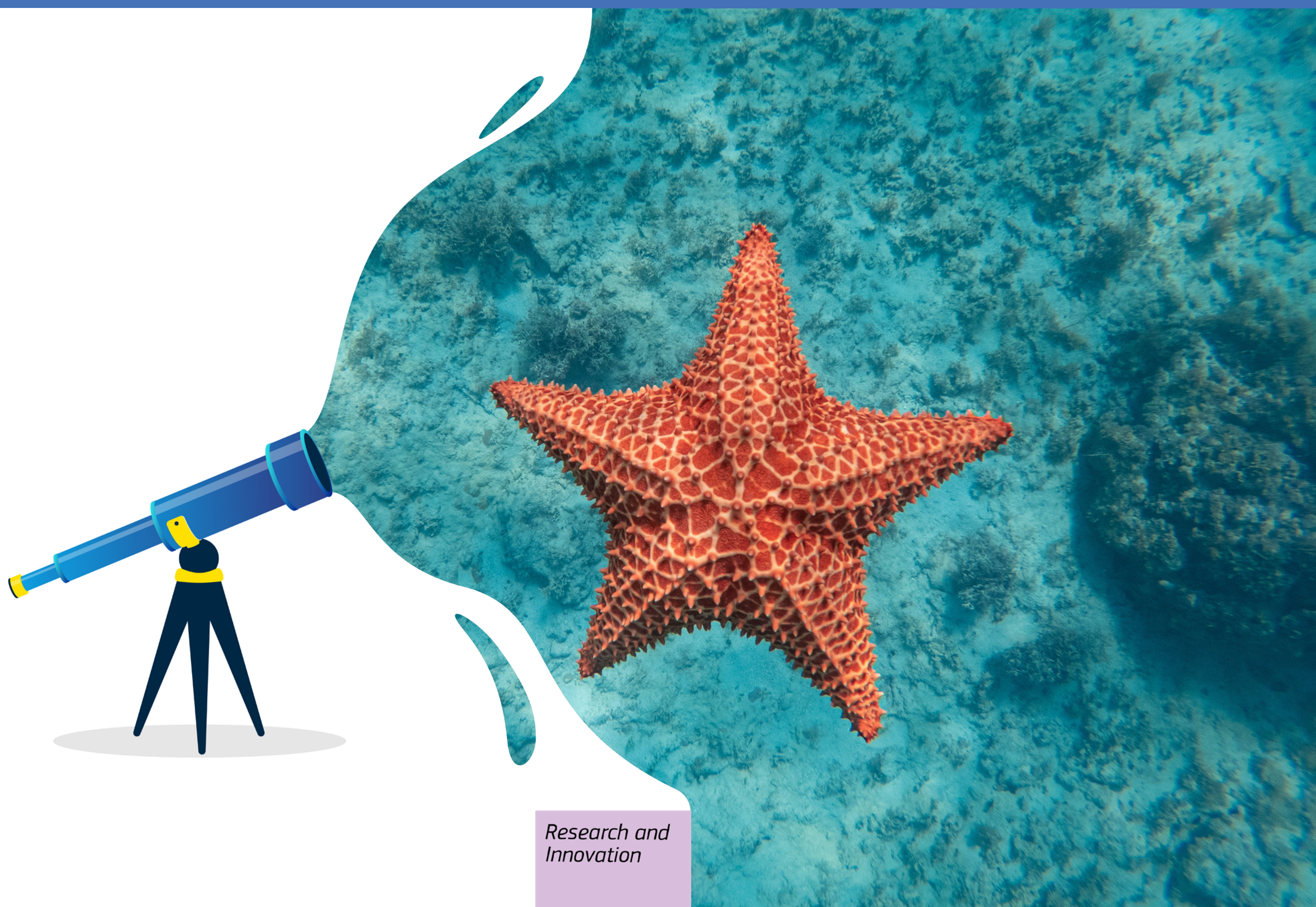
European Commission

FORESIGHT

Mission Area: Healthy Oceans, Seas, and Coastal and Inland Waters

Foresight on Demand
Brief in Support of the
Horizon Europe Mission Board



Research and Innovation

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Foresight on Demand Brief in Support of the Horizon Europe Mission Board

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Mission Area: Healthy Oceans, Seas, and Coastal and Inland Waters

Foresight on Demand Brief in Support of the Horizon Europe Mission Board

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Foreword

In 1969, the first human set foot on the moon. "A small step for a man. A giant leap for mankind" was what audiences across the world heard. The Apollo mission showed the world what directed science, research and innovation could make possible. It proved what humankind can achieve in not even a decade, by setting a clear goal, which manages to capture public imagination, and by investing the necessary resources into it.

The mission approach, directing and combining different resources and actors towards a common goal, is becoming a key element of transformative R&I policies in a world of increasing global challenges. The Commission introduced missions as a new instrument in Horizon Europe and appointed Mission Boards to elaborate visions for the future in five Mission Areas: Adaptation to Climate Change, Including Societal Transformation; Cancer; Healthy Oceans, Seas, and Coastal and Inland Waters; Climate-Neutral and Smart Cities; Soil Health and Food.

EU R&I policy missions are ambitious, yet realistic and most of all desperately needed in light of today's challenges. They endeavour to bring together policies and instruments in a coherent, joined-up approach, and tackle societal challenges by setting and achieving time-bound, measurable goals.

In September 2020, the Mission Boards handed over their reports to the Commission. Five foresight projects carried out in close interaction with the Boards supported their work. These projects provided advice on trends in the respective areas, elaborated scenarios on alternative futures, scanned horizons, and made aware of weak signals, and emerging new knowledge and technology, helping the Boards imagine how the future may evolve and how to shape it.

With the launch of the five Missions in Horizon Europe, we are making this valuable work available for the broader public. I am confident that the comprehensive material, creative ideas and exciting examples in the Mission Foresight Reports will prove useful to all those engaged in the Horizon Europe Missions.

Jean-Eric Paquet
Director General
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Table of Contents

BACKGROUND AND ACKNOWLEDGEMENTS

Missions and Horizon Europe

The notion of "missions" as one of the novel cornerstones of Horizon Europe, the European Framework Programme for Research and Innovation 2021-2027, was introduced in the course of the programmatic debates about the orientation of the EU's future R&I policy, in particular through the Lamy Report. This report, which was presented in July 2017, recommended adopting "a mission-oriented, impact focused approach to address global challenges". Missions would serve as targeted and longer-term ambitions around which to build a portfolio of Horizon Europe research and innovation projects.

The idea of mission-oriented research and innovation was subsequently further specified through various studies and reports, in particular also by two reports by Mariana Mazzucato, which inspired policy debates at European as well as national level. In line with this preparatory work, missions shall have a clear R&I content EU added value and contribute to reaching Union priorities and Horizon Europe programme objectives. They shall be bold and inspirational, and have scientific, technological, societal and/or economic and/or policy relevance and impact. They shall indicate a clear direction and be targeted, measurable, time bound and have a clear budget frame.

As a result of debates at European level, the European Commission (EC) proposed five initial broad Mission Areas in autumn 2018. This initial list was subsequently adjusted in interaction between the EC and Member States, leading to five Mission Areas:

i) Adaptation to climate change including societal transformation,

ii) Cancer,

iii) Healthy oceans, seas, and coastal and inland waters,

iv) Climate-neutral and smart cities, and

v) Soil health and food.

As spelt out in the specific request, these missions will be anchored in the pillar "Global Challenges and Industrial Competitiveness", but may well reach out to the other pillars of Horizon Europe.

Within each of these Mission Areas, a limited number of specific missions shall be defined in the context of the next framework programme, with a first set of missions to be launched in 2021. To this end, the EC has established Mission Boards of about 15 outstanding members for each of the five Mission Areas. Mission Board members were appointed in August 2019 and they started their work in September/October 2019. They presented their recommendations to the EC at the EU R&I days in September 2020. The titles and descriptions of the actual EU Missions launched by the European Commission are found here: https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/missions-horizon-europe_en

Foresight on Demand

Against this background, a request for services with five lots was put out under the Foresight on Demand Contract (FOD) of DG R&I to support the five Mission Boards. The five projects started in autumn 2019. For around a year they worked for and with the Mission boards, providing foresight expertise and methodology. They were aimed to feed the reflections of the Mission Boards with future-oriented inputs on challenges and options in the respective areas.

With the launch of the missions in Horizon Europe, this valuable work is now public as a part of the Foresight Papers Series. The five mission foresight reports give a detailed overview of the alternative futures, and the future perspectives in science and technology in the five mission areas build part of the basis for the considerations of the Mission Boards. They may serve as background material and a source for examples and ideas for coming mission activities.

Mission foresight project "Healthy Oceans, Seas, Coastal and Inland Waters"

The foresight project "Support to the Mission Board Healthy Oceans, Seas, Coastal and Inland Waters" (Framework Contract 2018/RTD/A2/OP/PP-07001-2018-LOT1) aimed to provide forward-looking evidence to support the Mission Board for this area.

The team of experts was set up to provide the Board with well-versed expertise in both foresight methodology as well as thematic developments on the future of oceans and water. The objective was to think along with the board and to stimulate the debates by raising surprising and challenging issues based on forward-looking analysis and exploration. The project provided the Mission Board with new information, (systemic) insights and/or alternative future visions that connect the extremely multi-dimensioned topics tackled by this Mission Board.

The foresight project started with the scanning of foresight reports looking towards 2050, foresight databases and news feeds to address long-term developments and emerging signals of change. In particular, the project developed five alternative focal areas that were presented and reflected with the Mission Board to provide interconnected insights as well as challenging and provocative ideas to enrich the work of the Mission Board.

Subsequently, the foresight team explored further future uncertainties and knowledge gaps via a real-time Delhi survey inviting approximately 3000 stakeholders from research and development, policy, industry and civil society to participate. The respondents learned from the views of others, without being unduly influenced by hierarchies or other societal structures and power relations. The results of the survey largely confirmed the challenges and lines of action proposed by the Mission Board. In particular, the results showed consensus on the need for recovery of the health of the oceans and waters and consensus about the need to adopt a holistic, ecosystem approach.

The foresight project contributed to the work of the Mission Board, which defined subsequently its goal of *the full recovery and regeneration of European marine and freshwater ecosystems by 2030* outlined by the Mission Board in “Regenerating our ocean and waters by 2030” (2020).

MISSION AREA: HEALTHY OCEANS, SEAS, AND COASTAL AND INLAND WATERS. FORESIGHT ON DEMAND BRIEF IN SUPPORT OF THE HORIZON EUROPE MISSION BOARD

SUMMARY

This report provides the findings from the 'Foresight on Demand' project supporting the Horizon Europe Mission Board for Healthy Oceans, Seas, Coastal and Inland Waters in its task of defining specific Mission(s) to be addressed in Horizon Europe. The overarching goal of the project was to support the reflections of the Mission Board from a forward-looking perspective.

The team of experts was set up by the 'Foresight on Demand' consortium to provide the Board with well-versed expertise in both foresight methodology as well as thematic developments on the future of oceans and water. The objective was to think along with the board and to stimulate the debates by raising surprising and challenging issues based on forward-looking analysis and exploration. The project provided the Mission Board with new information, (systemic) insights and/or alternative future visions that connect the extremely multi-dimensioned topics tackled by this Mission Board.

The project had started with the scoping phase of identifying focal areas of which results were discussed in the meeting with the Mission Board. Subsequently, the foresight team explored further future uncertainties and knowledge gaps via a real-time Delhi survey to stakeholders. The scoping phase began with the scanning of 33 foresight reports looking towards 2050, foresight databases and news feeds to address long-term developments and emerging signals of change. In particular, the foresight expert team developed five focal areas, which were presented to the Mission Board to provide interconnected insights as well as challenging and provocative ideas to enrich their work. The five focal areas are summarised in the table below:

Title	1. Climate-resilient coastlines	2. Clean water for the blue planet	3. Vital aquatic ecosystems	4. Open digital twin of oceans and waters	5. Humans at sea
Scope	Sea-level rise and coastal vulnerability	Clean water cycle	Biodiversity and sustainable ecosystem productivity	Observation and early warning	Human settlements and operations at sea
Key target	By 2030, to adapt to an unavoidable sea-level rise across Europe.	By 2030, cut by half industrial nutrients, plastics, pharmaceuticals and pesticides in European waters.	By 2030, harmonize aquatic ecology and economy in decision-making processes	By 2030, create an open digital twin of European aquatic systems.	By 2030, establish a smart and sustainable autonomous village at sea.
Present and future developments	Sea-level rise projections at 2100 are alarming but decision-makers deny its speed and magnitude. Towns, infrastructures, and several economic activities will be affected also by extreme	Healthy oceans rivers and lakes have always been important to mankind as all life depends on them. Important International and EU conferences have underlined the threats and effects for all pollutants and especially on marine litter on freshwater and	The exploration of biodiversity is largely incomplete and the public lacks awareness. A shift needed from compartmentalize d science to a global approach to ecosystem understanding (terrestrial, riverine, marine and oceanic systems).	Limited societal awareness of aquatic ecosystems. Scattered data on aquatic systems not interoperable Among technological advances to manage data, a digital twin provides a	Establishing communities at sea, not only floating cities or marinas but also a new way to live and work. Developments in aquaculture, aquaponics, water desalination, energy generation, would have to

	weather events.	marine environment.		digital replica of living or non-living physical or biological entities.	be adjusted and tested. Circularity would have to be further developed to avoid loss of precious resources.
Societal Impacts	Anticipation and strategic planning on consequences, e.g. migrations are needed to reduce costs and crises.	Poor water availability detracts human resources from development and increases public health budget of countries.	Vital aquatic ecosystems provide essential goods and services to human life, with major societal relevance.	Adapt to and mitigate diverse crises with major economic benefits, also for resolution of conflicts on water.	As overpopulation, intensive land use, coastal degradation, pollution, threaten land-based communities, it is an option to turn towards the sea and develop new solutions, even for land or coast-based communities.
Actions needed	Prepare programmes to address concerns and demand from the Member states and many other countries.	Engage all scientific disciplines, academia, business, policy and civil society in freshwater and marine science.	Strengthen the interfaces between sciences and society for globally coordinated and sustained aquatic biodiversity observation network.	Develop an open digital twin of European aquatic systems for observation and early warning by engaging stakeholders including citizens.	Plan and demonstrate for aquatic production, circular design, and sustainable living via living labs with semi-permanent structures that stay afloat.
EU-added value and implications of (non)action	All the watersheds are involved, even in Central Europe, as the management of river flows is depending on uses and policies upstream.	The EU action needed to create a complex and interconnected system as the non-action would escalate problems in the freshwater/marine water.	The EU added value is to develop a harmonized roadmap. Non-action would lead to the collapse of ecosystems and the economy.	Europe is best positioned to lead in integrating data to form a holistic understanding of hazards, risks and changes in the aquatic environment.	As further pressures on land use rise throughout Europe, there is a need to defer activities to the seas and test combined European capabilities.

After the initial phase of scanning and analysing emerging issues and synthesising the findings into five focal areas the results were discussed with the Mission Board. In the meeting the discussion led the Mission Board request the foresight team to continue the foresight work and identify further data and knowledge gaps related to oceans and waters, the recovery of oceans and waters and their role in climate change mitigation.

