that takes steps towards optimizing the overall yield of oceans. This reform comes after many years of battling discards in fisheries, a battle that was hard to win due to the economic incentives to discard.

The EU fishing fleet consists of around 86.000 vessels with a combined gross tonnage (GT) of 1.7 million tonnes and a combined engine power of 6.7 million kilowatts (kW). According to DCF data, the EU active fleet generated direct employment for around 151 thousand people in 2012, corresponding to 120 thousand full time employees. The fleet spent almost 5 million days at sea, consumed around 2.4 billion litres of fuel and landed 4.3 thousand tonnes of seafood in 2012 (AER 2014)[1].

In 2012, the EU fleet generated €6.9 billion in revenue, amounting to €3.3 billion in Gross Value Added and €458 million in net profit. In 2012, 6.6% of the fleet´s revenue was retained as net profit. However, as the EU fleet is very diverse, operating in many different fishing regions using a wide variety of fishing techniques, this overall positive result did not apply to all fleets. Five national fleets

[1] Scientific, Technical and Economic Committee for Fisheries (STECF), 2014: The 2014 Annual Economic Report on the EU Fishing Fleet (AER), https://stecf.jrc.ec.europa.eu/reports/economic

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made overall net losses, and while the performance of the large-scale and distant-water fleets improved in 2012, the small-scale fleets tended to deteriorate (AER 2014)

The European Union is a major fish market, regulated by the common organisation of the markets in fishery and aquaculture products (4). In 2011, the annual consumption per capita was 24.5kg, a total of 12.3 million tonnes, representing €52.2 billion. However, consumption varies considerably from one member state to another. Northern member states buy more processed fish, while those in the south prefer fresh fish products. Eastern European countries are still below the EU average, but are registering increased consumption. The major part (75%) of the fish for consumption comes from fisheries, while aquaculture produces the remaining 25% (FMR 2014)[2].

The consumption of the EU is larger than the combined landings and production, making EU the largest importer of seafood products, making up 24% of the total value of world fish trade. The seafood self-sufficiency rate has remained stable at around 45% between 2008 and 2011, meaning that more than half of the seafood consumed in Europe is imported. In terms of value, shrimp is now the leading imported species, although tuna, cod and salmon are still the main species consumed in the EU (FMR 2014).

Knowledge needs in policy

The scope of the **Common Fisheries Policy (CFP)** includes the conservation of marine biological resources and the management of the fisheries targeting them. A major challenge of the CFP is to make objectives and regulation that lies within the larger Europe 2020 Strategy for smart, sustainable and inclusive growth. With regard to the CFP, following challenges including knowledge needs can be defined:

- Ensure long term resource optimization
- Spatial management
- Improve communication flows on stock assessment
- Further implementation of ITQ systems
- Long term management plans in order to reach/keep MSY
- Improvement of stock assessment methods
- Compliance on landings obligations
- Optimize economic efficiency of fisheries

[2] European Market Observatory for Fishery and Aquaculture (EUMOFA): EU Fish market report 2014, http://ec.europa.eu/newsroom/mare/itemdetail.cfm?item_id=15471

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Food security is still a major issue worldwide and EU has its obligation to contribute to that. Even though aquaculture production has increased rapidly the past 10 years, fisheries is still the largest sea food provider (FAO, 2014). Furthermore, they are providers of feed to the aquaculture production. In order to optimize the amount of seafood that reach the consumers, there are following challenges:

- Secure maximum sustainable yield of the resources (MSY)
- Avoid discards in fisheries
- Search for currently unutilised fish resources
- Better utilization of the landed fish
- Improving safety on board of fishing vessels
- Waste of seafood should be minimized throughout the value chain

Climate changes lead to changes in the environment, and these lead to changed behaviour for some species. This is a challenge for both fisheries and the management of fisheries that may need to be adapted. Some of the challenges regarding climate change are:

- Migration of species
- Spatial resource disputes due to changed migration patterns
- Invasive species replacing commercial stock

The European Union (EU) is the world's largest maritime territory and marine resources make a significant contribution to each Member State's economic prosperity and social well-being. The **European marine environment** must therefore be protected to ensure that it is healthy, productive and safeguarded for the use of future generations. The environment is regulated by the Marine Strategy Framework Directive, the Nature Directives and the habitat directive and the fisheries are restricted to this. The challenges to fisheries include:

- Spatial planning
- Marine protected areas
- Good environmental status versus better fishing opportunities
- Incorporate an ecosystem based approach

The knowledge needs in the fisheries sector can be summarised as follows:

Challenge	Knowledge need
Improve methods and specific case studies of environmental impact assessment	Improve the methods of environmental impact assessment
	To make case studies that can be used of fisheries managers
Reduce by-catch in fisheries	Improvements of selective fishing gear

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Optimize fisheries in spatial planning	Identify how to optimize fisheries in spatial planning
Marine protected areas	Identify whether further marine protected areas should be established based on ecological and economic considerations
Good environmental status versus better fishing opportunities	Increase knowledge on how to optimize multi-objective issues within fisheries
Incorporate an ecosystem based approach	Gain knowledge of whether the ecosystem approach should supersede traditional approaches in stock and advice to Total Allowable Catch (TAC)

Knowledge needs in science

The marine research area supports fisheries and maritime research can be used to optimize fishing gear, procedures and yield.

- Improving sea habitat modelling, including sea habitat mapping
- Improving stock assessment data, monitoring and methods
- Improve methods and specific case studies of environmental impact assessment
- Profound knowledge about Invasive species (as new commercial fisheries?).
- Identification (need for data) of under-utilised fish resources – mesopelagic species.

Knowledge needs in industry

Fisheries and fisheries products can be divided up in two subsectors, the fisheries for consumption and the reduction fishery. In general, the value chain of seafood products is the same for both the reduction fishery and the fisheries for consumption. There are some key challenges which affect the fisheries sector as a whole and in this context, knowledge needs have evolved:

Challenge	Knowledge need
Reduce fuel & energy consumption in fisheries	Development of more energy efficient fishing gears
	Identify ways to recycle the energy in processing industries
Smart, green and integrated transport	Identify possible ways to reduce the transport through the value chain
	Identify how regional use of seafood products can be increased
Search for currently unutilised fish resources	Identification of possible unutilised fish resources, such as mesopelagic species
	Assessment of whether it is economically viable to explore this resource
	Identify whether there are need for new technologies to catch these species

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Better utilization of the landed fish	Identify potential use of landed by-catch
Waste of seafood should be minimized through the value chain	Identify seafood waste reduction potentials
Reduced Trade barriers	Identify whether there is a need to lower the trade barriers for seafood products in order to secure the future seafood supply
Improvements in environmental friendly technology	Development of passive gears that prevent seal consumption of catches
	Development of selective trawl gears
	Development of energy savings in vessel and gear design
	Analysis of the environmental, technologic and economic effects of technical developments

Knowledge needs in society

Fish is a very high quality source of animal protein for human nutrition. According to WWF (2010), three billion people cover at least 15% of their average protein consumption by seafood. Omega 3 is also an essential acid for **human nutrition**. With a growing population worldwide, the challenge is how to optimize the biomass of fish protein and omega 3. The development in the fisheries goes towards larger but fewer vessels, which provides a **challenge for the small scale fisheries** and small size fisheries dependent societies.

The CFP also aims for supporting society. This includes both social and economic factors for both fishermen and consumers.

- Ensure economically viable fishing enterprises, incl. small scale fishermen.
- Traceability and labelling of seafood products
- Certification of fisheries
- Regionalization and stakeholder involvement

The following key challenges and respective knowledge needs are relevant for the Fisheries sector:

Challenge	Knowledge need
Sustain small scale fisheries	Improve management measures on how to sustain small scale fisheries
	Identify whether there are initiatives that can sustain these areas
Regional seafood systems	Identify how regional use of seafood products can be increased
Certification of fisheries	Increase the amount of certifications within fisheries
Regionalization and stakeholder involvement	Enhance stakeholder involvement in the decision making of fisheries regulation

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Aquaculture

Description of Competence Node

European aquaculture is a diverse activity that covers the production of finfish, shellfish and other aquatic species, including algae, in both freshwater and marine conditions. Over the last decade, EU aquaculture has seen little or no volume growth (estimated at 0.5% Annual Percentage Rate), compared to estimated global aquaculture growth of 7% Annual Percentage Rate over the same period. Shellfish (mainly mussels and oysters) lead production in volume terms. Fish lead production in value terms.