In line with foresight practice as well as with the Mission Board's explicit desire to involve a wider public, the study engaged stakeholders via a real-time Delphi method highly suitable to address future uncertainties. The Delphi method is a structured group communication process, dealing with subjects, on which often unsure and incomplete knowledge is available, that are judged upon by experts. The idea is that the respondents can learn from the views of others, without being unduly influenced by the hierarchies or other societal structures and power relations.

Invitations to the survey were sent to stakeholder groups in different sectors of society, in particular: research and development, policy, industry and civil society. Approx. 3000 European stakeholders were invited. The survey platform was open two weeks in February 2020 leading to the total of 238 registered **participants of which 138 finished the survey**.

Participants assessed the total of 15 future statements and proposed new ones to be considered by the Mission Board, in three areas: i) oceans and other water ecosystems, ii) the recovery of healthy oceans and waters and iii) the role of oceans and waters in climate mitigation. The results of the assessments presented in mean values are summarised in the following table in each of the three areas.

Cluster	ID	Statements	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
Oceans and other water ecosystems	1.1	By 2030, the EU reduce the chemical pesticide runoffs to water ecosystems by 80%.	3,11	1,80	0,58	1,44	1,43
	1.2	By 2030 the status of all marine species in the EU waters is assessed, and actions have been taken to truly maintain marine biodiversity.	3,08	1,69	0,69	1,39	1,45
	1.3	By 2030, economists emphasise precautionary minimum standards and the future value of ecosystems.	2,84	1,87	0,71	0,89	2,01
	1.4	By 2030, the EU develops integrated approach to marine governance following the functions and structures of ecosystems beyond political boundaries.	3,25	1,99	0,91	1,09	1,80
	1.5	By 2030, the farming of bivalves for food quadruples in the EU providing a sustainable food source.	2,36	2,16	0,74	0,51	1,69
The recovery of healthy oceans and waters	2.1	By 2030, the EU together with international partners reverse the decline of healthy fish stocks in all its seas.	3,48	1,74	1,12	1,48	1,24
	2.2	By 2030, the detrimental impact of marine litter (especially plastics) on human health and the ecosystems is reduced by 60 percent in European waters.	3,31	2,09	0,86	1,55	1,42
	2.3	By 2030, the EU achieves rigorous control of ships' ballast water.	3,00	2,38	0,39	1,26	1,33
	2.4	By 2030, the multiplied effect of green consumer brand marketing and bottom-up social media campaigns generates major public response and environmental movement to clean the European water ecosystems.	3,01	2,43	0,86	1,00	1,67
	2.5	By 2030, the automated monitoring and big-data analysis will cover 95% of global fishing fleets revolutionising the management of commons in the sea.	3,03	2,34	0,80	0,91	2,15
The role of oceans and waters in climate mitigation	3.1	By 2030, European ecosystem restoration efforts for capturing blue carbon attract multi-billion euro investments.	2,85	1,90	0,85	1,19	2,14
	3.2	By 2030, the EU together with principal polluter countries curb climate change and achieve slowing down the melting of ice on polar caps.	3,45	1,34	0,89	1,57	1,62
	3.3	By 2030, Europe shows global leadership in managing transboundary inland waters to safeguard climate resilient water ecosystems.	2,98	2,21	0,80	1,15	1,80
	3.4	By 2030, offshore wind energy reaches to 10 percent of global electricity production.	2,96	2,53	0,93	0,58	1,35
	3.5	By 2030, major hurricanes inspire increased interest in improving coastal resilience, in particular by tripling global investment in wetland restoration.	2,69	1,93	0,84	0,98	1,91

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2

The findings form the survey can be summarised on each of the areas as follows:

- **Oceans and other water ecosystems:** In this area, all proposed issues are accepted as important but, with the current attitude towards marine and water ecosystems, respondents believed that actions will not be sustained properly. The reason for this lack of consistency between "right things to do" and what is actually done probably resides in cultural gaps that make it difficult to pass from theoretical analyses and legislation to action, with the reversal of current trends. Nonetheless, **the survey indicates consensus about the adoption of the ecosystem approach, recognising that humans, with their cultural diversity, are an integral component of ecosystems** and emphasizing the need for collaboration between the scientific community, the economic sector, policymakers and the public at large.

- **The recovery of healthy oceans and waters:** In this area, the survey showed a remarkable consistency, from all stakeholders, on the actions contributing to healthy oceans and waters. This point could almost guarantee the success of the mission as it seems that the society understands the enormous contribution of healthy oceans and waters on the planet earth. Although the list of what can be achieved in the near future could be endless, the fact that we have **to include society at large in addressing challenges**, should be our first step.

- **The role of oceans and waters in climate mitigation:** The respondents provided a global impression that Europe can be leader in several fields of climate mitigation. If, however, the rest of the world is not addressing these efforts of climate mitigation, the role of Europe will not have significant impact. There is no single major technological solution that, alone, would curb the climate change, a goal that might be achieved by a mix of technologies and regulations, at the right geographic scale, and as early as possible. Furthermore, positive and negative impacts of each technology have to be assessed carefully as very little is still known on the mid-term and long-term impacts of the different technologies available today. **Much more research and stakeholder cooperation are required to select the right technologies and the optimum strategies on time**, in order to avoid unmanageable trends.
- **Further areas to be explored:** Next to the topics proposed by the foresight expert team, stakeholders were asked to suggest other topics that should be understood better and acted upon in the EU. Three main topics emerged: **research and research infrastructure, civil society, and corporate social responsibility**.

Final remarks and recommendations

The first part of the foresight study led to the descriptions of five possible focal areas for European innovation action in the realm of oceans and waters: 1. Climate-resilient coastlines, 2. Clean water for the blue planet, 3. Vital aquatic ecosystems, 4. Open digital twin of oceans and waters, 5. Humans at sea. All these focal areas have similar magnitudes, notably if we consider an extensive view of "humans at sea" not only as an island network but as a continuum between a vulnerable and densely populated low elevation zone and a potentially harmful but also rich coastal ocean. In view of addressing the focal areas or their elements in the future actions towards sustainable development in Europe, it is worth prioritising such efforts in relation with the general theory of systems that establishes the hierarchy of systems in three spheres showing that human activities and economy are nested into natural systems and must obey their laws. Traditional illustrations of sustainability, however, show only a small overlap of the three spheres, this overlap representing sustainability.

The real-time Delphi survey confirmed that there is a need for a holistic approach leading to more structured actions. This is widely recognized but seldom satisfied. Too specific actions, undertaken while ignoring the behaviour of the rest of the ecosystems, may lead to temporary success but will surely not improve the overall situation. This calls for enhanced efforts in improving ocean literacy at all levels, from the scientific community (too focused on reductionistic approaches) to the economic, social and industrial sectors. Furthermore, the conceptual landscape embracing water ecosystems (linking oceanic and inland waters) is very fragmented, with the high risk that while fixing specific problems other problems are created. Hence, we conclude with three recommendations.

1. Adopt a holistic approach for balanced actions that calls for improving water literacy at all levels of society.

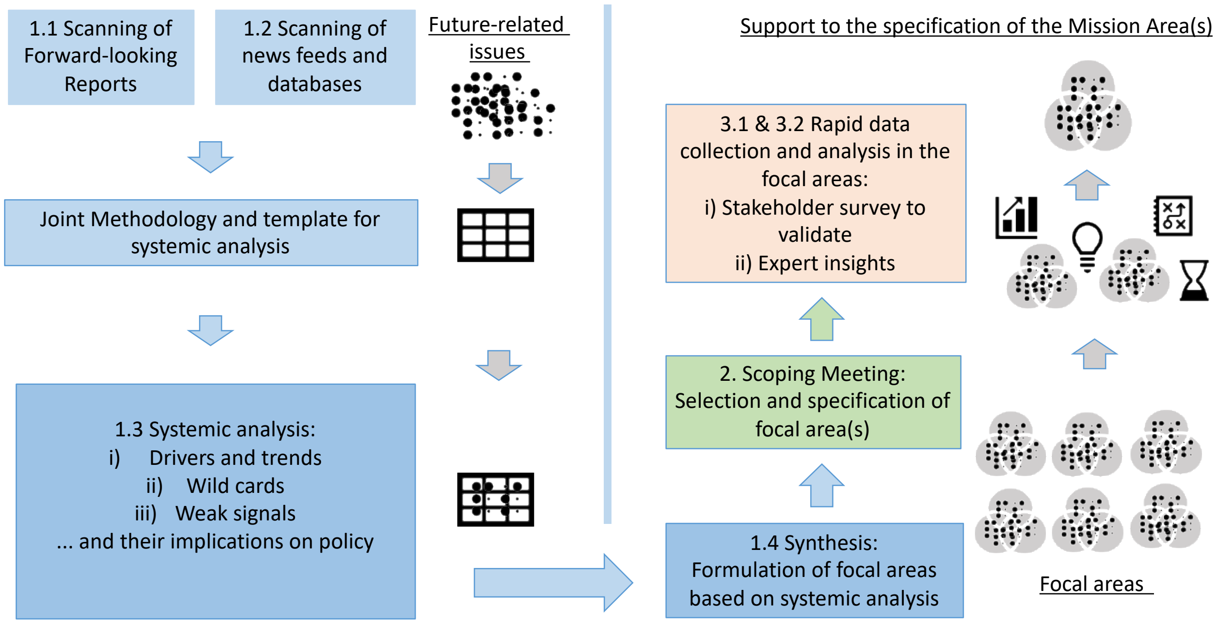
2. Create networks of interest using a common (not too technical) language embracing water ecosystems (including both oceanic and inland waters) to overcome fragmentation in society.

3. Conduct holistic impact assessments and establish monitoring mechanisms of measures implemented to fix specific problems to avoid creating in parallel new problems in complex ecosystems.

1 Introduction

This report summarises the findings from the 'Foresight on Demand' project supporting the Mission Board for Healthy Oceans, Seas, Coastal and Inland Waters in its task of defining specific mission(s) to be addressed in Horizon Europe. The overarching goal of the project was to support from a forward-looking perspective the reflections of the Mission Board. The team of experts was set up by the 'Foresight on Demand' consortium to provide the Board with well-versed expertise in both foresight methodology as well as thematic developments on the future of oceans and waters. The objective was to think along with the Board and to stimulate the debates by raising surprising and challenging issues based on forward-looking analysis, synthesis and exploration. The project provided the Mission Board with new information, (systemic) insights and/or alternative future visions that connect this extremely multi-dimensional topic.

The project started with a scoping phase to identify focal areas of which results were discussed in the meeting with the Mission Board. Subsequently, the foresight team explored further future uncertainties and knowledge gaps via real-time Delphi survey to stakeholders. In the figure below. in blue colour, tasks 1.1-1.4 relate to the scoping phase, task 2 to the meeting with the Mission Board and 3.1 and 3.2 to the Delphi survey, whose results were presented and discussed with the Mission Board.



The scoping phase began with the scanning of 33 foresight reports looking towards 2050, foresight databases and news feeds to address long-term developments and emerging signals of change. In particular, the foresight expert team developed five focal areas, which were presented to and reflected with the Mission Board to provide interconnected insights as well as challenging and provocative ideas to enrich the work of the Mission Board. Subsequently, the foresight project continued to the third phase addressing further future uncertainties and knowledge gaps. In line with foresight practice as well as with the Mission Board's explicit desire to involve a wider public, the study engaged stakeholders via a real-time Delphi survey highly suitable to address future uncertainties.

2 Horizon scanning and focal areas

This scoping phase aimed at supporting the Mission Board in defining the parts of the mission area by providing long-term developments and emerging signals of change and suggesting five focal areas.

The scoping is based on the scanning of reports looking forward towards 2050 and specific foresight databases and news feeds. Issues collected in the categories of 1) drivers and trends, 2) wild cards and 3) weak signals, were examined. The identified issues were documented in a standardized template, which facilitated the subsequent development of the joint synthesis on future developments. The collected issues were used to formulate 5 descriptions of possible focal areas to considering present and future developments and their impacts on Europe and European policies including the advantages of timely action and the consequences of non-action. The collection and analysis of the ***future-related issues*** within the scope of the Mission Board was structured initially in three categories:

- *Existing clearly observable factors of change* **(drivers**) *and long-term development paths* ***(trends).*** A trend is a general tendency or direction of development or change over time. A trend may be strong or weak, increasing, decreasing or stable with no guarantee that a trend observed in the past will continue in the future. Megatrends occur at a global or large scale, and they are the great forces in societal development that will likely affect the future in all areas over the next 10-15 years, for instance, the rising global climate temperature.

- *Low probability high-impact events (**wild cards**).* Wild Cards, also called 'black swans', are surprising and unexpected events with low 'perceived probability' of occurrence but with very high impact (e.g. 2001 attack to the World Trade Centre on 9/11 and the Covid pandemic). Serendipity or the faculty of making scientific discoveries by accident is another important source of wild cards, for instance the discovery of penicillin by Fleming.

- *Emerging signals of current changes subject of observation and intuition (**weak signals**).* Weak signals are past or current developments/issues whose origin, meaning and/or implications are ambiguous. They are unclear observable warnings about the probability of future events. For example, changes in public attitudes to one thing or another, emerging patterns of concern about emerging health problems, or the rise of jellyfish following the decline of over-exploited fish stocks.

The search for these three types of issues was performed by desk analysis of 33 foresight reports of national (e.g. UK and Japan), European (e.g. JPIs, EEA and European Marine Board, EASAC) and international organisations (e.g. IPCC, OECD, G7) and other stakeholders (e.g. WEF and McKinsey) that are listed in the annex, as well as a web newsfeed search and foresight databases for future developments. This led to the identification of 52 trends, 37 weak signals, and 9 wild cards that we grouped per category in the traditional foresight STEEP (Social, Technological, Economic, Ecological, and Political/legal) categories. Full descriptions of each issue can be found in Annex 1, organised in trends, weak signals and wild cards in alphabetical order.