More than 70 different fish species are cited for aquaculture in the EU, but production in 2013 was dominated by rainbow trout, Atlantic salmon, gilthead sea bream, European sea bass and common carp. These five species make up 90% of all fish production in the region. Large cage systems are the dominant production technology for cold-water marine fish; smaller cage systems for warm water marine fish; intensive flow-through systems for freshwater fish and supported or suspended culture for shellfish[3].

Within the EU28, the sales value of aquaculture was €4 billion for 1.35 million tons (fish and shellfish), employing more than 80,000 people; the number of micro-enterprises/family firms, as well as employees in processing/distribution in vertically-integrated companies makes such calculations very difficult. France, Greece, Italy, Spain and the UK provide nearly 80% of all aquaculture production. While EU aquaculture is dominated in number by microenterprises and family firms, certain sub-sectors contain large multi-national companies (marine cold and warm water sub-sectors).

The major effects of public policies are related to the environment, water use, disease treatment and control, food safety. Furthermore, aquaculture is an evident component of many recent and new European strategies, including Blue Growth and the Bioeconomy. The reformed Common Fisheries Policy will contribute to the Europe 2020 strategy for smart, sustainable and inclusive growth. Multiannual national strategic plans should lay out the response of the Member States to the Strategic Guidelines established in the COM 299 (2013), contribute to governance and link priorities to financial allocation of European Maritime and Fisheries Fund along with the identification and presentation of national best practices.

Knowledge needs in policy

Aquaculture is one of five identified focus areas of the EU Blue Growth strategy. The sector has enormous growth potential but challenges like lack of maritime space, lack of investment, licensing

[3] European Parliament (2014): The Long-Term Economic and Ecologic Impact of Larger Sustainable Aquaculture, http://www.europarl.europa.eu/thinktank/de/document.html?reference=IPOL_STU%282014%29529084

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procedures or knowledge gaps regarding the environmental footprint of Aquaculture are hindering aspects. With the Blue Growth strategy, the establishment of the Technology Platform EATiP (European Aquaculture and Innovation Platform) and the allocation of research funding via HORIZON 2020 the EU has provided a framework for future activities. From the governmental point of view, following challenges and respective knowledge gaps were identified:

Challenge	Knowledge need
Spatial Planning	Adapt existing and develop of new planning tools used for site selection based on ecosystem assimilative capacity and spatial planning for further aquaculture development
	Avert licensing impediment due to lack of locality data
	Adapt existing and develop new management tools and measures used for environmental monitoring, production optimization and minimizing aquaculture impact
	Harmonize environmental regulations and legislation, and implement regulations between European Countries (for example, the case of shellfish farming in Natura 2000 sites and Marine Protected Areas)
Evaluation of the ecological impact of biogenic wastes from fish aquaculture in benthic and pelagic ecosystems (Biogenic waste assimilation capacity)	Establish a scientific based concept for the management of biogenic waste emission to open waters and relevant indicators for chemical impacts and ecosystem state as a basis for and an implementation of the Water Framework Directive (WFD)
	Determine assimilative capabilities per volume and area of sea floor of coastal ecosystems and the critical loading rates of biogenic wastes for main water types
	Establish integrated management tools which consider assimilation capabilities, hydrodynamic energy and presence of sensitive and habitats as a tool for siting, spatial planning and ecosystem based management of aquaculture

Knowledge needs in science

Primarily applied research is needed to understand interactions between aquaculture systems and the environment (open systems), to gain better knowledge about the animals welfare or to provide the knowledge for basic questions regarding terms of nutrition or animal's welfare and health. In detail, following knowledge gaps exist:

Challenge	Knowledge need
Understand the fate and cumulative effects of persistent agents used in aquaculture and minimizing their impact on the environment	Understand mechanisms and risks for harmful ecosystem interactions of alternative products for disease control (e.g. vaccines, probiotics, immunostimulants), chemical antifoulants, new feed diets and new feed ingredients
	Focus research on the impact of pollutants on shellfish' health (e.g. pesticides) and the means to eradicate the sources of pollution

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	Improve access to field data with the possibility to build a transparent surveillance and reporting network of the fish infections and volumes and classes of pharmaceuticals used by fish farms to regulatory agencies in order to minimize their usage and their impact into the environment
Minimise the threat of existing, emerging and exotic diseases	Understand of transmission and infection mechanisms, of pathogens at all levels to and from farm, through country to Europe wide
	Improve strategic data availability through standardization
	Evaluate the relative importance of health and welfare threats, including bio-economic modelling and risk assessment
	Understand the causes of the shellfish mortality crisis and find solutions
	Improve environmental monitoring (including predictive tools) and information towards professionals, including a better responsiveness of monitoring networks.

Knowledge needs in industry

The aquaculture industry covers quite a range of technical, environmental and economic challenges. On one hand, we are aiming for high quality products to a competitive prize. On the other hand, the impact on ecosystems should be as small as possible. Following knowledge needs are actually on the agenda:

Challenge	Knowledge need
Minimising emissions of biogenic matter from aquaculture and thus the impact on ecosystems	Improve feeding technology and feed composition in order to minimize fish feed discard and biogenic emission from aquaculture installations per unit fish produced, and to examine if reduced emissions can allow larger production units
	Learn how optimal siting and the best available technology for environmental management can minimise the potential environmental impacts of emissions per unit fish produced
	Under conditions of minimal biogenic emissions, to explore the potential environmental benefits of an expansion of marine aquaculture of fish, shellfish and macroalgae to exposed Atlantic and European marginal seas
	Explore potentials and technological challenges of utilising wastes from existing and new European cage fish farms in exposed waters for IMTA, with a focus on co-farming of macroalgae and vulnerable marine invertebrates
Environmental use of resources	Minimize pressure on terrestrial plant production, land and water resources used for production of nutrients and raw materials

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	Explore the use of nutrients from natural reserves and/or eco-friendly production schemes, e.g. algae from bioremediation projects, insects raised on recycled organic waste
	Design and implement energy efficient systems for production, collection, processing and storage of aquaculture products
	Ecosystem services: Conduct research on the goods and services of shellfish and pond aquaculture, and quantify them in order to better address the benefits of these forms of aquaculture in a broader environmental and social context
	Establish beneficial impacts of shellfish and algal culture as a carbon and nitrogen sink (improvement of coastal waters)
Novel Nutrient Delivery Systems	Improve knowledge on nutritional value of European farmed fish
	Novel and improved larval feed technologies
	Adapt and Utilize advanced methods to understand and model nutritional responses
Improved Feed Utilization	Formulation of targeted feed compounds, feeding and fish management practices that condition farmed species to novel feeds, increase adaptability, reduce stress, and increase biological efficiency
	Novel technology and improved processing routes for cost effective and sustainable fish feed production
	Development of feed and breeding methods to a) maximize protein accretion and minimize lipid deposition, b) achieve optimal product composition promoting human health

Knowledge needs in society

The challenge regarding societal issues in the aquaculture sector can mainly be identified in **awareness rising** and elucidation of the wider public. Especially in Europe, society is increasingly critical towards aquaculture products. In order to promote sustainable aquaculture one has to improve the image of the sector. A further aspect is the **local marketing as p**eople prefer purchasing products from their region. For society, the following needs could be identified:

Challenge	Knowledge need
Communicate unbiased scientific knowledge on the environmental interactions of aquaculture in order to improve public perception	Provide and make available unbiased information on the interaction of aquaculture and the environment
	Identify the key stakeholder groups to target with proactive advocacy and reactive response and develop and strengthen measures for improving the public perception of aquaculture
	Understand consumer perceptions of aquaculture across Europe so that public communication campaigns are targeted and responsive

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Successful communication of the role European aquaculture sector plays in the society	Base Aquaculture Communications upon scientific evidence validated by Agencies or Environmental Protection Agencies
	Cultivate the societal understanding that aquaculture is a viable source of safe and healthy food production, providing employment, rural development, and food security
	Position strategically and positively differentiate European aquaculture from other recognised competent authorities at a regional, national and European level (e.g. Food Safety sources of food production, and to bring consumer acceptance for European aquaculture products in-line with other mainstream food production sectors)
	Conduct more comprehensive and reliable studies on the socio-economic aspects of the aquaculture profession, other than those relating to the production, to better understand the sector: market conditions, economic importance of the sector, sociological knowledge, business needs, economic sustainability of businesses, etc.
	Promote sustainable aquaculture practices globally by transferring knowledge and technology, and to tackle the global challenges of food production, environmental protection, and public health
Educate consumers and improve their attitude towards aquaculture products	Conduct evidence-based risk-benefit analysis for all consumer groups including people with special dietary needs
	Issue clear recommendations and guidelines for informed policy making on recommended consumption levels
	Develop communication strategies to educate consumers about the facts to change incorrect perceptions of aquaculture products
	Conduct studies on the carbon footprint of local aquaculture products compared to non-EU products and to other products from aquaculture and from other farmed animals
	Develop communication strategies to persuade consumers to consume sufficient aquaculture products to optimise their health through targeted briefings to relevant media, medical personnel and schools
	Map the consumption patterns of aquaculture product across Europe
	Revise the system of ongoing communication in respect of Rapid Health Alerts

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Monitoring & Observation

Description of Competence Node

Currently Europe's ocean observing infrastructure capability, although technologically quite advanced are not properly coordinated among owners and governments. It ranges from research vessels, observing and monitoring infrastructures, (which include networks of satellite-based, airborne and *in situ* platforms and sensors), ROV's and AUV's as well as marine stations and data management facilities. Until recently, the collection, storage and accessibility of marine observations and data has been proceeding in an uncoordinated and *ad-hoc* fashion.[4] There is a large degree of variability in spatial and temporal data coverage and many gaps exist. Initiatives such as EMODnet have made strides towards integrating with other EU initiatives - namely the Copernicus Marine Service (formerly GMES - Global Monitoring for Environment and Security) and WISE-Marine - using common standards (such as INSPIRE) and in compliance with the principles of the Shared Environmental Information System (SEIS). Yet certain data and information – especially from monitoring activities - is lacking, hidden from users, or is not available in a usable form. There is currently a lack of sustained funding and a complex policy and governance framework making an integrated European Ocean Observing System a concept more than a reality.

Europe's current observing capacity, designed mainly for monitoring and understanding the marine environment, must now be developed with user needs in mind, for marine and maritime management and policy development but also addressing the needs of industry and civil society. These needs will vary on a sectoral and regional basis and in response to as yet unforeseen events.

The '**Monitoring and Observation Node' could be considered to cover any sector that contributes to, or utilises, marine knowledge** (data, data-products, information and services). Sectors generating marine knowledge could range from space technology industries to IT specialists, to academic researchers in various fields (modelling and simulation, climatology, oceanography), public monitoring bodies, the fishing industry etc. Users of marine knowledge could include policy makers, academic researchers, port and harbour authorities, the offshore energy industry, aquaculture and fisheries sectors, maritime transport, deep sea mining and maritime security, to name but a few. In some cases, the sectors generating marine knowledge are also using marine knowledge e.g. academia, fisheries.

For the purposes of this exercise we will consider **'Monitoring and Observation' as the 'marine knowledge sector'** and define it as the infrastructures (e.g. research fleets, observing and monitoring systems, marine stations and e-infrastructures), people (technicians, technical experts, scientists, engineers, IT specialists) and services (public environmental monitoring bodies, companies producing

[4] EU COM (2010): Marine Knowledge 2020: Marine data and observation for smart and sustainable growth, http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52010DC0461

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value added data products) that combine to support the generation of marine knowledge in the form of data, data-products, services and information via *in-situ* or *ex-situ* marine monitoring and observations for end-users in policy, science, industry and civil society.

Funding of marine knowledge is only one component of the total EU maritime policy budget. For the period 2014 – 2020, the Commission estimates annual funding of marine knowledge to be in the range of €207million for data collection (including data collection for fisheries and satellite observations (Copernicus), €26.8 for data assembly, and €10million for ocean forecasts.

Future funding mechanisms could include public-private partnerships and industrial investment; European structural funds for Marine Research Infrastructures and improved mechanisms to enable coordinated Member State investments, possibly via JPI Oceans.

Knowledge needs in policy

The European landscape of Marine Research Infrastructures (MRIs) governance initiatives is too **complex and fragmented** and this is an obstacle to achieving optimal impact of MRIs. Considering oceanographic research vessels as an important component of MRIs, initiatives such as EuroFleets and OFEG have made some progress towards the **coordination of these at European level**. However, this could be further improved to maximise their potential.

The multiplication of governance frameworks for specific categories of ocean observing infrastructures calls for a **strategic framework identifying key societal needs and objectives** at European level, and providing for a coordinated development of the different initiatives, MRIs, projects and networks via an integrated European Ocean Observing system or EOOS.

More detailed the knowledge challenges and knowledge needs within the Monitoring and Observation Competence Node can be described as follows:

Challenge	Knowledge need
Gaps in the knowledge base on the condition of marine ecosystems and marine biodiversity	What process can facilitate targeted interdisciplinary research to e.g. progress MSFD implementation?
Outdated and internationally not integrated nor harmonised research infrastructures	Whilst AUVs and drones have huge potential as observation platforms, there is an urgent need for international maritime regulations on their use.
	Consider how European observation and monitoring platforms (e.g. via initiatives such as Fixed point Open Ocean Observatory network (FixO3) and OFEG) can be integrated.
	What mechanism can ensure sustainable funding for ocean sensors, new platforms and cross-sector research?

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Knowledge needs in science

As provider of marine knowledge, the Monitoring and Observation Node is engaged to describe scientific challenges and needs. Generally, there are spatial, temporal and thematic gaps in marine data collection programmes/projects and a sustained effort is needed. There is a special need to meet important gaps in the mapping of European sea beds.

The following scientific knowledge needs on European level were discovered:

Challenge	Knowledge need
In-situ synoptic multi-variable sensing of the whole water column worldwide	How do we ensure to continuously observe the deeper ocean (below 2000m)?
	There is a need to integrate both, coastal and open ocean observations.
	Development of biogeochemical and biological sensors for automated observational platforms
	New platforms (e.g. gliders), methods and technologies like genomics and marine acoustics should be explored
Predictive capability in identifying observational gaps	Improved methodologies on statistical data assimilation

Knowledge needs in industry

Besides MSFD implementation and ecosystem based management there is a big challenge to meet the **growing demand for marine observations and data in support of blue growth**, e.g. marine resources or better climate predictions through the development of an effective, integrated and sustainably-funded European Ocean Observing System.

It is a bottleneck that some **data is not freely available** to industry and that data generated by resp. for industry may not freely available to other potential users.

Knowledge needs in industry are especially focused on technical challenges:

Challenge	Knowledge need
Communication/information exchange gap between industry and science on needs in ocean observation and monitoring	There is a need for advanced technology in long-endurance automated underwater vehicles (AUVs) to facilitate monitoring and high resolution seabed mapping in remote areas.
	An improved industry / science interface would guide scientific research towards greater societal relevance

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	and focus knowledge creation on areas where new technologies and products are most needed
Availability of cross-sectorial monitoring data	There is a need for mechanisms to establish if the present observation infrastructure is the most effective possible - such as via the EMODnet sea basin check-points
	lack of expertise to implement big data applications, synchronisation across data sources, data accessibility and integration, ownership issues, security concerns with regard to data protection and a rapidly changing technology landscape

Knowledge needs in society

The **cross-sectoral understanding** of the complex interactions of the ocean with most other branches of science, as well as the major influence of the ocean in issues of societal importance is rather under-developed.

There is a need for greater **awareness raising** and promotion of initiatives such as EMODnet, amongst all potential end-users – not just those in the marine and maritime communities – to highlight the wealth of available marine data with potential for application in numerous areas.

Valuable marine knowledge (data and by-products) generated by academic institutions, projects or industrial stakeholders can remain hidden. There is a necessity for raising awareness amongst marine data generators of the benefits to utilising data repositories for safeguarding, adding value and maximising the potential of their knowledge.

End-users needs must be considered to establish if the present observation infrastructure is fit-for-purpose. In more detail, societal challenges and knowledge needs, and not to forget the regional aspect can be detailed as follows:

Challenge	Knowledge need
Access to ocean observing infrastructure & data	Consider how to provide wider access to observatory infrastructures, particularly to those countries lacking MRIs
	Oceans observing platforms can be extended to include novel and / or indirect observation platforms such as ships of opportunity and scuba divers. Use of the latter could also contribute to citizen science & ocean literacy

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	Provide wider access to quality-assured, standardised and harmonised marine data, products and metadata which are interoperable and free of restrictions on use – for both for public and private users
Harmonisation of analytical methodologies and data processing	Develop international standards even across disciplines
	Process and validate data at different levels - at national, sea-basin and European level
	Develop a decision-making process for priorities that is user-driven so that available data are fit-for-purpose
Sustainable funding	Develop common mechanisms on sustainable financing at national and international/EU level to maximise the value from contributions of individual Member States

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Marine Biological Resources

Description of Competence Node

The 'Marine Biological Resources' node could also be understood as the 'Marine Biotechnology' node in a broad vision that is "Marine Bio-resources as the source or the target of Biotechnological applications".[5] This definition thus covers all the value chain's elements from the marine living resources to the products and services and to the markets. Marine Biotechnology in Europe (and in the rest of the world) is considered as an emerging field with great economic potential.