2.1 Trends and drivers

Social trends

A growing proportion of humankind living close to the sea	Degrading water and sanitation systems in sprawling metropolises	Lack of awareness on a healthy ocean and its impact on our activities

Technological trends

A growing technological ability to monitor illegal activity at sea	Advances in virtual water sensors improve real-time data interpretation	Alternative fuels for shipping
Cybersecurity improving in infrastructure and equipment	Digital certification for easier administrative processes (at sea)	E-learning to increase the reach of programmes
Global ocean observing system advances	Virtual reality for (safety) training purposes	Increasing use of automation in the marine environment for various activities
Long-running leaks in water distribution addressed with technological solutions	Marine early warning systems become interconnected	Remote sensors and monitoring systems are increasingly deployed
Resilient agriculture technologies to overcome climatological changes	Satellite earth observation providing new insights on water systems	Scattered data on water resources and use are integrated with new technologies

Economic trends

Carbon-based energy generation heating local water systems (heat pollution)	Declining coastal economic activities due to environmental and economic pressure	Growing blue economy leading to busier seas
Growing use of offshore renewable energy	Increase in activities around Arctic coastal zones	

Ecological trends

Accumulation of plastics due to increased plastic use	Acidification of oceans and waters	Altered biodiversity and species distribution
Changes of temperature and precipitation (climate change) and weather extremes	Declining biodiversity due to human activity	Declining fish stocks due to over-fishing
Declining freshwater sources due to over-use	Degradation of chemical status of groundwaters	Degradation of drinking water quality
Degradation of surface water ecosystems	De-oxygenation of seas	Growing importance of pollutants such as plastics and pharmaceuticals
Rapid decrease of sea ice extent in the Arctic.	Increase of chemical and persistent organic pollutants	Larger temperature extremes, water excess and/or drought
Nitrogen pollution due to fertilizer runoff	Non-indigenous species altering the functioning of ecosystems (due to shipping and transport)	Ocean absorption of increased atmospheric heat and carbon dioxide
Rapid melting of the Greenland ice sheet and mountain glaciers.	Restoring coastal wetlands is getting increasing attention	Seawater rising globally
Seawater temperature rising	The impairment of the cold engines of oceans and seas due to global warming	Increasing evapotranspiration of soil moisture due to climate change
Coastal erosion and changes in Arctic Ocean biogeochemistry driven by thawing permafrost.	Growing frequency of floods in Europe and the world	Surface water temperature rising in rivers and basins

Political trends

Holistic/integrated marine governance	Shifting towards multi-stakeholder governance models	Increasing deep-sea exploration and conflicts over appropriation

2.2 Weak signals

Social weak signals

Coastal living linked with better mental health	Integrated risk assessment is increasingly used in the emerging blue economy	Microplastic fibres found around the world
Water innovation ecosystems to promote technological solutions	Water-saving at home	

Technological weak signals

Ecological weak signals

Farmed oysters able to protect themselves from acidification	Melting of the Antarctic ice sheet	

Economic weak signals

Adaptation of North Atlantic Albacore fishery to climate change	Co-management for sustainable common-pool resources	Conflicts over offshore drilling and use of resources
Diversification in stock use, shifting the burden	Ecological ocean farming - focusing on seaweed and shellfish	New kelp forests of marine permaculture to enhance ecosystem and capture carbon
Stimulating trade-offs in the water-energy-food nexus		

Political/Legal weak signals

Disaster risk reduction for transboundary river basins	Drought is considered a national security issues for trade and geopolitical relations	Inadequate water safety standards may lead to health risks
Legal barriers for the blue bioeconomy due to focus on traditional industries	Pacific islands aim for zero carbon shipping emissions	Water problems becoming a national emergency (Zimbabwe)

2.3 Wild cards

Social wild cards

Multiple oil platform spills/failures	Ocean piracy	

Ecological wild cards

Atmospheric river mega-storm	Massive earthquakes on northern sections of the Cascadia Subduction Zone	Subsea permafrost and methane hydrates
Mercury pollution of oceans, rivers, and lakes due to runoff from thawing permafrost.		

Political/Legal wild cards

Major diplomatic crisis on disputed areas	Political shift towards more regionalised economies	Reassignment of rights over genetic resources

2.4 Focal areas

The collected future-oriented issues were interconnected by formulating five detailed descriptions of possible ***focal areas*** identified based on the expert insights on future-oriented issues and their interconnections. Each expert proposed areas that were jointly further elaborated to come up with the five areas. Each focal area was further developed to detailed descriptions addressing:

- *Scope and clear ambitious target(s)* that are measurable and driven by creating impact.
- *Present and future developments* (problems and opportunities): Including the possible interactions of challenges facing the ocean, seas, coastal and inland waters.
- *Societal Impacts* to Europe and European policies: Of potential interests also to Member States with no direct access to the sea; with impact on society and policy-making through science and technology, and relevant for a significant part of the European population and a wide range of European citizens.
- *Actions needed:* Potential cross-disciplinary, cross-sectoral, cross-actor R&I&D actions; enabling social, economic, regulatory, investment measures; Citizen engagement; leverage additional public and private funds.
- *EU-added value:* Implications of (non)action; Potential implications of European R&I&D action or non-action with regard to ecological, social and economic development and the management of healthy oceans, seas, coastal and inland waters as a public/common good – either by preserving them or by sustainable use.

Furthermore, the following **horizontal considerations** have been considered for all focal areas:

- Any programme that addresses the challenges of seas and oceans need to include holistic understanding of the **interconnected aquatic systems** of Oceans, Seas, Coastal and Inland Waters. Ecological sustainability is the foundation for social and economic sustainability.
- The oceans and seas are the largest examples of **commons** on the planet and related activities should avoid creating tragedies of the commons with good international governance.
- Citizens can play a critical part in engaging directly and empowering the policy and business through their decisions and actions. In all focal areas, awareness-raising is fundamental and connected with the **direct engagement of citizens, including citizen science**.

The below comparative table provides an overview of each of the suggested five focal areas (See Annex 2 for the detailed descriptions of each focal areas).

Title	**1. Climate-resilient coastlines**	**2. Clean water for the blue planet**	**3. Vital aquatic ecosystems**	**4. Open digital twin of oceans and waters**	**5. Human at sea**
Scope	Sea-level rise and coastal vulnerability	Clean water cycle	Biodiversity and sustainable ecosystem productivity	Observation and early warning	Human settlements and operations at sea
Key target	By 2030 to adapt to an unavoidable sea-level rise across Europe.	By 2030 cut half industrial nutrients, plastics, pharmaceuticals and pesticides in European waters.	By 2030 Harmonize aquatic ecology and economy in decision-making processes	By 2030 create an open digital twin of European aquatic systems.	By 2030 establish a smart and sustainable autonomous village t sea.

Present and future developments	Sea-level rise projections at 2100 are alarming but decision-makers deny its speed and magnitude. Towns, infrastructures, and several economic activities will be affected also by extreme weather events.	Healthy oceans rivers and lakes have always been important to mankind as all life depends on them. Important International and EU conferences have underlined the threats and effects for all pollutants and especially on marine litter on freshwater and marine environment.	The exploration of biodiversity is largely incomplete and the public lacks awareness. A shift needed from compartment-talized science to a global approach to ecosystem understanding (terrestrial, riverine, marine and oceanic systems).	Limited societal awareness of aquatic ecosystems. Scattered data on aquatic systems not interoperable Among technological advances to manage data, a digital twin provides a digital replica of living or non-living physical or biological entities.	Establishing communities at sea, not only floating cities or marinas but also a new way to live and work. Developments in aquaculture, aquaponics, water desalination, energy generation, would have to be adjusted and tested. Circularity would have to be further developed to avoid loss of precious resources.
Societal Impacts	Anticipation and strategic planning on consequences, e.g. migrations are needed to reduce costs and crises.	Poor water availability detracts human resources from development and increases public health budget of countries.	Vital aquatic ecosystems provide essential goods and services to human life, with major societal relevance.	Adapt to and mitigate diverse crises with major economic benefits, also for resolution of conflicts on water.	As overpo-pulation, intensive land use, coastal degradation, pollution, threaten land-based communities, it is an option to turn towards the sea and develop new solutions, even for land or coast-based communities.
Actions needed	Prepare programmes to address concerns and demand from the Member states and many other countries.	Engage all scientific disciplines, academia, business, policy and civil society in freshwater and marine science.	Strengthen the interfaces between sciences and society for globally coordinated and sustained aquatic biodiversity observation network.	Develop an open digital twin of European aquatic systems for observation and early warning by engaging stakeholders including citizens.	Plan and demonstrate for aquatic production, circular design, and sustainable living via living labs with semi-permanent structures that stay afloat.
EU-added value and implications of (non)action	All the watersheds are involved, even in Central Europe, as the management of river flows is depending on uses and policies upstream.	The EU action needed to create a complex and interconnected system as the non-action would escalate problems in the freshwater/marine water.	The EU added value is to develop a harmonized roadmap. Non-action would lead to the collapse of ecosystems and the economy.	Europe is best positioned to lead in integrating data to form a holistic understanding of hazards, risks and changes in the aquatic environment.	As further pressures on land use rise throughout Europe, there is a need to defer activities to the seas and test combined European capabilities.

It is clear that these focal areas have similar magnitudes, notably if we consider an extensive view of "human at sea" not only as an island network but as a continuum between a vulnerable and densely populated low elevation zone and a potentially harmful but also rich coastal ocean. In view of addressing the focal areas or their elements in the future actions towards sustainable development in Europe, it is worth prioritising such efforts in relation with the general theory of systems. For instance, Von Bertalanffy (1968) and Passet (1979) and many others have established the following hierarchy of systems in three spheres: Sphere 1: Environment or Biosphere (which laws rule also Spheres 2 & 3); Sphere 2: Human activities (which laws rule also Sphere 3); and Sphere 3: Economy (systems elaborated by Man). This hierarchy of rules shows that human activities and economy are nested into natural systems and must obey their laws. Traditional illustrations of sustainability, however, show only a small overlap of the three spheres, this overlap representing sustainability.

3 Real-time delphi survey on further uncertainties

3.1 Introduction

After the initial phase of scanning and analysing emerging issues and synthesising the findings into five focal areas the results were discussed with the Mission Board. In the meeting the discussion led the Mission Board request the foresight team to continue the foresight work and identify further data and knowledge gaps related to oceans and waters, the recovery of oceans and waters and their role in climate change mitigation.

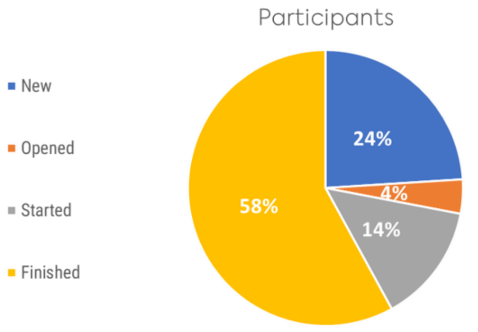
In line with foresight practice as well as with the Mission Board's explicit desire to involve a wider public, this study engaged stakeholders via a Delphi method highly suitable to address future uncertainties. The Delphi method is a structured group communication process, in which experts judge on subjects whose knowledge is naturally unsure and incomplete. Respondents learn from the views of others, without being unduly influenced by hierarchies or other societal structures and power relations.

This Delphi study invited participants to assess 15 future statements, and to propose new ones to be considered by the Mission Board, in the following areas: i) Oceans and other water ecosystems, ii) The recovery of healthy oceans and waters and iii) The role of oceans and waters in climate mitigation. Invitations to the survey were sent to stakeholder groups in different sectors of society, in particular: research and development, policy, business, and civil society. Approx. 3000 European stakeholders were invited by means of:

- personal contacts of expert group members
- contacts of expert group and wider networks, via e-mail lists, newsletters and social media (especially, related Linkedin groups)
- the Commission services inviting the members of the Mission Board and Assembly.

The survey platform was launched on 10.02.2020 and it was closed on 24.02.2020 leading to 238 registered participants, of which 138 finished the survey (58%), in the following stakeholder categories:

- Business (12)
- Civil Society (5)
- Other (17)
- Policy (10)
- Research and development (94)
- All (138)



New: Have gone through the registration process, but have not opened the Delphi
Opened: Have opened the Delphi, but did not participate.
Started: Have opened the Delphi and answered one or more questions
Finished: Have run the Delphi to the last question and closed it on "Finish Delphi"

Real-time Delphi – Rating Criteria

All the future statements were assessed with five criteria:

- **Relevance –** How important do you consider addressing this topic through joint European innovation actions?
- **Likelihood of occurrence:** - How likely you consider this statement to come true?
- **Novelty** – How novel is this topic for you? Did you ever hear of it?
- **Socio-economic impact:** - If considered this statement to occur, what kind of a societal-economic impact would it have on Europe?
- **Ecological impact** - If this statement will occur, what ecological impact would it have on Europe?

CRITERIA / Values	0	1	2	3	4
Relevance	not important	somewhat important	important	very important	extremely important
Likelihood of occurrence	extremely unlikely	somewhat unlikely	likely	very likely	extremely likely
Novelty	not new at all	somewhat new	quite new	really new	never heard of it before

CRITERIA / Values	–2	–1	0	+1	+2
Socio-economic impact Ecological impact	enormous negative impact	considerable negative impact	minimal impact	considerable positive impact	enormous positive impact

Global view on the survey results

The below summary table provides an overview of the mean values of all the assessments by each criterion.

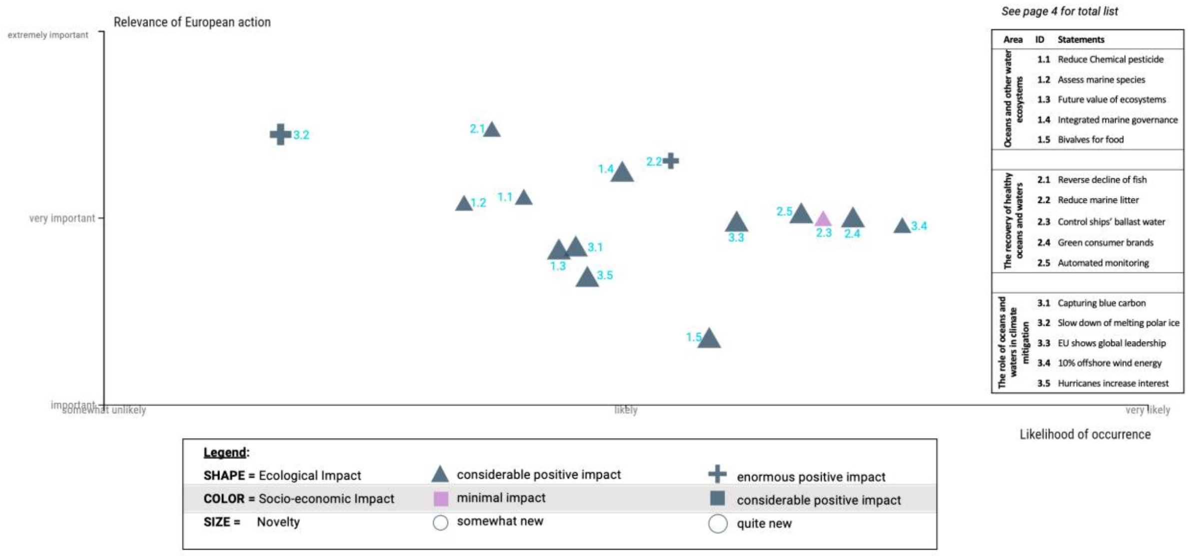
Table – All Rating Results by Topic Cluster

Cluster	ID	Statements	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
Oceans and other water ecosystems	1.1	By 2030, the EU reduce the chemical pesticide runoffs to water ecosystems by 80%.	3,11	1,80	0,58	1,44	1,43
	1.2	By 2030 the status of all marine species in the EU waters is assessed, and actions have been taken to truly maintain marine biodiversity.	3,08	1,69	0,69	1,39	1,45
	1.3	By 2030, economists emphasise precautionary minimum standards and the future value of ecosystems.	2,84	1,87	0,71	0,89	2,01
	1.4	By 2030, the EU develops integrated approach to marine governance following the functions and structures of ecosystems beyond political boundaries.	3,25	1,99	0,91	1,09	1,80
	1.5	By 2030, the farming of bivalves for food quadruples in the EU providing a sustainable food source.	2,36	2,16	0,74	0,51	1,69
The recovery of healthy oceans and waters	2.1	By 2030, the EU together with international partners reverse the decline of healthy fish stocks in all its seas.	3,48	1,74	1,12	1,48	1,24
	2.2	By 2030, the detrimental impact of marine litter (especially plastics) on human health and the ecosystems is reduced by 60 percent in European waters.	3,31	2,09	0,86	1,55	1,42
	2.3	By 2030, the EU achieves rigorous control of ships' ballast water.	3,00	2,38	0,39	1,26	1,33
	2.4	By 2030, the multiplied effect of green consumer brand marketing and bottom-up social media campaigns generates major public response and environmental movement to clean the European water ecosystems.	3,01	2,43	0,86	1,00	1,67
	2.5	By 2030, the automated monitoring and big-data analysis will cover 95% of global fishing fleets revolutionising the management of commons in the sea.	3,03	2,34	0,80	0,91	2,15
The role of oceans and waters in climate mitigation	3.1	By 2030, European ecosystem restoration efforts for capturing blue carbon attract multi-billion euro investments.	2,85	1,90	0,85	1,19	2,14
	3.2	By 2030, the EU together with principal polluter countries curb climate change and achieve slowing down the melting of ice on polar caps.	3,45	1,34	0,89	1,57	1,62
	3.3	By 2030, Europe shows global leadership in managing transboundary inland waters to safeguard climate resilient water ecosystems.	2,98	2,21	0,80	1,15	1,80
	3.4	By 2030, offshore wind energy reaches to 10 percent of global electricity production.	2,96	2,53	0,93	0,58	1,35
	3.5	By 2030, major hurricanes inspire increased interest in improving coastal resilience, in particular by tripling global investment in wetland restoration.	2,69	1,93	0,84	0,98	1,91

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2

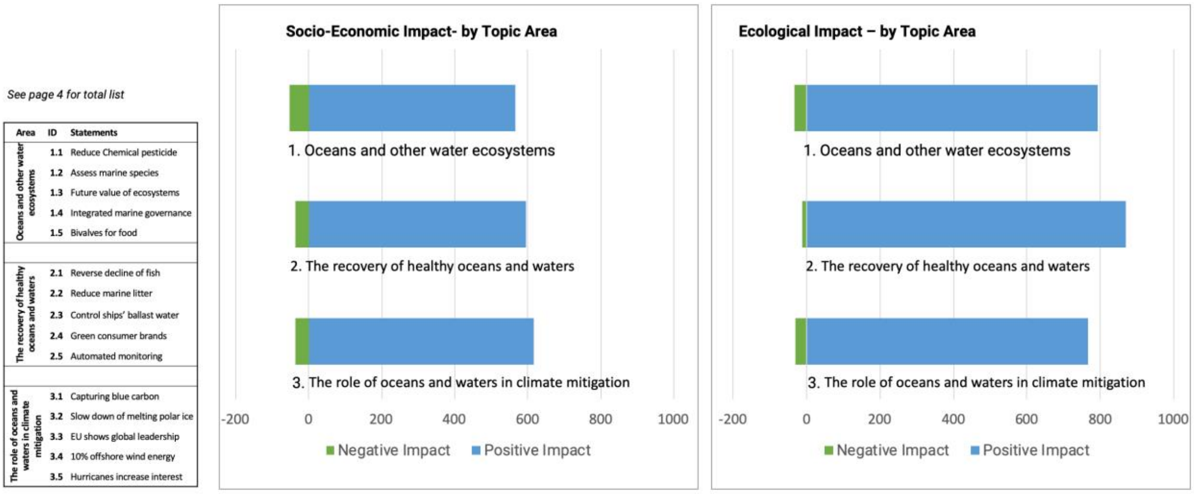
The summary graph below provides an overview of the mean values of all assessments by their relevance and likelihood. The legend provides further detailed information on how to interpret the figure with regard to impact and novelty assessments. In particular, the topic 3.2 ‘slow-down of melting polar ice’ stands out in terms of its low likelihood and extremely high importance.

Graph: Overview – All Rating Results as Portfolio



The summary graph below provides a cumulative view of all assessments per topic area, on their socio-economic and ecological impact, indicating perceived positive impact of addressed statements.

Graph: Quantitative Stacked Rating Results of Socio-Economic and Ecological Impact – by Topic Area



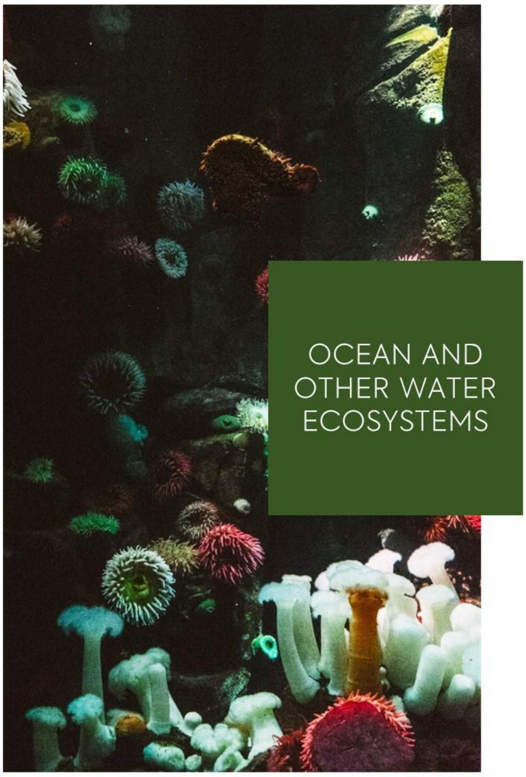
The detailed findings from the survey responses on the statements in each of the three areas are detailed in Annex 3.

3.2 Discussion of survey results on oceans and water ecosystems

Introduction

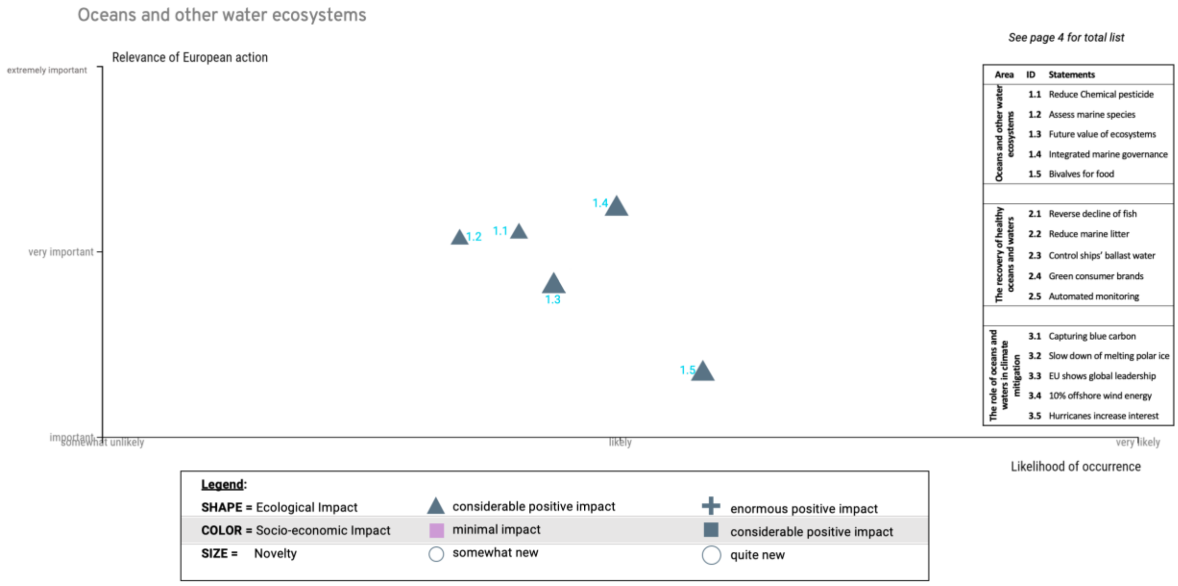
The survey solicited opinions on some approaches to the knowledge of water systems that seem important but that are currently neglected. It was suggested that, with proper investments during the next decade, significant progress could be achieved in the following areas:

1. The impact of pesticides on aquatic systems will be considered and measures will be taken.
2. Knowledge on aquatic biodiversity and its state will significantly improve.
3. Alternative approaches, besides monetary ones, will be adopted to evaluate natural systems.
4. Natural boundaries, rather than political ones, will be recognized to plan our use of nature.
5. Sustainable aquaculture will focus on organisms with low trophic positions such as bivalves.



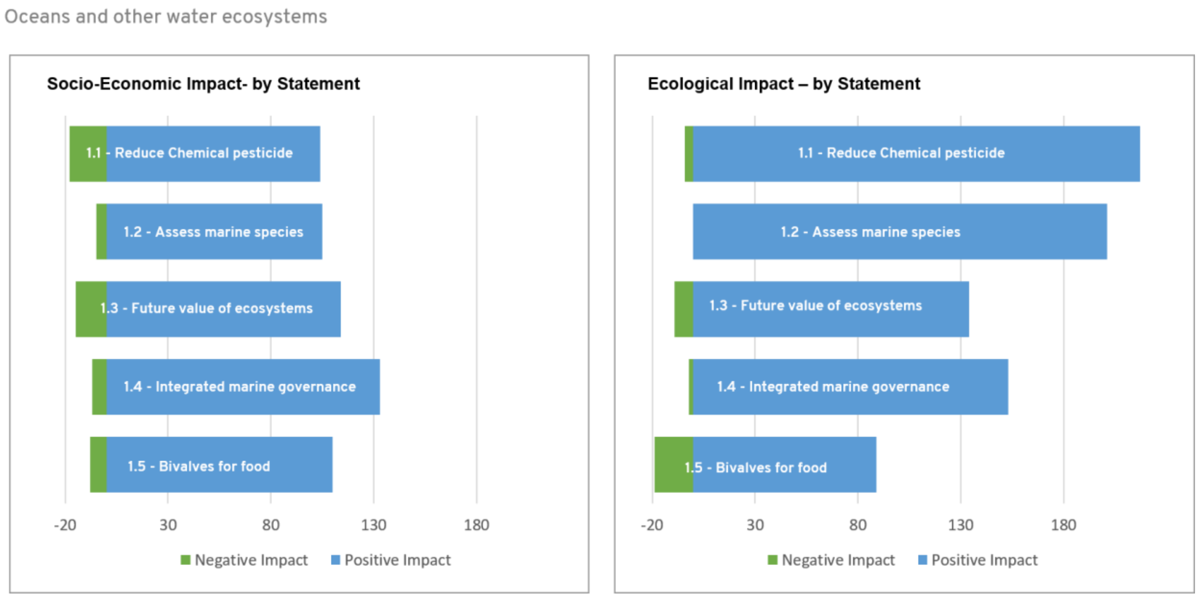
Graph: Overview – Rating Results as Portfolio

Oceans and other water ecosystems



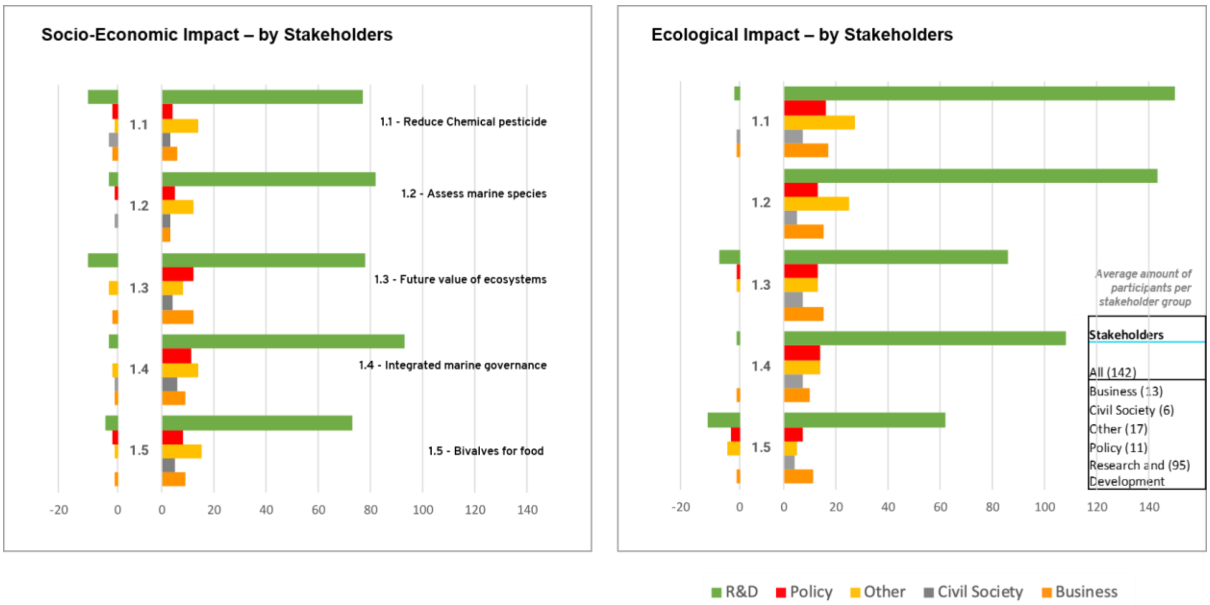
Graph: Quantitative Stacked Rating Results of Impacts all Participants

Oceans and other water ecosystems



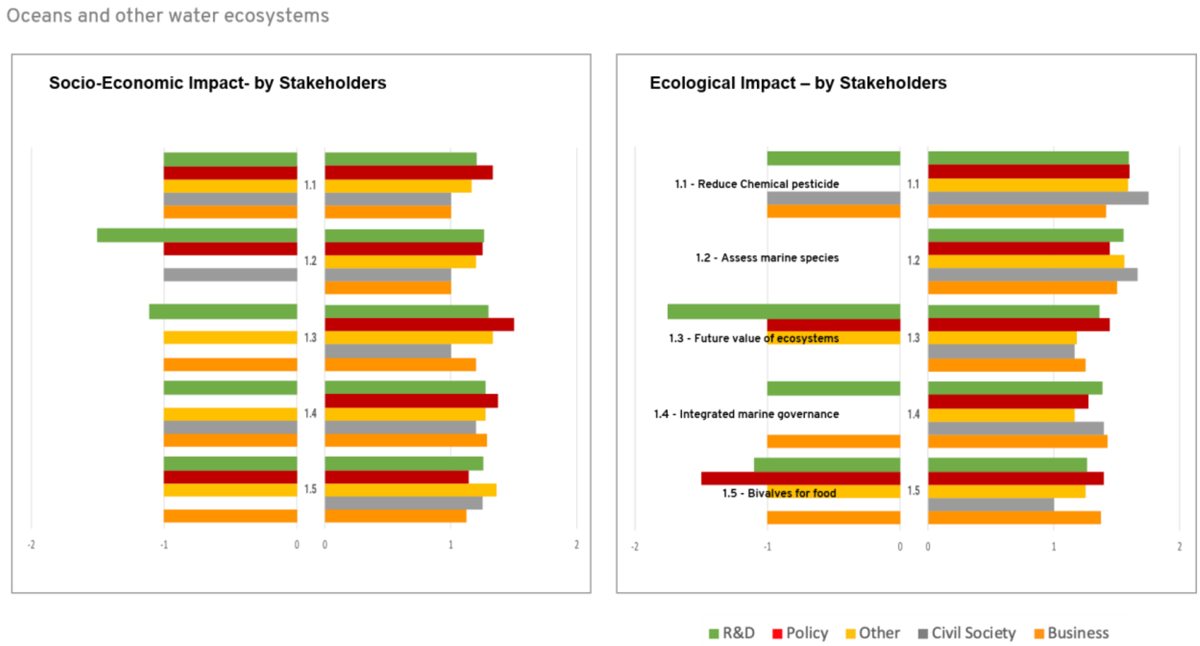
Graph: Quantitative Stacked Rating Results of Impacts all Participants

Oceans and other water ecosystems



Graph : Quantitative Levelled Rating Results of Impacts all Participants

Oceans and other water ecosystems



Observations on Delphi statements

All respondents agree about the relevance of research and innovation initiatives aimed at reaching such goals. However, most respondents retain that current programs do not invest much efforts in these directions (especially for biodiversity, where expertise is to be re-built). Some respondents stated that economic drivers might become an obstacle to actions that should be fostered, e.g. in the case of pesticides, due to the power of the industry engaged in the field.