The use of marine biological resources through development and application of biotechnology is one of the ten strategic areas (that can be translated in challenges) identified by the JPI Ocean (SRIA) with four recognized main activities to be promoted:

- Support actions towards the exploitation of genetic resources, including bioprospecting, identification and the valuation of biological resources
- Research to enhance knowledge of taxonomy and genomics to provide policy advice for Blue Growth and GES
- Develop new organism models to understand basic biological, ecological and evolutionary processes which underpin the discovery of biotechnology and application of biomimetics
- Support coordinated efforts along the value chain from marine biomass to markets to reduce the EUs dependency on imports of biomass.

It is often said that the Marine biotechnology sector is still too young to be evaluated by only economic output indicators and the value of its contribution is difficult to quantify given the wide range of marine biotechnology applications and the current difficulty of measuring and tracking these different markets. According to OECD the potential of marine biotechnology is clear, but delivering on its promises may require the attention of governments, policy makers and other stakeholders.

The global market for marine biotechnology products and processes is believed to offer a significant and growing economy. The Global Industry Analyst, Inc., estimated the global market for marine biotechnology at € 2.8 billion (2010 estimate) with a compound annual rate of 4-5% (or 10-12% under less conservative assumptions). The sector is also considered as an enabler to other industries. This reflects an **increasing need for developing tools and knowledge for sustainable development of marine based products**, including food, feed, nutraceuticals, cosmeceuticals, biomedicals, biopolymers, enzymes with industrial applications and a range of other commodities.

[5] OECD definition, http://www.oecd.org/sti/biotech/marinebiotechnologyattheoecd.htm, 08.02.2016

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Knowledge needs in policy

There is **no common strategy on Marine Biotechnology** on European level. Within the last years some efforts were undertaken e.g. by the publication of the "Study in support of Impact Assessment work on Blue Biotechnology" (DG MARE 2014)[6] or by the establishment of the Marine Biotech ERA-Net (www.marinebiotech.eu). There are also varying national policies, strategies, initiatives and programmes. However, harmonisation of single activities is needed on a greater political/European scale.

Furthermore, there is a need for legal certainty in Blue Biotechnology. **Regulatory issues** relating to the traceability of marine resources is a possible barrier to investment. In general researchers are not aware of regulatory requirements and nor do they understand how newly drafted regulation will work in practice. There is a lot of uncertainty in the sector.

Knowledge needs in science

It is very difficult to map what marine biotechnology activities are taking place and who is involved. **Mapping the Blue Biotechnology landscape in Europe** could be beneficial to financing and collaboration, two issues which are connected. The idea of an interface between industry, research and policy could be a way forward to **facilitate knowledge sharing and communication** between stakeholder groups. Knowledge is vital in motivating actors to collaborate and informing potential investors.

Scientific knowledge needs are:

Challenge	Knowledge need
The need to enhance knowledge from genomics and taxonomy on marine biodiversity and ecosystems for policy advice	Genome bioinformatics and computational biology, sequence and structure analysis, molecular evolution and genomic technologies
	Genomics for maker-assisted selection, genome and metabolic engineering
	Access to technological Platforms (omics, screening ...)
new organism models to understand basic biological, ecological and evolutionary processes	Mechanisms to facilitate access to high-end marine research infrastructures which underpin the discovery of biotechnology and application of bio-mimetics

[6] ECORYS (on behalf of EU-COM, DG MARE): Study in support of Impact Assessment work on Blue Biotechnology, Download: http://www.marinebiotech.eu/news-and-events/other-news/blue-biotechnology-study-european-commission, 08.02.2016

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Knowledge needs in industry

The real issue is a lack of **collaboration between investors, industry, SMEs and researchers**. However, marine biotechnology activities in Europe need to be mapped to inform where collaboration is needed and to provide information to industry and investors to inform on opportunities in Blue Biotechnology.

Blue Biotechnology is considered to be 'invisible' and as such investment is hard to come by. Blue Biotechnology is complex and there is little understanding of it outside the 'sector' which does make it an unattractive proposition to investors who lack the expertise, understanding and time to fully realise the applications and potential of Blue Biotechnology. An interface or platform which would bring investors, SMEs and researchers together could facilitate a better understanding and potentially **attract more investors** to the sector.

The following technical and industrial challenges and knowledge needs were identified:

Challenge	Knowledge need
The need for a sustainable exploitation of marine genetic resources	Establish a maximum sustainable yield (MSY) for the use of marine bio-resources to avoid overexploitation and assess the impact and risks from exploiting marine biodiversity.
	Improve cultivation techniques of marine organisms
	International intellectual property rights and regulatory issue regarding the use of marine genetic resources (benefit sharing and Nagoya protocol)
	Better link with Monitoring and observatory activities/structures/programs
The need for coherent and coordinated efforts along the value chain from marine biomass to markets	Mechanisms for sustainably increase the supply of marine bioresources through environmentally friendly cultivation of biomass to reduce the EUs dependency on importing food supplies
	Improve coordination with repository and sampling logging
	Improved collaboration along the value chain with regards to proof of concept, product development, up-scaling and commercialization
	Overcome disconnection between research and commercialization of Marine Biotechnology products and services
	The need for a Capacity building plan to improve training and education to support Marine Biotechnology in Europe

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Knowledge needs in society

Territories such as maritime regions will be an essential driver for the development of blue biotech as blue biotechnologies will be first developed next to the coast. **Regional policy will be an essential thread of the „quadruple helix" for the knowledge-based development (research, education, innovation and policy)**. Many maritime regions in Europe indeed have identified Blue Biotechnology as an interesting sector for their economy). Regional policy will be aimed at locally climbing the TRL ladder and implementing innovation in their blue bio-economy. Furthermore, there is a need to implement a **communication strategy on marine biotechnology** to increase public and stakeholder awareness with regards to the issues and benefits of the sector

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Maritime Transport & Logistics

Description of Competence Node

By 2050, Europeans will be using their maritime and inland waterways space for not only transport, manufacturing and trade but to a great extent also for offshore food production, energy generation and mineral exploitation. Moreover, the costal and maritime space is an alternative dwelling as well as land-based tourism. Key parameters for a future development of the maritime sector are to **achieve well organised, safe, sustainable, competitive and resource efficient systems throughout the whole industrial, societal and environmental value chain**.

The worldwide transport of goods is dominated my maritime modes. Moreover, ships and structures are an essential part in many economic fields and enable the use of the marine resources. While the transport-sector is more or less standardised with respect to the ship types used, their design and production, etc., new business fields grow in specialised markets. This technological border is also separating the European market from the Asian one and others: high value ships with special equipment, operational or customer requirements are the common products built in Europe. The "one-of-a-kind" production methodology led to significant **improvement of production technologies** in the last decade driven by less raw material, improved lead time, and high quality.

The fast rising activity level within the field of offshore renewables in European waters is another driver in the field of shipbuilding and logistics including all types of service vessels as well as the structures itself. The **latest challenges are rising with the exploration of new routs (Polar Route), deeper grounds for resources (Oil & Gas + Minerals) as well as the trend for larger and long-lasting vessels** and structures, summarised in the "cold-deep-complex" challenge. Meanwhile, this is "solved" to a certain extent with known technologies. To "explore new grounds with unknown boundary conditions" is the state of the art in exploring these new fields.

Knowledge needs in policy

It is mainly the task of policy to provide a good framework for the maritime transport and logistics sector in Europe with the aim to reach worldwide competitiveness. On European level, the Technology platform **WATERBORNE** and the initiative **"Vessels for the Future"** represent important platforms for knowledge sharing between several stakeholders and they give advice to the EU-COM (DG MOVE & DG Research & Innovation) as well as acting as think tank for the sector as a whole.

Regarding rules and regulations, the **International Maritime Organization (IMO)** acts as the global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented.

Knowledge needs in science

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R&D in the maritime sector aims at finding innovative technological and environment-friendly solutions and at meeting new challenges like the exploration of new shipping routes or deep sea mining. The Maritime & Logistics node is focused on industry, so the challenges and needs are mainly directed to this end user group.

Knowledge needs in industry

Throughout all sub-sectors, the main challenge is to **withstand the market pressure from outside the EU** in relation to the products and services within the maritime transport and logistics sector. Beside, specific challenges in terms of methods, materials, processes, rules and regulations and the thinking in terms of short-term economic efficiency are the main challenges to bring innovation into application. Therefore, the challenges in the sector are to enhance the competitiveness of the EU shipping sector and to maximise opportunities for innovation in the European shipbuilding and marine equipment industry. In detail, the challenges and needs versus to the 2015 vision can be described as follows:

Challenge	Knowledge need
Serve the societal needs	support by technologies to unlock potentials of food from the oceans
	Provision of leisure vessels or structures at sea or the coast for tourism and recreational purposes
	Ensure robust transport by new and flexible vessel concepts
	create new multi-use space offshore by platforms and structures
	implementation of practicable standards of maritime safety and security, efficiency of navigation and prevention and control of pollution leading to 80% reduction in casualties
	maintaining energy security from renewable resources
	Ensuring ballast water treatment technologies are implemented
fighting climate change	reduction of emissions (including noise) towards an eco-efficient vessel [CO_2: -80%; NO_x & SO_x -100%; Noise: -10dB]
	resource efficient transport systems (raw material and consumables)
	increased use of renewable energies
Improve the global position and competiveness of the sector	be a world leader in the design, production and operation of waterborne assets with related services including logistic processes
	meeting safety requirements with the advent of new technologies
	training highly specialised manufacturing and operating personnel
	use the entire value chain for an accelerated creation and deployment for SMEs as well as large industries
	new design methodologies aiming for life cycle designs
	established research and innovation solution network to foster the fast use of innovation in applications

Knowledge needs in society

Industry always has a responsibility towards the society. With respect to maritime transport & logistics that means primarily the responsibility towards environmental issues.

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Marine Physical Resources

Description of Competence Node

Blue Growth is the long term strategy to support sustainable growth in the marine and maritime sectors as a whole. The Blue Growth Strategy considers five high potential sectors for sustainable jobs and growth, such as: aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining.

Marine Physical Resources includes several sub-sectors. In COLUMBUS we will focus on **Marine Energy** and **Deep Sea Mining**. Even if these activities are more market-driven, a lot of research is needed for sustainable technological solutions.

Europe is currently at the forefront of **ocean energy** development. However it is facing increasing competition from China, Japan, United States, Canada and other industrialised nations. **Offshore wind is the most advanced technology** in the ocean energy sector. The EC objective is to install 100GW of wave and tidal technologies by 2050. However, there are a number of barriers that need to be overtaken to achieve that aim. Slow growth of the sector (especially technologies) that triggers a very low market development rate. At the current stage, most deployment activities are looking at single device and small pre-commercial arrays; even for single prototype devices, the licensing process leading to test deployments is still very time-consuming and discouraging for investors. The ocean energy sector has reduced its forecasts for 2020. The EU is at the forefront of marine technology development, with more than 50% of tidal energy and about 45% of wave energy developers being located in the EU. The majority of ocean energy infrastructure, such as ocean energy test centres, is also hosted in the EU.[7]

The **deep sea mining sector**, though small, has been identified as having the potential to generate sustainable growth and jobs for future generations. Numerous organisations within the EU are presently engaged in seabed mining activities, both as technology providers and as mine operators.

Between 2000 and 2010 there has been an annual increase of about 15% in the price of many non-energy raw materials, mainly as a result of consumer demand in emerging economies. There is a risk of supply shortage for several of these, including those identified as critical to Europe's economy. Advances in technology as well as concerns over security of supply have encouraged mining companies to consider what the sea can provide.

The exploitation and mining of minerals, other than sand and gravel, from the sea have just started. Most current activity is in shallow water. By 2020, 5% of the world's minerals, including cobalt, copper and zinc could come from the ocean floors. This could rise to 10% by 2030. Global annual

[7] JRC Ocean Energy Status Report 2014: https://setis.ec.europa.eu/system/files/2014%20JRC%20Ocean%20Energy%20Status%20Report.pdf

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turnover of marine mineral mining can be expected to grow from virtually nothing to €5 billion in the next 10 years and up to €10 billion by 2030. It may also become economically feasible to extract dissolved minerals, such as boron or lithium, from seawater.

Knowledge needs in policy

In general, regulatory frameworks are needed to develop the ocean energy sector as well as the deep sea mining efforts further. Many critical aspects especially possible environmental impacts require a governmental support and political strategies on European level. Furthermore, there is a lack of guidelines and standards for MRE (Marine Renewable Energy) technologies.

There is especially a challenge to **establish policy and regulatory frameworks**:

Challenge	Knowledge need
Lack of policy and regulatory framework	Specific national strategies & policies for MRE to be developed
	Risk assessment in the Marine Energy Sector
	Need to set up expedite leasing and licensing arrangements in both MRE and DSM
	Specific national and international strategies and policies for the DSM (Deep Sea Mining) sector to be developed
	Most of the potentially exploitable resources lie within the Economic Exclusive Zone of non-European countries, or in international waters- therefore a key challenge is the development of legislation to regulate industrial DSM
	A European DSM strategy should be developed to ensure future autonomy of metal supply

Knowledge needs in science

Scientific gaps in respect to the Marine Resources are first of all missing knowledge on the **environmental impact** e.g. of deep sea mining as most parts of the deep sea are still unexplored. Ongoing research efforts should feed into **better maps of seabed ecosystems** and the results of monitoring the first extraction projects should be made widely available in order that appropriate **lessons are learned for subsequent activities and environmentally friendly technologies** are identified.

Challenge	Knowledge need
Investigation of environmental impacts	Understanding DSM pressures on the oceans and how to ensure DSM does not prevent future generations from benefiting from hitherto untouched ecosystems
	Lack of modelling for environmental effects of MRE devices
	There is a risk to ecosystems as a result of the resuspension of particles. It is unknown how high this risk is or what the consequences will be.
	Little is known about the recovery times of these ecosystems

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	There is a risk that DSM could increase coastal erosion
Investigation on resources availability and exploitation	There is a lack of knowledge of whereabouts of deposits, or which of them can be commercially exploited There is a lack of observations of MRE resources suitable for sound design and engineering purposes (most work is still carried out based on estimates with relatively large uncertainties)
DSM technology research	There is a challenge for engineering as many potential sites are at great water depths and extremely far from land. The extraction methods required will depend on the targeted resource
	There is a challenge to develop technologies that minimise the risk to the environment while maximising the economic efficiency of mining
	Need for advanced sampling technologies for rocks, sediments, fluids, fauna and microbiota

Knowledge needs in industry

The main economic driver for the development of the DSM industry is cost. Investors need to be sure that the added cost due to increased extraction costs (compared to terrestrial sources) will be compensated by higher concentrations of metal in the ore. **Investment is a key challenge** for the whole energy industry. Such investment may be beyond the reach of private mining companies. As such, a European marine investment fund partially funded by the EIB and with private equity and guarantees from Member States could be envisioned. There is a lack of long term clarity on profitability and commercialisation of the Ocean Energy (OE) sector. OE would benefit from clear, stable and supportive policy framework in order to attract investment.

There should be focused funding, so that the development of validated technologies can be accelerated. With regard to DSM foster the **development of new technologies** for the safe and sustainable harvesting of marine mineral deposits in an environmentally-friendly manner. With regard to plan new infrastructure and upgrades: Adequate port facilities and specialized vessels for the equipment are required for DSM activity.

Furthermore, there is a lack of clarity on the rules **of intellectual property, collaboration and knowledge sharing.** It is still highly uncertain if the DSM industry will be economically viable, and if so, how much of the deposits can be commercially exploited.

Knowledge needs in society

Societal challenges with regard to Marine Physical Resources and especial connected to the topic DSM are mainly environmental questions and concern. An **investigation of environmental impacts** is needed to minimise the footprint of MRE technologies. **ISA Regulatory processes** require the developer to set or reserve areas for compensation for environmental damage caused by the excavation- this has been called a "tax" by the industry and could slow down the rate of return on investment.

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The **demand for these industries will grow as current consumption rates are unsustainable**, and also as a result of human populations growth and the rapid industrialisation of highly populated countries (China, India, Brazil). Informing the wider society about the complexity of natural resources, environmental impacts and consumption is needed to raise awareness. Participatory processes could help to involve citizens and to prevent propaganda and negative associations. There is a **need for greater expertise in socio-economics and governance research** on the deep sea.

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Maritime Tourism

Description of Competence Node

As part of EU's Blue Growth strategy, the coastal and maritime tourism sector has been identified as an area with special potential to foster a smart, sustainable and inclusive Europe. It is the biggest maritime sector in terms of gross value added and employment and, according to the 'Blue Growth Study', is expected to grow by 2-3% by 2020. In 2012, Cruise tourism alone represented 330,000 jobs and a direct turnover of €15.5 billion and is expected to grow.