All agree on the relevance of the ecosystem approach and call for the upgrade of observation systems so as to cover biodiversity, involving marine stations as important components of observing systems.

Apart from other issues, the respondents had more diverging views on the importance of bivalves in aquaculture.

A common perception is that the "business as usual" approach would continue and that things will not change much due to lack of willingness to change them, in spite of the urgency for a change. It is obvious that natural boundaries are better than political boundaries, if effective environmental policies are to be enforced. However, the respondents felt that national peculiarities would prevail over unifying ecological principles.

All respondents agree about the importance of the proposed issues, but many have doubts about the likelihood of any improvement of the current situation in the next decade. They based this perception on the fact that, so far, such issues did not receive much support, and gave for granted that the situation will not change. This is particularly evident for the biodiversity issue: all agree about its paramount importance, but many have doubts that the study of biodiversity will be fostered in the future.

The knowledge and conservation of biodiversity are labelled as crucial for our well-being. However, in spite of all statements (e.g. Rio Convention in 1992; Good Environmental Status in MSFD D1 descriptor on biodiversity; UN Decade 2010-2020 dedicated to biodiversity), biodiversity research is not receiving the necessary support from national and international sources: the basic expertise in biodiversity exploration (i.e. phenotypic taxonomy), which is fundamental for the well-being of our planet, is disappearing from the scientific community. This situation (i.e. all agree that biodiversity is important, but investments on it are not supported) is simply absurd.

Most respondents are sceptical about the possibility of achieving ambitious targets of the statements proposed in the survey, in spite of stating their high importance. Only the target on cultivating bivalves is retained as possible in the next decade, whereas important drivers might prevent other necessary action from being enacted. Different rationales for inaction were given in fields such as pesticides (i.e. industry resistance), shift from political to natural boundaries (i.e. action focused on national interests), alternative evaluation measures of natural assets (i.e. resistance of mainstream economists), biodiversity (i.e. lack of support within the scientific community).

Other suggestions from survey participants

Participants were asked to provide further reflections and suggestions on the topic. These are summarized here in a telegraphic format (in bold the topics that are not simple developments of the already proposed topics):

- Aquaculture; Ocean space
- Unmanned surface vehicles
- **Exploitation of deep-sea resources**
- Studies in marine field stations
- Integrated ocean observing system
- Monitoring of species
- Impacts on ocean megafauna
- Impacts through marine economic activities
- **Marine biotechnology**
- Explore deep-ocean areas
- Protect all offshore deep marine habitats
- Characterization of marine biodiversity
- Carrying capacities of all ecosystems
- Mapping of deep seabed
- **Make oceans accessible through virtual reality**
- Invest in ocean observatory
- **Use marine resources in feed**
- **Equal approaches of agri- vs aquaculture**
- **Global lifecycle approach on agri- and aquaculture**
- Ecosystem approach to fishery
- Understand marine environments better though real-time observatory systems
- Monitoring of coastal sediments
- Gap analysis on different ocean, seas and coastal water ecosystems
- **Sustainable marine-cultural, considering environmental, economic and social impact;**
- Oceans as source of food in a food security perspective
- **Land based aquaculture and RAS**
- **Economic ripple effect analysis from marine activities and the importance to coastal society**
- Promote new ocean governance at UN level
- **Launch awareness campaign**
- **Promote concept of positive impacts of marine infrastructures**
- **Erasmus of the Sea**
- Transform existing EU agencies, EU committee and EU commission it builds a strategic vision for a maritime Europe
- By 2030, the various ecosystem services our ocean, seas and coasts provide can be quantified and are considered in policy and management
- Development of integrated multiparameter environmental observing system
- **Launch the Ocean of Things initiative**
- Monitoring system to decide on the evolution of the state of the Ocean
- Integration of all aquatic ecosystems
- More funding and long-term policy to build an inventory of marine life
- Historical perspective of the ecological status of our coasts

- **Efficient use of water in households, industry and agriculture - water saving systems and water recycling.**

Some respondents suggested to consider the impacts of fertilizers together with pesticides. As the survey explored specifically less known areas, it did not address fertilizers since their role in enhancing eutrophication in aquatic systems is already well established. Many “new” proposals were simple details of the proposed topics (e.g. observing systems, biodiversity, etc.).

The use of technologies was advocated so as to cope with operational necessities in monitoring efforts. Besides the importance of protection of ecosystems, some stakeholders highlighted the necessity of pro-actively finding alternatives and good practices. Industry can play an important role in this direction by developing business opportunities ranging from sea-based biotechnologies to ecosystem services. The respondents advocate sustainability in all its facets as a major issue: **re-forming our production and consumption models is an unprecedented occasion to foster innovation and economic development while preserving the natural capital.**

Conclusion

All proposed issues are acknowledged as important but achieving the targets are considered less likely. The reason for this lack of consistency between “right things to do” and what is done probably resides in cultural gaps that make it difficult to pass from theoretical analyses and legislation to action, with the reversal of current trends. Legislation, especially at EU level, is focused on relevant issues, namely the ecosystem approach and the definition of Good Environmental Status (GES) in the Marine Strategy Framework Directive (MSFD), but the adoption of measures is mostly inconsistent. This makes it difficult for the EU institutions and national governments to identify priorities and to even realize that stated priorities (one for all: biodiversity exploration) are not producing concrete action. Ocean literacy is to be enhanced, at all levels.

The shift from reductionistic (i.e. focused on single aspects) to holistic (i.e. focused on the connections among various relevant aspects) approaches is felt as extremely necessary. However, specialists tend to focus on their special topic and implicitly belittle the importance of other topics. This was particularly evident in some responses to the survey, where specialists praised the urgency of supporting their specific topics (e.g. seabed mapping, nutrients, biotechnologies, etc.). Overspecialization on single aspects, in fact, is often accompanied by lack of competence on other equally relevant aspects, with a non-profitable competition among different approaches. All agree that the ecosystem approach is important, but only few respondents suggested integration of topics, even if this is the logic behind the ecosystem approach.

This survey helps focus policy by indicating total consensus about the adoption of the ecosystem approach, including humans as a portion of biodiversity, in all programmes, and emphasising the need for collaboration between the scientific community, the economic sector, policymakers and the public at large.

3.3 Discussion of survey results on the recovery of healthy oceans and waters

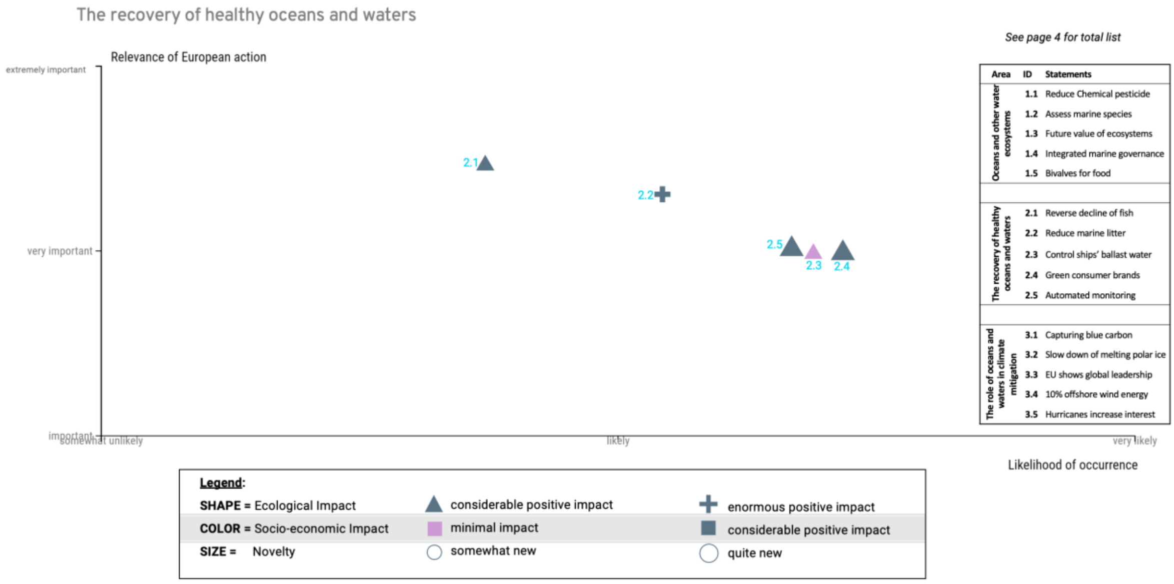
Introduction

The survey solicited opinions on some approaches to the recovery of healthy oceans and waters. It was suggested that, with proper investments, actions and ideas, significant progress could be achieved in the following areas within the next decade:

1. Reverse the decline of fish and aquatic fish resources in all seas
2. The impact of marine litter (especially plastics) on human health and the ecosystems will be seriously considered and measures will be taken
3. The treatment of ballast water from ships will be increased
4. Multiplied societal effects and actions from green consumer brand marketing will generate major public response
5. Automated monitoring and big-data analysis will be used to better manage of commons in the sea.

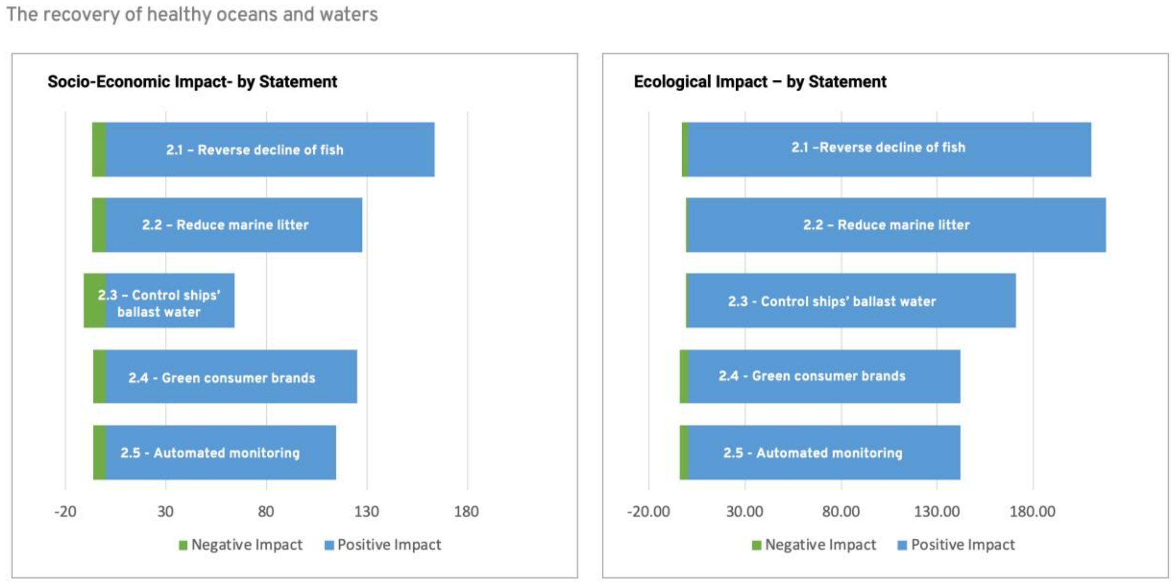
Graph: Overview – Rating Results as Portfolio

The recovery of healthy oceans and waters



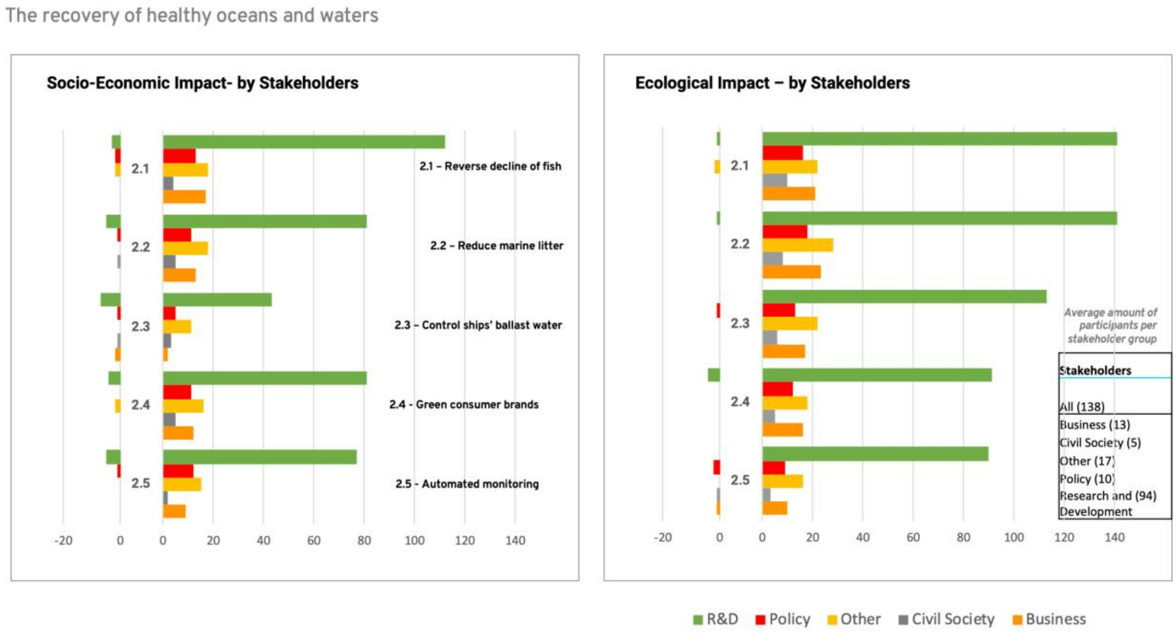
Graph: Quantitative Stacked Rating Results of Impacts all Participants

The recovery of healthy oceans and waters



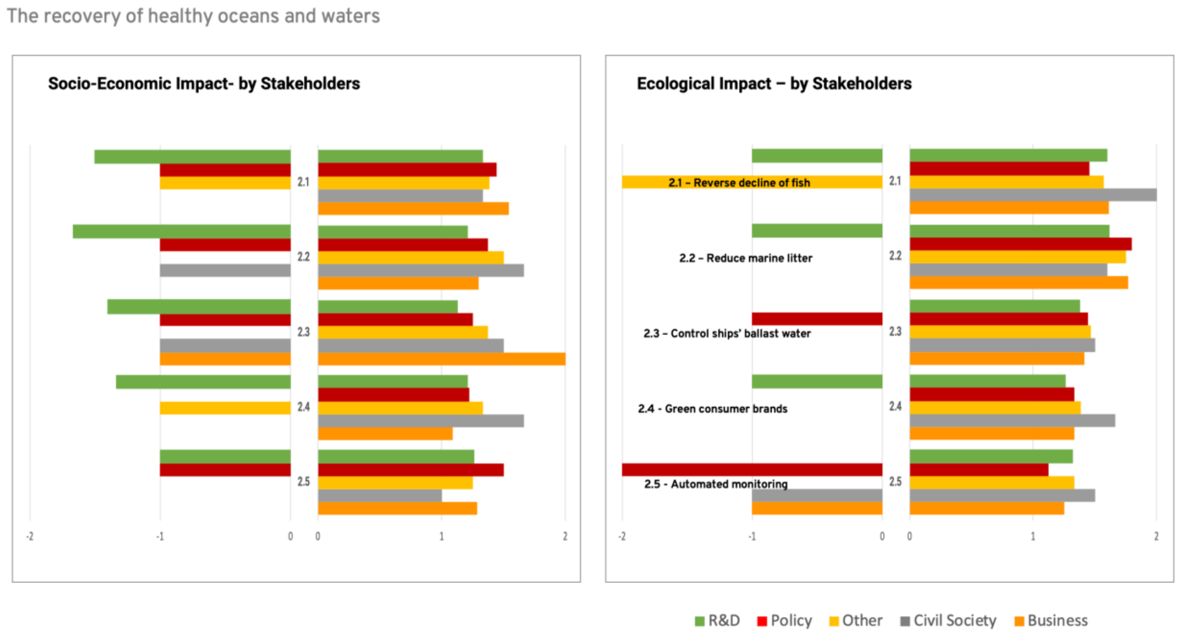
Graph: Quantitative Stacked Rating Results of Impacts all Participants

The recovery of healthy oceans and waters



Graph: Quantitative Levelled Rating Results of Impacts all Participants

The recovery of healthy oceans and waters



Observations on Delphi statements

The respondents considered all statements as very important, having a considerable positive impact towards healthy oceans and waters. The reverse of the decline to fisheries was considered as the most important and very relevant as a European action, but it was considered as probably the less likely to be achieved in the next decade.