The EU Commission adopted a Communication on "A European Strategy for more Growth and Jobs in Coastal and Maritime Tourism" on 20 February 2014, presenting a new strategy to enhance coastal and maritime tourism in Europe in order to unlock the potential of this promising sector.[8]

The Commission has identified 14 actions which can help the sector grow sustainably and provide added impetus to Europe's coastal regions. For example, the Commission proposes to develop an online guide to the main funding opportunities available for the sector and to support the development of trans-national and interregional partnerships, networks, clusters and smart specialisation strategies in coastal and maritime tourism. The Commission will work with Member States, regional and local authorities and the industry to implement these actions.

EU coastal and maritime tourism employs over 3.2 million people and generates a total of € 183 billion in gross value added and representing over one third of the maritime economy. As much as 51% of bed capacity in hotels across Europe is concentrated in regions with a sea border.

It is the biggest maritime sector in terms of gross value added and employment and, according to the 'Blue Growth Study' is expected to grow by 2-3% by 2020. In 2012, Cruise tourism alone represented 330,000 jobs and a direct turnover of €15.5 billion and is expected to grow.

Knowledge needs in policy

The maritime tourism sector faces a number of challenges as identified in the 2014 EU strategy for growth & jobs in coastal & maritime tourism[9]. The strategy proposes actions to be implemented by the Commission, Member States, regional and local authorities, private operators and other stakeholders to address these challenges and enhance the sector's sustainability and competitiveness. From the political point of view, the knowledge is there, now it depends on implementation.

[8] EU-COM (2014): European Strategy for more Growth and Jobs in Coastal and Maritime Tourism, Download: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2014%3A86%3AFIN, 08.02.2016
[9] EU COM (2014): A European Strategy for more Growth and Jobs in coastal and maritime tourism, http://ec.europa.eu/maritimeaffairs/policy/coastal_tourism/index_en.htm, 29.02.2016

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The EU's Natura 2000 network protects vulnerable coastal and marine habitats which, if managed well, can provide significant recreational opportunities and contribute to sustainable growth and employment. EU legislation such as the Water Framework and Marine Strategy Framework Directives require Member States to ensure good status of coastal and marine waters, a pre-requisite for tourism to prosper. Integrated Coastal Management and Maritime Spatial Planning help ensure sustainable and Green Infrastructure development through smart planning and cooperation between governmental, public and private partners.

Knowledge needs in science

The Maritime Tourism sector needs better knowledge with regard to economic assessment. There is a lack and poor comparability of data, both at local, sea basin and European level. A better cooperation with universities and research institutes who are focusing on leisure and tourism science could be beneficial. The results of inter- and transdisciplinary research should be a precondition to develop sustainable products in maritime tourism in future.

Environmental and especially coastal research could help to develop a sustainable maritime tourism. Tourism depends on a healthy environment and the sustainable use of natural capital, but activities are often concentrated in already densely populated areas, leading to vast increases in water demand, more waste and emissions from air, road and sea transport at peak periods, more risks of soil sealing and biodiversity degradation (from infrastructure developments), eutrophication and other pressures. Scarcely populated and pristine areas can be affected too. In addition, the impacts of climate change exacerbate pressures on these areas and could reshape tourism's geographical and seasonal distribution.

Improving bathing water quality: Availability of accurate and affordable monitoring systems and information sharing tools. In detail, there is a need for:

- Affordable & reliable real-time water quality measurement tools sampling with sufficient temporal and spatial concentrations.
- Reliable water quality models of catchments and the near-shore zone
- Real time public information tools
- Tracking and quantification of microbial sources

Knowledge needs in industry

Due to the continuing economic crisis most tourism SMEs have limited or no access to credit for investments and innovation. Moreover, coastal regions often struggle to create and fully capture economic benefits generated by cruise tourism, though pressures to invest in port infrastructures and to preserve the environment is increasing. This is partly because businesses across EU sea basins do not sufficiently use synergies, which causes fragmentation and limited economic gain. Sharing

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best practice between Member States, regions and stakeholders is essential. Cooperation among research institutes, museums, tourism companies and other stakeholders should be promoted to develop innovative and sustainable products that respond to visitors' expectations.

Skills availability: Need to attract workers into the sector and equip them with the required skill-set.

The need to compete year-round with maritime tourism destinations outside Europe

Knowledge needs in society

Basically, within maritime tourism there are several recreational sectors (boating, wind-surfing, bathing, sport-fishing, scuba-diving, etc.) claiming more or less the same coastal area and thus providing a high intrinsic potential of conflicting interests, which besides conflicts with other stakeholder groups need to be resolved through regional and local regulations. This should be based on participatory processes including all relevant stakeholder/interest groups.

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Marine Governance & Management

Description of Competence Node

The fact that the ocean is among the most paradigmatic cases of globally shared natural resources, even nowadays 60% of the oceans are outside the borders of national jurisdiction, has meant that from the ancient cultures the governance and management of the seas and oceans has been a matter of concern. The idea of "open/free seas" set out during the Roman Empire prevailed for many centuries until scientific progress evidenced that unregulated use of marine environment and resources in many areas was in the roots of serious damage to the environment, with, among other matters, a dramatic depletion of resources and biodiversity.

After a long negotiation period, of more than 50 years, the United Nations Convention on the Law of the Sea (UNCLOS) entered in force in 1994. The convention stipulates, "Maritime issues need to be examined in their entirety and managed comprehensively," and established for the first time an international legal framework through which all countries get bind to manage and protect the oceans. The setting up of this common international framework for maritime development, use, and protection of the sea meant the beginning of a number of international initiatives[10] to guarantee a sustainable use and preservation of the marine environment for the benefit of present and future generations.

The European Union adopted for the first time an integrated approach to ocean management and maritime governance within the Integrated Maritime Policy for the European Union ('IMP'), including, as its environmental pillar, Directive 2008/56/EC of the European Parliament and of the Council (Marine Strategy Framework Directive, (MSFD)). The objective of the IMP is to support the sustainable development of seas and oceans and to develop coordinated, coherent and transparent decision-making in relation to the Union's policies regarding the different activities affecting the oceans, seas, islands, coastal and outermost regions and maritime sectors, including through sea-basin strategies or macro-regional strategies, whilst achieving good environmental status as set out in Directive 2008/56/EC. The European Commission did also first laid down its vision on international ocean governance in the 2009 Communication on 'Developing the international dimension of the Integrated Maritime Policy (IMP) of the EU' (COM(2009)536). During the last decade, at sea basin level, the corresponding strategies, action plans and agendas[11] (for the Mediterranean, the Baltic

[10] Chapter 17 of Agenda 21 from 1992 Río Summit;

[11] Atlantic Action Plan: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/atlantic_ocean/index_en.htm
Adriatic and Ionian Seas strategy: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/adriatic_ionian/index_en.htm
Arctic Ocean strategy: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/arctic_ocean/index_en.htm
Baltic Sea strategy: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/baltic_sea/index_en.htm
Black Sea strategy: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/black_sea/index_en.htm
Mediterranean Sea Strategy: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/mediterranean_sea/index_en.htm
North Sea strategy: http://ec.europa.eu/maritimeaffairs/policy/sea_basins/north_sea/index_en.htm
Seas around Europe's Outermost Regions strategy:

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Sea, the Atlantic including Galway Strategy, the North Sea, the Adriatic and Ionian Seas, the Black Sea and the strategy for the Outermost Regions), constitute a complementary bunch of policies to facilitate and increase effectiveness of the implementation of overarching regulations within a regional context. Those, in combination with the EU Biodiversity Strategy to 2020 and the 7th Environment Action Programme, the Marine Strategy Framework (MSFD - 2008/56/EC) and the Maritime Spatial Planning Directives (2014/89/EU) have created a new and comprehensive legal framework within the EU aiming for good ocean governance and compliance with international commitments.

Apart from the above, other outstanding European and International references form part of the policy and regulation framework for European Marine and Maritime Governance and Management; among those which are, to some extent, relevant for the purposes of this Competence Node (CN) it can be mentioned:

- The Common Fisheries Policy (REGULATION (EU) No 1380/2013)
- The European Union Maritime Security Strategy. (Note from Council of the EU No. 11205/14)
- The Communication on Better situational awareness by enhanced cooperation across maritime surveillance authorities: next steps within the Common Information Sharing Environment (CISE) for the EU maritime domain
- The Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity and the Regulation for compliance at EEA level (REG No.511/2014)

The regulations framework relevant for Marine and Maritime governance and Management by definition affects and applies to every single activity carried out in the marine and maritime context. The MSFD and MSPD, selected as core regulations at European level to this node, are relevant for all marine and maritime activities. At international level, the UN Convention on the Law of the Sea complies also with this cross-cutting criteria, even though it has been considered a good opportunity for COLUMBUS project and for this particular Node to focus on the progress expected in the two coming years regarding the resolution for developing a legally binding instrument on biodiversity conservation and sustainable use of marine biological resources in areas beyond national jurisdiction.

Moreover, to increase the Governance and Management Competence Node potential impact, it is expected crucial to put important efforts in facilitating policy coherence and cohesion. Thus, it would be of particular relevance to concentrate part of the work in identifying and promoting the transfer and exploitation of those knowledge outputs from MSP research which are also relevant for MSFD implementation; or on those that integrate inputs from Birds and Habitats Directive, i.e., to

http://ec.europa.eu/maritimeaffairs/policy/sea_basins/outermost_regions/index_en.htm
Galway Statement on Atlantic Cooperation:
http://ec.europa.eu/research/iscp/pdf/galway_statement_atlantic_ocean_cooperation.pdf

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guarantee the application of the ecosystem approach and an integrated and sustainable perspective of environment, human activities and cross-border cooperation. In fact MSP is subject of increasing attention at international level in fora like: UNESCO/IOC, the Convention on Biological Diversity and the International Council for the Exploration of the Sea. Facilitating Policy coherence can in fact constitute an important challenge for the Node while it also is a key relevant issue for the policy success itself.

Knowledge needs in policy

MSFD

Challenge	Knowledge need
Missing harmonisation between EC, Regional Seas Conventions and Member States and thus avoiding duplication	Developing a mechanism to jointly define GES taking into account the requirements of the MSFD that this definition is ultimately within the responsibility of Member States
	Intensify discussions between stakeholders to benefit from other policies and legislations
Capacity building at various levels	Facilitate CP for managers, scientists and technicians to allow a full scope implementation of the MSFD tasks

The general objective of EU action is to ensure the sustainable development of the EU's coastal zones and maritime areas in accordance with the ecosystem approach. It also aims at supporting the achievement of various other EU Treaty, legislative and policy objectives including Europe 2020, environment, energy, fisheries, maritime transport and cohesion policy. Any EU action in this context should limit itself to setting out tools for achieving the above-mentioned policy objectives. To this end, the operational objectives are of procedural nature: a coherent development and implementation of processes to manage and plan human uses of maritime space (defined as MSP) and to coordinate coastal management policy instruments in all coastal Member States (defined as ICZM; the delivery and further development of common principles and approaches for MSP and ICZM processes and the development and implementation of appropriate cross border co-operation.

Recently, the EU has released an informal checklist for the transposition of the MSP that remarks the core elements of the Directive and puts them into the specific context of transposition to Member States, determining which elements have to be part of the national regulations and which not. This exercise, despite of its informal character helps the common understanding of the Directive and its consistent future implementation.

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The importance of Marine Ecosystem Services cannot be underestimated as it is estimated that about 50% of the world's population lives within 60km of the shore-line[12] and that over three billion people depend on marine and coastal biodiversity for their living[13]. In the UNCLOS report *the* open consultative process launched on "Oceans and sustainable development: integration of the three dimensions of sustainable development, namely, environmental, social and economic" global challenges with regards to ocean biodiversity management, including both national and beyond national jurisdiction waters are identified and remark the importance of issues such as:

Challenge	Knowledge need
Assess the marine biological diversity and its impact and value for society & economy	Quantify the economic, social and environmental significance of coral reefs, in particular to small islands and other coastal States' development to ensure their preservation
	Assessment of traditional and community-based knowledge for sustainable livelihoods of indigenous communities around the world and thus for poverty eradication and development
	Mechanisms to reduce anthropogenic pressure and biodiversity loss and thus enabling sustainable economic growth and development
Enabling, facilitating and strengthening capacity building on sustainable behaviour	Rising awareness on the economic benefits of the ecosystem services, and on the role of access to, and benefit-sharing arising from the utilization of, genetic resources in contributing to the conservation and sustainable use of biodiversity, poverty eradication, and environmental sustainability
	Strengthening efforts towards the implementation of international instruments through: - Capacity building: better understanding of the causes and drivers for biodiversity loss that exacerbate poverty - Scaling up successful approaches - Technology and knowledge transfer - Stress emphasis on links between biodiversity loss and consumption patterns - Reward positive action

Knowledge needs in science

Research needs regarding the implementation of MSFD and the respective descriptors were extensively elaborated and analysed within the EU project STAGES. The outcomes of three workshops with stakeholders from outside the STAGES project were summarized in following reports:

[12] UNEP, http://www.unep.org/urban_environment/issues/coastal_zones.asp
[13] SCBD, Biodiversity for Development and Poverty Alleviation, 2012

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- Needs for further research to support improved and more efficient monitoring programmes under MSFD, Brussels, 13-15 May 2013
- Further Research Needs on Pressures and their Impact on the Marine Ecosystem under MSFD, Rome, 4-5 September 2013
- Workshop on research needs with regard to the socio-economic analysis under MSFD, Joint Research Centre of the European Commission, 9-11 October 2013[14]

Further deployment on gaps and barriers identified for MSFD implementation has been gathered mainly in two EU projects through their deliverables: DEVOTES and PERSEUS.

With reference to the previously mentioned document **UNCLOS-UNGA RES 69/292 the** scientific knowledge needs/gaps are:

Challenge	Knowledge need
Not sufficient cutting edge scientific research in emerging fields (e.g. genomics)	Fostering research new and quickly evolving fields in order not to hamper innovation by cumbersome and excessive bureaucratic procedures; intellectual property rights issues should be addressed
	Enable knowledge transfer from scientific understanding of areas beyond national jurisdiction for decision-making.

Knowledge needs in industry

Due to the fact that this Node is dealing with governance, regulations and management of seas and oceans the industry is one of the key target groups in respect to regulating fisheries, shipping and energy production. However, based on the nature of economic interests of this group there is no direct knowledge need which can be allocated under this specific knowledge node.

Knowledge needs in society

The EU member states are required to identify measures that contribute to the achievement or maintenance of GES set out in their Marine Strategies and that will address the predominant pressures and impacts identified in the initial assessment of their marine waters. There should be a direct link between the proposed measures and the established national targets. Where relevant it is possible that measures may address several descriptors / targets / pressures / economic sectors / activities.

[14] The Workshop reports can be downloaded at: http://www.stagesproject.eu/stages-results/presentations, 08.02.2016

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The Commission Staff Working Document "Executive summary on the impact assessment accompanying the Proposal for a Directive on MSP" SWD (2013) identifies the key issues MSP should contribute to:

The overarching problem relates to the competition for maritime and coastal space and the ongoing depletion of resources that can be broken down in six key problems:

- Conflicting claims on space
- Inefficient use of sea space
- Unbalanced use of coastal space
- Suboptimal exploitation of economic potentials
- Insufficient adaptation to climate risks
- Degradation of maritime and coastal environment

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Marine Environment & Futures

Description of Competence Node

Media, NGOs and even social network groups are discussing with increasing intensity anthropogenic impacts on our environment and especially on seas and oceans. Besides the seafloor, which is protected through the ISA convention, the oceans outside national jurisdiction seem to be missing a strong lobby or stakeholder to fight for its conservational interests. This and the sensitivity of marine ecosystems are the main reasons why human interaction is actually impacting our oceans quite significantly. Based on the UN Rio declaration climate change and related issues like coral bleaching or sea-level rise as well as pollution by plastic littering or harmful substances and over-exploitation of its recourses, eventually leading to the extinction of species, are the predominant marine issues actually discussed in the media.

Consequently, in the recent years the above mentioned issues have been taken up by politicians too, but real intergovernmental action has not really started before Rio or with respect to marine litter just recently with e.g. the G7 leaders' declaration 2015 and its focus on the future of the oceans. However, the real polluters of the G20 are still bailing out when it comes to implementing joint actions based on precautionary principles. Marine plastic litter has been addressed by a single FP7 call and last year the *Joint Programming Initiative Healthy and Productive Oceans and Seas* started a joint pilot action on microplastics with 10 participating European member states. In this context a joint call for proposals was issued in January 2015 offering 7.5 Mio. € on projects developing SOPs for analytical detection, exploring the microplastics distribution along the marine food chains and determining possible toxicological impacts on the coastal ecosystems and our food.