The adoption of holistic views towards the ecosystem approach and the connectivity of fisheries with the ecosystem health was underlined as significantly important. A better management of Marine Protected Areas can play a significant role for species recovery and sustainability of fisheries and ecosystems.

There are many cross-cutting issues from the respondents, the most pronounced ones being related to the governance, even outside EU waters. The results were a bit skewed from the plethora of answers from researchers. However, overall the statements from research are almost aligned with all other stakeholder groups.

Other suggestions from survey participants

Participants provided also further reflections and suggestions on the topic, which are summarized here in a telegraphic format (in bold the topics that are not simple developments of the already proposed topics):

- Assess influence of mixture of negative factors on marine ecosystem health
- Define marine protected areas;
- **Improve management of marine upwelling ecosystems**;
- Understand marine food webs
- Positive impacts of degrowth on environment and human well-being;
- Impact on marine ecosystem through reduced fishing;
- **Impacts of shifting to ecologically inspired and organic agriculture**
- Conservation status of marine benthic ecosystems to return to the pre-industrial situation.
- Underwater noise pollution,
- Underwater noise

- Effects of biodiversity loss
- Stop overfishing and harmful fishing gear
- Big data analysis and monitoring of microbial components
- **Role of ocean acidification on socio-economical services**
- **Restoration initiatives to bring back lost goods and services**
- **Effects of autonomous shipping and transportation**
- Influence of oil & gas exploration on seafloor and marine biota
- Impacts of underwater noise on species
- Impacts of exploiting seabed sediments as resource
- Fight loss of marine life
- **Assess industrial and urban discharges into aquatic environments**
- **Impacts of other anthropogenic risks and medicines in the marine environment**.
- Acidity of seas, oceans and marine habitats
- Evaluate impact of bycatch
- **Pollution due to maritime transport and coastal developments**.
- **Vegetable aquatic biomass as global food source**
- **Implement policies for sustainable and resilient planning of waterfront and offshore development**
- Improved fisheries practices that reduce impacts on the marine ecosystems
- **Black Sea's Hydrogen sulphide occurrence and trend due to the climate change**
- **Improvement of the expertise and capacity of the Black Sea laboratories**
- **Focus on better sewage and storm run-off management**
- Establish and protect Marine Protected Areas
- **Encourage migratory species back into healthy rivers**
- Focus on the impacts of marine acidification on fisheries and ecosystems
- Communicate well to citizens
- Socio - economic discrepancy in natural resource exploitation
- Military sonars
- **Impacts of pharmaceuticals release**
- Protect offshore and deep-sea areas
- **Ban of deep-sea mining**
- Increase ocean literacy
- **Cost-effective and environmentally friendly production of novel blue bio products**

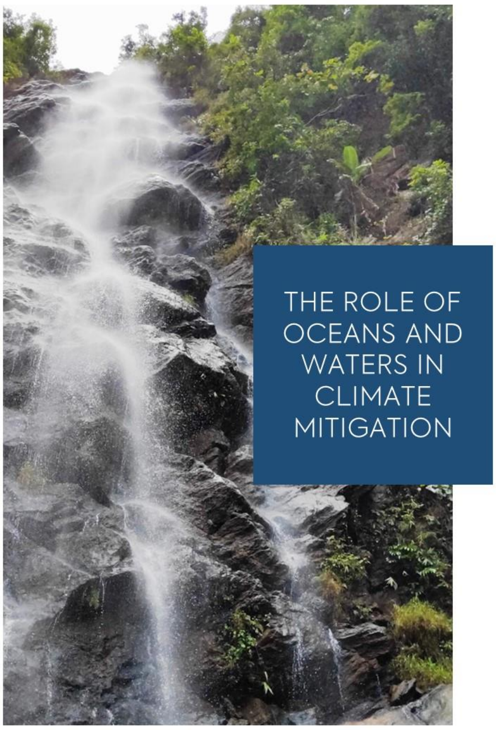
Conclusion

The survey showed a remarkable consistency, from all the different groups of stakeholders, on the actions in trying to contribute to healthy oceans and waters. This is one point that could almost guarantee the success of the mission as it seems that the society understands the enormous contribution of healthy oceans and waters on the planet earth. The problem is well framed, but the solutions might turn out into an endless list of what can be achieved in the near future. However, the first step is made and shows that we have to include society at large in the process of addressing challenges.

As with the previous section, a plethora of solutions is proposed so as to tackle a single, large problem: Ocean Health. This is not due to inconsistency in the answers, but to the extreme complexity of the problem that, indeed, cannot be solved with single actions, focusing on single fractions of the scenario.

3.4 Discussion of survey results on the role of oceans and waters in climate mitigation

Introduction



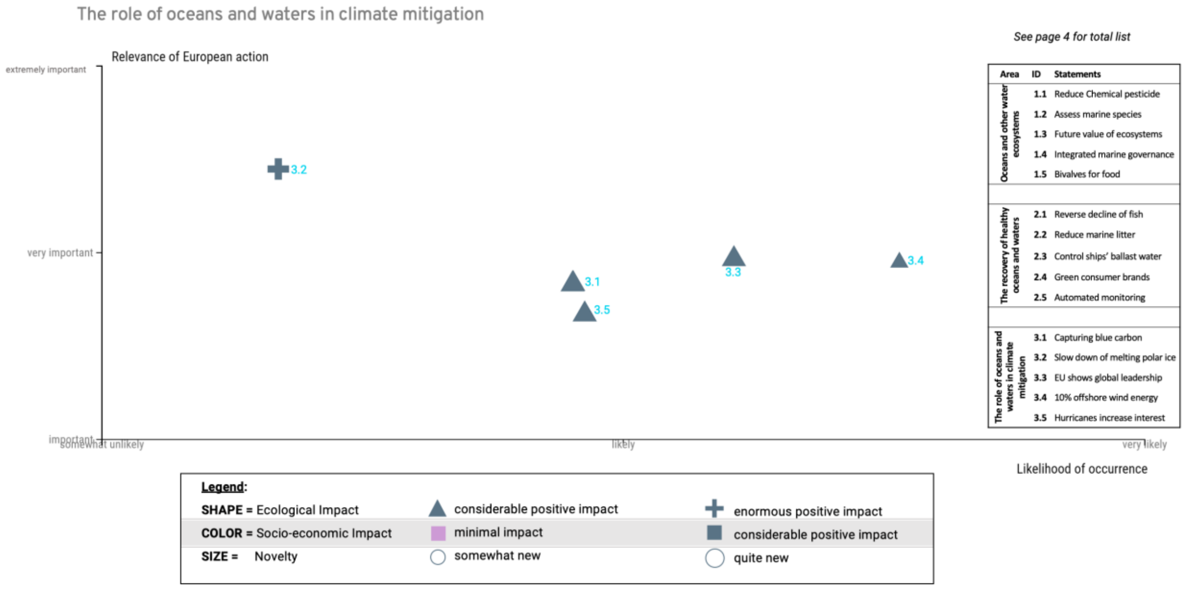
The climate mitigation is greatly depending on human activities and, consequently, on human decisions. Today, most decision makers admit that the global trend about climate change is becoming alarming and could lead soon to a more dangerous and chaotic evolution.

Subsequently, there is less and less time to mitigate efficiently the climate evolution, with horizon 2030 as a non-negotiable ultimate deadline. In these developments oceans and waters play a crucial role in climate evolution because they play a key role at the interface of atmosphere, biosphere and human activities.

Consequently, Europe has the opportunity, and the responsibility, to be one of the leading regions heading for a stabilized climate and developing strategies, skills and technologies in that aim.

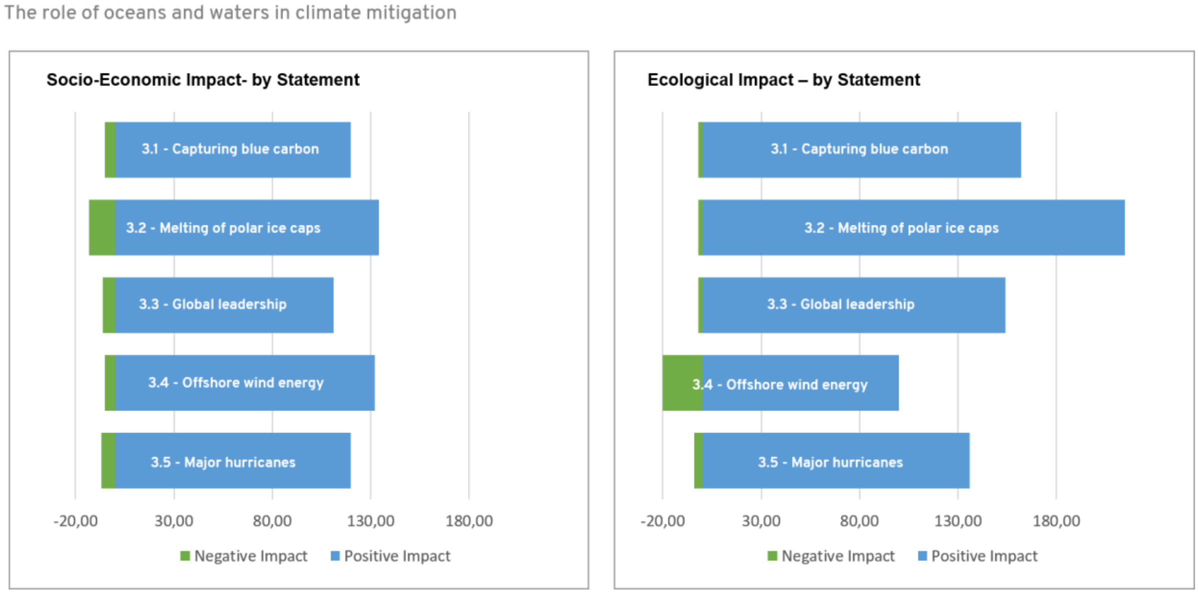
Graph: Overview – Rating Results as Portfolio

The role of oceans and waters in climate mitigation



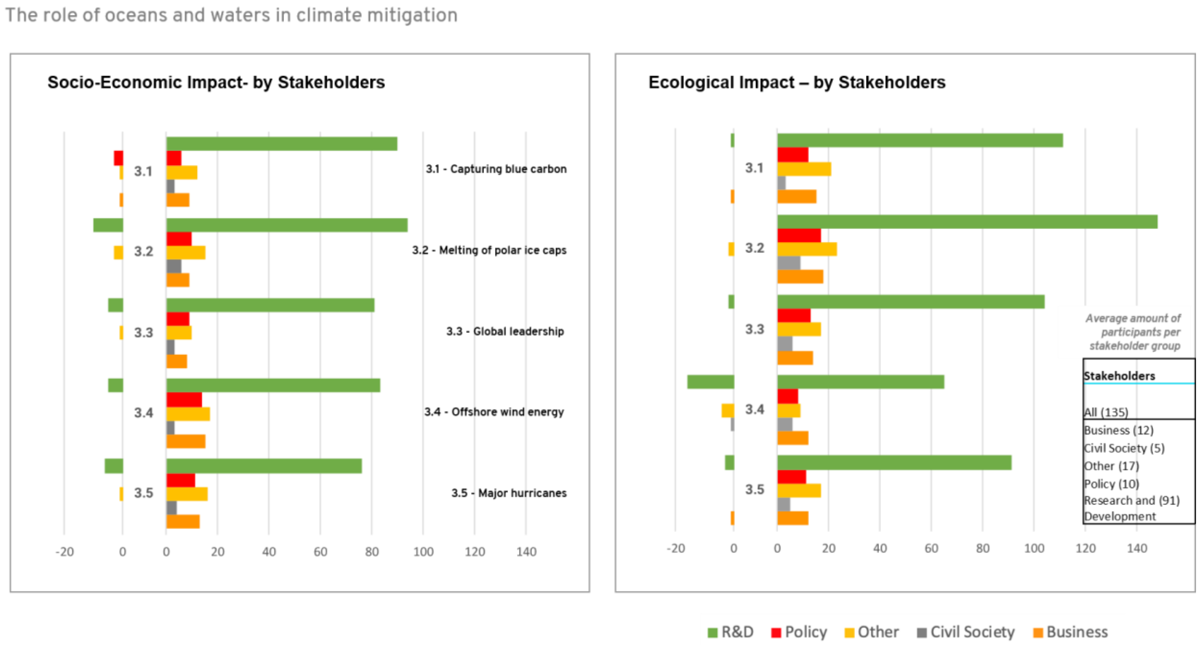
Graph: Quantitative Stacked Rating Results of Impacts all Participants