Tackling the comprehensive marine problems requires strong collaboration between scientists, politicians, industry and the civil society. In the recent years, environmental awareness and precautionary action because of the ongoing global change have found their way into societal behavior and norm setting, but it requires much more education and elucidation for consciousness turning into sustainable action and internationally harmonised regulations.

In consequence the Marine Environment & Futures node will especially focus on two main topics: (1) marine litter, (2) climate change.

Knowledge needs in policy

Impacts on the marine environment are of transnational nature. From the governmental point of view there is a strong need to gain more and scientifically sound information on the functioning of the marine ecosystem and its changes, possible human impacts or the land-sea-interactions. This information is required as a solid basis for legal frameworks and governmental regulations, especially

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in emerging fields like deep sea mining or polar shipping routes but also to mitigate human impact on our marine environment.

Member states driven activities like the JPI OCEANS pilot actions or the G7 Science Ministers communique in 2015[15] are addressing urgent issues like marine litter. In general, innovative and flexible funding opportunities for transnational research matters like climate change should be promoted. With regard to marine environment and our main topics climate change (with focus on Arctic) and marine litter (with focus on microplastics) and ballast water the following challenges and knowledge needs are important:

Climate change:

Challenge	Knowledge need
Impact of climate change on our seas and oceans	Process studies and the development of models with the goal of predicting future sea level variations more reliably
	How do increasing atmospheric greenhouse gases impact the marine ecosystems e.g. through ocean acidification, SST and heat content? How do these effects interplay and eventually weaken or amplify the impact of the single effects?
	Which species and consequently ecosystems will be migrating to higher latitudes or eventually be extinct?
Decline of Arctic sea ice	Deepen the understanding of the interaction between sea ice, oceanic heat content and atmospheric fluxes
	Predict sea ice developments and the effects of reduced sea ice cover on our climate, biochemical cycles and marine ecosystems
	Identify those Arctic regions where receding ice cover offers opportunities for future human use
Impacts on environment and society	Enabling coastal management to meet the various challenges
	Predicting scenarios for socioeconomic consequences of rapid climate changes
	Exploring how environmental changes affect biodiversity, food webs productivity and ecosystem functions
Shifting species composition	What is the ecologic and economic impact of non-native, pathogenic or exotic species from other habitats?
	When do we regard the introduction of a new species as irreversible?
Preventing the release of further invasive species	Are there better technological methods to treat ballast water?
	Are there effective management procedures preventing the introduction of invasive species?

Marine litter:

Challenge	Knowledge need

[15] Communiqué, Meeting of the G7 Ministers of Science Berlin, 8-9 October 2015, https://www.bmbf.de/files/English_version.pdf, 11.02.2016

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Fragmented data base	Better synoptic coverage on regional and water column distribution
Microplastics	Harmonisation of analytical methodologies (interlaboratory study)
	Weathering factors and timescales in decomposition of plastic particles into microplastics
Impact of marine microplastics on the ecosystem	Microplastics abundance and the composition of involved polymers in the marine environment, e.g. water column, sediment, biota
	Identification and quantification of microplastics in the food chain
	Eco-toxicological effects of microplastics – impact on marine organisms

Knowledge needs in science

Profound and applicable research results provide the basis for further actions in policy, industry or society. However, with regard to the marine environment and our main focus areas climate change (with focus on Arctic) and marine litter (with focus on microplastics) very much the same challenges from policy (see above) apply while the knowledge needs are a little bit more focused on data availability and providing more access to high-end and costly research infrastructures. Regarding microplastics the harmonization of analytical methodologies is a prerequisite for further scientific research in this field. The latter is actually implemented through an international, 24 partner project BASEMAN[16] funded through JPI OCEANS.

Beyond applied research (e.g. supporting policy or serving societal needs) within *Marine Environment & Futures* 'gaining knowledge' is one of the major driving factor for new projects. Thus no direct application of possibly achieved knowledge is foreseen within projects under the basic science umbrella, and results or outcomes can only accidentally contribute to knowledge applications and knowledge transfer.

Knowledge needs in industry

With regard to the above mentioned challenges on climate change (reduction in fuel consumption or renewable energy), marine litter (preventing dumping or developing biodegradable products) and invasive species (looking into economically feasible regulations), the industry plays major a role. However, their driving principle is more as a stakeholder who is interested in cost-effective solutions for a sustainable economic field. In this respect representatives from industry are usually actively participating in political norm- and regulation-setting processes and in some cases even voluntary waivers (e.g. for refraining from using microplastics in cosmetic products[17]) from certain industrial sectors are possible, especially if the societal pressure has an impact on their economic interests.

[16] BASEMAN, Defining the baselines and standards for microplastics analyses in European waters http://jpi-oceans.eu/sites/jpi-oceans.eu/files/public/Press%20release/Short%20description%20BASEMAN.pdf

[17] CREST: http://crestfaq.tumblr.com/

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Knowledge needs in society

Our seas and oceans are under pressure from constant and increasing pollution, e.g. from oil spills or littering. Through over-exploitation of our seas as a food-source and as a convenient location for waste disposal, coastal cities compromise the benefits provided by their logistic whereabouts. Damage to coastal ecosystems by sea level rise or more and intensive storms from climate change is affecting the population in coastal areas while half the world's population already lives within 50 km of the sea, and 60% of all megacities are located on the coast. Contaminated seafood by plastics or other pollutants is impacting human health. Besides governmental regulations (which usually take years from identifying a problem until an appropriate legal framework can effectively change the situation) raising societal awareness on urgent and upcoming issues is an essential element to foster a change in human behavior and thus protecting our seas and coastlines. Activities like “Coastal Cleanup Days”, the “Ocean Cleanup project” or the FP7 funded project MARLISCO are good examples with regard to society involvement and fostering responsive behavior. Many environmental conservation groups, like WWF or Greenpeace, are also using awareness campaigns, e.g. through media, as their main tool to fight harmful human activities affecting the marine environment as such.

Furthermore, public participation when introducing new governmental regulations is essential to obtain broad acceptance in society, as modifications to our daily routine e.g. when shopping or dining are not easily implemented and one can expect huge reluctance on deviations from habits.

Challenges and knowledge needs are very much the same as already tabled under the policy chapter.

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Conclusions

Based on the identified knowledge needs in the above mentioned chapters by the Competence Nodes, and the main European strategies on marine and maritime R&D, a few key common or generic elements can be derived.

- There is an ongoing need for fundamental research to comprehensively understand processes and functions of our coasts, seas and oceans. There are knowledge and data gaps in relation to the state of our oceans, impacts relating to marine resource exploitation and the risk of pollution to habitats, ecosystems and human health.

- Policy requires a solid knowledge base for decision making. This knowledge base can be evidenced by intensified (automated) ocean observation by fundamental and applied research.

- The complex challenges of sustainable Blue Growth should be addressed by combining expertise from a range of scientific disciplines and stakeholders.

- Fragmented and non-coordinated research efforts in marine and maritime science hinder interdisciplinary learning and slow the progress of technological breakthroughs in key technologies and innovative business sectors.

- Frequent assessment of risks, impacts and vulnerabilities must be ensured, through high temporal and regional resolution monitoring, analysis and prediction.

- Access to existing databases and continuously securing availability of data (sustainable data management) is essential for proper policy decisions and governmental management.

As the nine Competence Nodes in COLUMBUS are covering the whole range of marine and maritime stakeholders and interest groups, a direct comparison of knowledge gaps is difficult to achieve. We therefore assigned the main end user groups (policy, science, industry, society) to the single nodes, and thus serving our ultimate aim to transfer knowledge into practical applications.

Thus sorting the knowledge needs by end user group leads to the following listing:

End user group	Main knowledge need
Policy	Comprehensive, frequently updated and reliable databases for decision making
	Ensure cross-discipline and transnational funding possibilities
	Provide an international framework for discussing governmental issues
Science	Provide synoptically dense and interdisciplinary databases for data-assimilation and reliable predictions on the state of the oceans and its role in climate change

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	Inter- and transdisciplinary research is needed to understand the complexity of the e.g. ecosystem functions and human impact on oceanographic processes
Industry	Affordable technological developments/ solutions to implement governmental regulations and saving energy or additional costs
	Fostering ownership for environmental friendly technologies (e.g. stronger focus on renewable energies)
	Replacing harmful substances (e.g. new packaging solutions instead of plastics)
Society	Intensify awareness rising for the wider public on harmful behavior, individual habits and environmental responsibility to foster healthy seas and oceans
	Implement participatory processes on a sustainable way to achieve acceptance when introducing new technologies or paradigm shifts in policies

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