The role of oceans and waters in climate mitigation



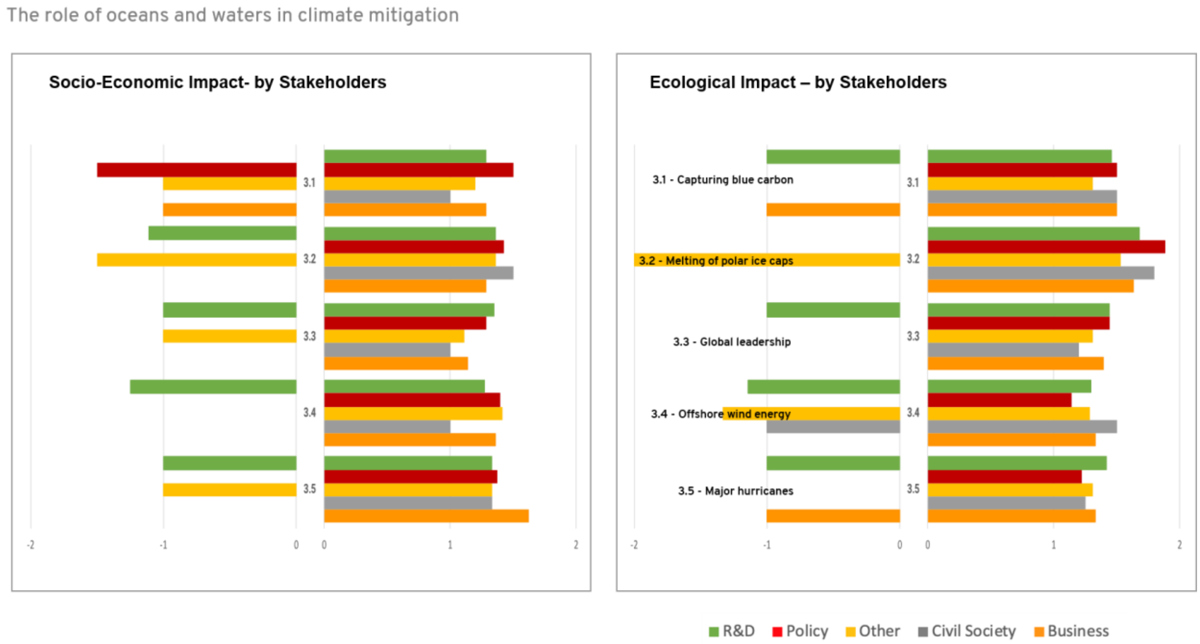
Graph: Quantitative Stacked Rating Results of Impacts all Participants

The role of oceans and waters in climate mitigation



Graph: Quantitative Levelled Rating Results of Impacts all Participants

The role of oceans and waters in climate mitigation



Observations on Delphi statements

All the statements in this area dealing with the role of oceans and waters in climate mitigation show that:

1. Europe can be leader in several fields of climate mitigation. If, however, the rest of the world is not addressing efforts towards climate mitigation, Europe will not have significant impact.
2. There is no single major technological solution that, alone, would curb the climate change: a mix of technologies and regulations is needed.
3. Positive and negative impacts of each solution have to be assessed carefully as very little is still known on the mid-term and long-term impacts of the solutions available today.
4. Much more research and stakeholder cooperation are required to select the right technologies and the optimum strategies on time, in order to avoid unmanageable trends. ("If you don't take change by the hand, it will take you by the throat." W.S. Churchill).

Other suggestions from survey participants

Participants were asked to provide further reflections and suggestions on the topic, of which are summarized here in a telegraphic format (in bold the topics that are not simple developments of the already proposed topics)::

- Increased seaweed farming as new source of food
- **Carbon transport across land - river - ocean**
- Nuclear energy as low carbon footprint energy
- Link between oceans and atmosphere
- By 2027, ocean energy will power 100,000 European homes
- Use nuclear energy carefully to reduce CO_2 impacts
- Reach a climate-neutral, sustainable and productive Blue Economy
- Evaluate sustainable use of marine waters for aquaculture, harnessing of energy, etc.
- Climate change impacts on oceans
- **Circular economy with focus in waste and water management**

- **Zero-pollution of ships and shipping in 2050**
- Fully integrated oceans, seas and inland waters monitoring system by 2030
- Monitor environmental impacts
- **Systems to support and protect offshore workers**
- Energy demand exploitation
- Highlight link between ocean and climate change.

Comments from the Delphi survey revealed a number of concerns. In particular, the high level of awareness about the magnitude of climate change issues and the urgency to react is not only a terrain of experts but of all society. For instance, the civil society is increasingly concerned about not only coastal areas but also hinterlands.

One of the main issues is related to energy as most decision makers are aware that fossil fuels have to be replaced in a climate-sustainable economy, today promoted for e.g. via the European New Green Deal. It sounds realistic to need time to move from a « Carbon based » economy to a « Renewable energies based » economy. Logically, the huge potential of MREs (Monitoring Reporting Evaluation) is clearly identified as one of the major solutions. This evolution should also have positive effect in the reduction of negative CO_2 impacts: acidification, deoxygenation, pollution related to Carbon industries, albedo (reflectance capacity) stabilisation… But harnessing of kinetic energy should be evaluated across all dimensions and only the most environmentally neutral technologies should be developed at a large scale, with strict standards.

In more general, a societal (R)evolution, vital not only for Europe but for the whole world, to meet the climate targets can be formulated around three broad fields of development:

- Firstly, the need to better understand and predict natural phenomena as well as the impact of human activities on ocean ecosystems, their resilience and the effect that they have on the Earth's climate. This requires new observations, technologies, modelling and projections capacities, in a more integrated, coordinated and consistent way as it is recommended by the G7 "Future of the Oceans" declaration, and also by "Navigating the Future V" by the European Marine Board. This network of systems should provide a holistic view of the environmental impact of waterborne operations (including deep sea), enabling the EU to show the way to a fully integrated oceans, seas and inland waters observation system by 2030. This knowledge should entail in the deployment of a world-scale automated surveillance system, based on biomimetic sensors and marine organisms support (trackers on fish or cetacean to better understand migrations, molluscs for pollution follow-up…) and to enhance human capacities in "reading" the environment, especially in terms of biodiversity changes and ecosystem responses.
- Secondly, all activities related to the use of water should be assessed in terms of environmental and climate impacts, from irrigation (cultures and forests notably) to freshwater and marine aquaculture (carbon sinks notably in the seaweed industry). Indeed, Carbon is processed and transported across land-river–ocean through a complex continuum. A clearer understanding of these processes would help to manage carbon flows and an increasing number of harmful molecules including plastics.
- Thirdly, the waterborne sector will open opportunities to multi-purpose offshore platform modular systems (floating cities and industries, combination of industrial and recreational activities, new high sea observatories). This new approach of waterborne activities could develop the sense of responsibility of human communities, but also, adversely, the risk of fragmentation among countries and growing gaps between high-tech societies and low-tech ones. We could have a risk of an archipelago of rich floating smart cities offshore unprotected slums around abandoned vulnerable megalopolis (Alexandria, Manila, Lagos, Dacca…).

All these positive views on the adaptation of human activities imply a higher level of integration of laws and regulations from the upper watersheds to the bottom of the open sea. Indeed, would it make sense to regulate strictly pollutants in the sea, if the system of norms, control and penalties were not efficient inshore and in the whole watershed? This implies an ambitious, comprehensive and exacting system of laws and regulations, at a regional scale first, and at the world scale level on the mid-term. This is the condition to secure the sustainable utilisation of oceans, seas and rivers that represent not only vast (but not unlimited) resources, but also vital flows and ecological services. This recommendation is particularly necessary in traditional activities (e.g. shipping, fisheries, oil & gas industry, tourism and coastal activities) and new large-scale activities (e.g. offshore MRE, aquaculture...) and, globally speaking, to the whole « blue economy ». Since ecosystems are not defined by political borders, it is crucial that these norms and regulations are designed by respecting ecosystem boundaries.

This « blue economy » has to be a component of the paradigm change in economy, otherwise the negative impact of « Business as usual » activities on climate and the quality of rivers, seas and oceans will still increase. Therefore, there is a strong need of a circular economy with focus on waste and water management. A flagship target at a world scale could be the zero-pollution of ships and shipping by 2050, a fully integrated oceans, seas and inland waters observation system by 2030 and the related social protection of offshore workers.

Conclusion

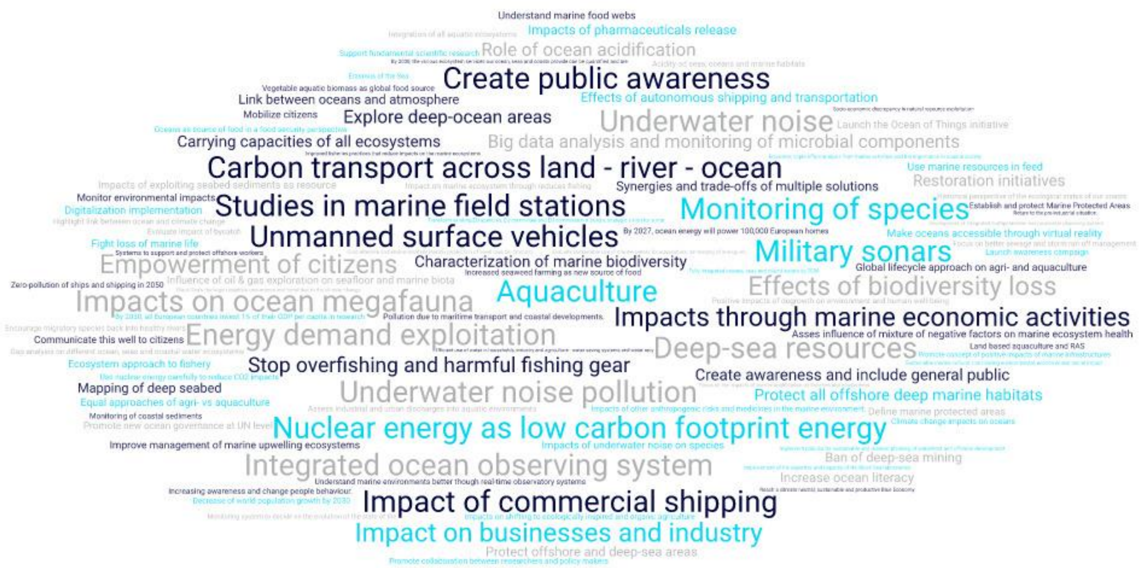
The challenges related to climate mitigation and sustainability of the water cycle on earth are numerous and huge. They all require a higher level of knowledge, technologies, funding, but moreover a better awareness of our responsibility to secure healthy fresh and marine waters. This is not just a sector of the biosphere. It is life, for all, for the long term. It is one of the major responsibilities of Europe and of humanity at large.

The conceptual landscape embracing water ecosystems (including both oceanic and inland waters) is very fragmented and the risk of fixing climate change while creating other problems is concrete. The need for a holistic approach, leading to more balanced actions, is widely recognized but seldom satisfied. Too specific actions, undertaken while ignoring the behaviour of the rest of the ecosystems, might lead to temporary success but will surely not improve the overall situation.

3.5 Further areas to be explored

Introduction

Next to the topics proposed by our own foresight team, participants in the Delphi were asked to suggest other topics that should be understood better and acted upon in the EU (see below world cloud of topics addressed.



Three main topics emerged: research and research infrastructure, civil society, and corporate social responsibility. We address these in the following paragraphs. Some additional findings are mentioned at the end.

Research and research infrastructure

Many of the respondents would agree that research can provide an important contribution to tackle the challenges of the oceans and seas. On the one hand, it would certainly be a mistake to conclude that we know all there is to be known: basic/fundamental research can contribute to better know and thus better manage the challenges. On the other hand, we cannot wait to know everything to act, keeping in mind the precautionary approach. The suggestions put forward mainly address the broader conditions in which scientists (of any field) need to work on:

- Open data and open innovation: research centres, academia and businesses should work together more intensively to apply theory, but also use the opportunities of “being out there” to feed theory with data. This starts by being aware of each other’s interests and being open-minded about meeting each other half-way. The openness of the data does not regard their availability only, it implies their circulation across the scientific and the civil community, and their integration into holistic scenarios.
- There is much to gain in better use of sensors (Internet of things and sharing the information) and in the development of new sensors that will measure what is currently not measured, first of all biodiversity and ecosystem functioning (the pillars of Good Environmental Status in MSFD).
- The relationship between researchers and policy makers has to be open and constantly connected, being aware of the needs of each party and how the other party can support these needs.
- There is a more basic feeling that more efforts should be put into research and fundamental research. For many years the goal of the European Commission was that Member States have to spend 3% of GDP (private and public money) on research and development. Still, in 2017 only Sweden, Denmark, Austria and Germany reached this target in, according to Eurostat.
- The specialisation of reductionistic approaches needs to be complemented with equal efforts towards holistic understanding of the links across the different fields of investigation. This is already recognised by the ecosystem approach but is not practised enough.

Civil society

It is the explicit goal of the Missions to address and involve the civil society. Our Delphi respondents certainly think this should be the case.

- The general public should be aware of the issues facing oceans and seas. The level of awareness regarding the environment in general, and the marine environment, is steadily rising. Still, more awareness should lead to improve people’s (wasteful and polluting) behaviour and the understanding of priorities based on sound scientific knowledge.
- One suggestion was to focus on freshwater first: if citizens learn to appreciate clean freshwater and healthy inland ecosystems, and take action to further clean freshwater, the seas and oceans will benefit from avoiding pollution which, indeed, is often land-based.
- To move from the so-called “Triple Helix” of academia, business and government to the “Quadruple Helix” that includes civil society, citizen science may be a good way complement other type of research and to involve citizens in gathering information. There is need to design ways for rewarding collaboration – those who contribute to results should somehow have access to benefits from such results and recognition for their work.

- Finally, citizens could be involved in marine governance and common good management. Rethinking the governance of seas will be achieved through new participatory processes, empowering citizens. This can be achieved only by rising the oceans and waters literacy of the public: popular topics are not always the most relevant ones, and all actions must have a solid scientific basis.

Corporate Social Responsibility

- Business and industry start to realise that without protecting the oceans, they lose the basis for their return on investment due to a collapse in ecology and social upheaval.
- Increasing awareness may lead to rethinking the impact of commercial shipping – with its huge benefits come risks from e.g. ballast water introducing foreign species.

Respondents note that many solutions have multiple trade-offs and that it is difficult to make these calculations. Whatever policy or research directions are taken, there should be consistent monitoring for effects – both wanted and unwanted – and the willingness to alter choices based on scientific evidence.

4 Conclusions

The first part of the foresight study led to the description of five possible focal areas for European innovation action in the realm of oceans and waters: 1. Climate-resilient coastlines, 2. Clean water for the blue planet, 3. Vital aquatic ecosystems, 4. Open digital twin of oceans and waters and 5. Human at sea. All these focal areas have similar magnitudes, notably if we consider an extensive view of "human at sea" not only as an island network but as a continuum between a vulnerable and densely populated low elevation zone and a potentially harmful but also rich coastal ocean. In view of addressing the focal areas or their elements in the future actions towards sustainable development in Europe, it is worth prioritising such efforts in relation with the general theory of systems that establishes the hierarchy of systems in three spheres showing that human activities and economy are nested into natural systems and must obey their laws. Traditional illustrations of sustainability, however, show only a small overlap of the three spheres, this overlap representing sustainability.

The real-time Delphi survey confirmed that there is a need for a holistic approach leading to more balanced actions. This is widely recognized but seldom satisfied. Too specific actions, undertaken while ignoring the behaviour of the rest of the ecosystems, might lead to temporary success but will surely not improve the overall situation. This calls for enhanced efforts in improving ocean literacy at all levels, from the scientific community (too focused on reductionistic approaches) to the economic, social and industrial sectors. Furthermore, the conceptual landscape embracing water ecosystems (including both oceanic and inland waters) is very fragmented, creating, among other factors, the high risk that while fixing specific problems other problems are created. Hence, we conclude with three recommendations.

- Adopt a holistic approach for balanced actions that calls for improving water literacy at all levels of society.
- Create networks of interest using a common (not too technical) language embracing water ecosystems (including both oceanic and inland waters) to overcome fragmentation in society.
- Conduct holistic cost-benefit assessments and establish monitoring mechanisms of measures implemented to fix specific problems to avoid creating in parallel new problems in complex ecosystems.

ANNEX 1: FUTURE-ORIENTED ISSUES

The analyses entailed a number of foresight reports numbered below and newsfeed and foresight databases of which sources are indicated in each of the issues description.

Foresight reports analysed:

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1 Trends and drivers

1.1 A growing ability to monitor illegal activity at sea

Type: Trend/Driver **Categories:** Technological Legal

Present and future developments

A growing ability to monitor illegal activity at sea. Policing large spaces is inherently problematic, but developments in satellites and other technologies are likely to make policing illegal fishing and other activities easier. This will require robust mechanisms for enforcing the law.

Actions needed

Three areas that could markedly improve decision-making are:

Standardising approaches to measuring and valuing ocean-based industries, and integrating them into national accounting via satellite accounts;

Measuring and valuing marine natural resources and ecosystem services, and exploring ways also to integrate them into national accounting frameworks;

Better identifying and measuring the benefits of public investment in sustained ocean observation systems.

References

Reports: 10, 2

1.2 A growing proportion of humankind living close to the sea

Type: Trend/Driver **Categories:** Social

Present and future developments

With a growing popupolation and the growing proportion living close to the sea and depending on a number of oceanic services, our societies will become increasingly vulnerable to natural oceanic disasters (European Marine Board, 2019).

Coastal ecosystems account for proximately half of the sequestered total carbon in ocean sediments, the great majority in sea grasses, angroves, and salt marshes. The ability to measure and monitor ocean health and function in coastal areas, and to model the potential impacts of policy intervention, are particularly important for sustainable development. New science could create new opportunities for sustainable ocean uses.

Actions needed

Interdisciplinary research to support maritime spatial management is needed to integrate environmental concerns into the planning of multi-industrial activities in coastal and marine areas.

Develop a common strategy for sustained long-term monitoring of human impacts and climate change in coastal areas.

• Research to understand marine ecosystems goods and services and their environmental, economic and social value.

• Research on the land-sea interface: Activities will take into account the need for the use of existing and the development of new economic and environmental models, based on a multi-disciplinary approach engaging industry and policy makers to enhance predictive capabilities and new services based on user requirements.

References

Reports: 1, 5, 13, 22, 31, 32

1.3 Accumulation of plastics due to increased plastic use

Type: Trend/Driver **Categories:** Ecological Social

Present and future developments

Plastic in the ocean is projected to treble between 2015 and 2025. Plastic does not decompose, instead breaking down into ever smaller pieces. The full effects are not understood, but there is growing evidence of plastic harming sea creatures and restricting their movement, as well as polluting beaches. - One issue that is high on the policital agenda is marine litter and especially the flow of plastic debris. Plastic-free oceans can be coupled with targets to reduce plastics entering the marine environment by 90 % and to collect more than half of the plastics present in our oceans, seas and coastal areas by 2025.

Actions needed

Reduce plastic pollution in the sea, which is projected to treble in a decade without further intervention. The major response is likely to lie in preventing it from entering the sea, introducing new biodegradable plastics, and potentially public awareness campaigns about marine protection – again addressing the out of sight, out of mind challenge.

References

Reports: 3, 10, 12, 29, 32

1.4 Acidification of oceans and waters

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Ocean acidification is the ongoing decrease in the pH of the Earth's oceans, caused by the uptake of carbon dioxide (CO2) from the atmosphere. Dissolution of CO2 in seawater produces a weak acid that has decreased surface ocean pH by ca. 0.1 below pre-industrial levels, and an additional 0.3-0.4 decline is expected by the year 2100. The sea has absorbed very large amounts of CO2. This decreases the pH levels of sea water, making it less alkaline, threatening the biological processes of many marine species including reef-forming corals. Shellfish, whose ability to form shells is reduced by acidification, are particularly vulnerable.

Impacts in society

Ocean acidification has been recognised as one of the major challenges for marine ecosystems in the coming decades. Monitoring of ocean acidification across the European regions, from estuaries and coasts to open ocean, and its relationship with warming, remains largely underdeveloped.

Actions needed

Effects of ocean acidification, de-oxygenation and warming require long-term aligned research, concerted monitoring effort and modelling. This must be based on common methods and protocols. Efforts must be scaled up in under-sampled areas, such as the deep-sea, to understand the impacts on ecosystems.

References

Reports: 3, 5, 12, 14, 22, 32

https://news-oceanacidification-icc.org/2019/11/19/arctic-ocean-acidification-may-cause-emission-of-more-harmful-greenhouse-gas-study/

1.5 Advances in virtual water sensors improve realtime data interpretation

Type: Trend/Driver **Categories:** Ecological Technological

Present and future developments

Virtual sensors employ artificial intelligence (AI) software that uses deductive reasoning to process information from various machines to determine what a physical sensor output would be. The results are transcribed in a real-time configuration that is understandable and accessible for water managers and stakeholders alike.

Impacts in society

Virtual sensors are particularly useful when physical sensors cannot withstand harsh environments, are too expensive, or if abnormalities persist in physical sensor readings.

References

Reports: 2, 8

1.6 Altered biodiversity and species distribution

Type: Trend/Driver **Categories:** Economic Ecological

Present and future developments

This leads to tropic effects, eutrophication and increasing hypoxic zones and the increased dispersal of various antropogenically produced substances.

Actions needed

Research to understand impacts of climate change on ocean circulation, biogeochemical processes and the effects on ecosystem dynamics and pelagic ecosystems. This should include primary production trophic web interactions and distribution, abundance of marine organisms, changes in biodiversity and the spread of invasive species.

References

Reports: 12, 22

1.7 Alternative fuels for shipping

Type: Trend/Driver **Categories:** Technological Ecological

Present and future developments

Alternative fuels for shipping. In the absence of new technologies to reduce emissions, global shipping could be responsible for up to 17% of carbon emissions by 2050. Industry has identified a growing demand for cleaner fuels and a subsequent search for alternative fuels as one of the major trends affecting sea transportation.

References

Reports: 10

1.8 Carbon-based energy generation heating local water systems (heat pollution)

Type: Trend/Driver **Categories:** Technological Ecological

Present and future developments

Crude oil, coal, and natural gas supply about 85% of the energy used in the world. Sustainability transitions can involve disruption and conflict when the diffusion of new technologies and practices affects existing systems and businesses. Impacts on particular sectors or regions can be severe, implying a role for public policy in offsetting inequities and facilitating structural change. Sustainability transitions can be accelerated by deliberately phasing out unsustainable technologies and systems, for example using bans or targeted financial disincentives, or by removing implicit subsidies.

Ensuring a just transition requires measures to alleviate negative consequences and help firms, employees and regions to reorient (e.g. compensation, retraining and regional adjustment).

References

Reports: 29

1.9 Changes of temperature and precipitation and weather extremes

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

Both the tempature and percipitation will increase at the end of the 21st century. In those parts where a large increase in temperature is predicted some models show a decrease in the percipitation amount and percipitation days, but an increase in percipitation days larger than 20mm. Most likely the increase in temperature triggers convection in summertime resulting in more heavy precipitation events.

Impacts in society

This might result in floods (resulting in marine litter) as well as problems related to droughts.

References

Reports: 6

1.10 Coastal erosion and changes in Arctic Ocean biogeochemistry due to thawing permafrost

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Impacts of accelerating coastal erosion on nearshore ecosystems are immediate and irreversible. Arctic warming and sea level rise account for the observed coastline collapse as an abrupt form of permafrost degradation that leads to the rapid release of large amounts of previously frozen organic carbon to the nearshore zone. The fate of this permafrost carbon, however, has never been properly quantified. Eroding coasts will also liberate more nutrients such as nitrogen and phosphorus into an ocean that is considered limited in nitrogen or phosphorus.

References

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https://www.researchgate.net/publication/312046234_Collapsing_Arctic_coastlines

1.11 Cyber security taken more seriously in infrastructure and equipment

Type: Trend/Driver **Categories:** Technological Economic

Present and future developments

The first step in preventing cyber-attacks is identifying threats and vulnerabilities, assessing the risk exposure attached to these matters and developing both protectionary measures and contingency plans to neutralise these risks as much as possible.

References

https://safety4sea.com/5-digital-innovations-that-are-changing-the-maritime-industry/

1.12 Declining biodiversity due to human activity

Type: Trend/Driver **Categories:** Ecological Social

Present and future developments

Marine biodiversity will face growing threats linked to human activities. Over-exploitation is the key threat, but will be compounded by climate change. The decline and, in some cases, extinction of marine organisms will damage the long-term health of the oceans and its services, such as carbon sequestration and food provision.

Impacts in society

Human activities have had a large and widespread impact on the world's oceans. These include direct exploitation, in particular overexploitation, of fish, shellfish and other organisms, land- and sea-based pollution, including from river networks, and land-/sea-use change, including coastal development for infrastructure and aquaculture. For instance, scientists have found that global tuna catches have increased over 1,000 per cent in the past six decades, fueled by a massive expansion of industrial fisheries.

Actions needed

Address the key threats to biodiversity and protect marine ecosystems to preserve the long- term sustainability of the sea. This will require an internationally targeted effort, focused on improved monitoring and fisheries management, and addressing activities on land as well as at sea. It includes supporting public awareness campaigns about marine.

References

Reports: 10, 21, 32

https://www.sciencedaily.com/releases/2019/10/191001132650.htm

1.13 Declining coastal economic activities due to environmental and economic pressure

Type: Trend/Driver **Categories:** Economic

Present and future developments

Climate change, coastal erosion and diverse human activities will compound declining fish stocks, coastal infrastructure, and other economic activities that rely on a healthy and resilient marine environment. Coastal habitats, including estuaries and deltas critical for marine biota and regional economies, have been severely affected by sea-use changes (coastal development, offshore aquaculture, mariculture and bottom trawling) and land-use changes (onshore land clearance and urban sprawl along coastlines, plus pollution of rivers).

Impacts in society

The potential for global instability linked in particular to flooding of low-lying coastal regions, and food insecurity in seafood-dependent regions. Loss of coastal habitats and coral reefs reduces coastal protection, which increases the risk from floods and hurricanes to life and property for the 100 million to 300 million people living within coastal 100-year flood zones.

Actions needed

Address local issues in coastal communities that could limit the potential of the marine economy, particularly meeting changing skills needs in communities, and addressing digital and physical connectivity challenges. Valuation of marine ecosystems and assets

References

Reports: 1, 14, 13, 21, 32

1.14 Declining fish stocks due to over-fishing

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Over fishing, sea water warming, infertility due to contamination, chemicalisation (contraseptives in the water ecosystems). Fisheries loss threatens to destabilise countries that rely on them.

Impacts in society

According to FAO, food supply will have to increase 60% by 2050 to meet the demands of seafood production. Severe impacts to ocean ecosystems are illustrated by 33 per cent of fish stocks being classified as overexploited and greater than 55 per cent of ocean area being subject to industrial fishing.

Actions needed

Technological developments in aquaculture production including research on innovative feeds, and research based on DNA sequencing brood stock, new species and stock baselines adapted to climate change impacts.

Sustaining and conserving fisheries and marine species and ecosystems can be achieved through a coordinated mix of interventions on land, in freshwater and in the oceans, including multilevel coordination across stakeholders on the use of open oceans. Specific actions could include, for example, ecosystem-based approaches to fisheries management, spatial planning, effective quotas, marine protected areas, protecting and managing key marine biodiversity areas, reducing run-off pollution into oceans and working closely with producers and consumers

References

Reports: 5, 10, 12, 14, 17, 21, 22, 32

https://www.researchgate.net/profile/Gabriella_Caruso/publication/284625083_Fishery_Wastes_and_By-products_A_Resource_to_Be_Valorised/links/565584c908ae1ef9297723b1/Fishery-Wastes-and-By-products-A-Resource-to-Be-Valorised.pdf

1.15 Declining freshwater sources due to over-use

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

With a projected 40% gap by 2030 between global water supply and demand under business-as-usual practices (e.g. public policy and technology).

Impacts in society

Competition for already scarce water resources will intensify, leading to difficult and painful allocation choices affecting the public sector, businesses, civil society and ecosystems. Unfortunately, issues of data access and quality prevent leaders at every level of society from comparing priorities for water, evaluating potential solutions and making informed decisions that balance economic, social and environmental interests. According to the International Food Policy Research Institute (IFPRI), "current 'business-as-usual' water management practices and levels of water productivity will put approximately $63 trillion, or 45% of the projected 2050 global GDP at risk".

Actions needed

Balancing these trade-offs requires an understanding of the quality of the water, how much water can be sustainably used, and an accurate picture of current and projected water demand from human as well as economic use (water used for agriculture, energy generation and industrial use). The reuse of wastewater for irrigation and personal consumption, but to be used with caution.

References

Reports: 3, 14, 8, 22, 29

1.16 Degradation of chemical status of groundwaters

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Agriculture is the main cause of groundwater's failure to achieve good chemical status, as it leads to diffuse pollution from nitrates and pesticides. Also Increased salinization. Much of the increased salinity is a consequence of an interconnected suite of antropogenic pressures such as irrigation, leaching of fertilizer, stormwater runoff and urban wastewater discharge.

Actions needed

It is important to improve the situation reverse any significant and sustained upward trend in groundwater pollutant concentrations and, as with priority substances in surface water, progressively reduce pollution.

References

Reports: 3, 4

1.17 Degradation of drinking water quality

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Geogenic pollutants (heavy metals, fluoride, mercury...) enter drinking water. Some of this occurs naturally in some locations but others don't (aging and corroding pipes). water distribution services often struggle to deliver a constant supply of potable water due to underground water leaks and poor water-quality monitoring. Furthermore, pollutants from agricultural and pharmaceutical run-off, ageing infrastructure or insufficient water treatment systems threaten the health of communities and ecosystems throughout the world.

References

Reports: 8, 17, 29

1.18 Decradation of surface water ecosystems

Type: Trend/Driver **Categories:** Ecological

Present and future developments

For decades, humans have altered European surface waters (e.g. straightening and channelisation, disconnection of flood plains, land reclamation, dams, weirs, bank reinforcements) to facilitate agriculture, produce energy and protect against flooding. These activities have resulted in damage to the morphology and hydrology of water bodies.

Hydromorphological simulation (how physical alterations affect future water bodies). The main significant pressures on surface water bodies are hydromorphological pressures (affecting 40 % of water bodies), diffuse sources (38 %), particularly from agriculture, and atmospheric deposition (38 %), particularly of mercury, followed by point sources (18 %) and water abstraction (7 %). The main impacts on surface water bodies are nutrient enrichment, chemical pollution and altered habitats due to morphological changes.

Impacts in society

Nutrient enrichment, chemical pollution and altered habitats due to morphological changes.

Actions needed

The restoration of hydromorphological conditions includes: • employing measures related to river continuity, such as removing obstacles and installing fish passes; • employing measures focused on restoring aquatic habitats, such as improving physical habitats; • managing sediment in a way that ensures that it is transported along the length of rivers; • reconnecting backwaters and wetlands to restore lateral connectivity between the main river channel, the riparian area and the wider floodplain; • implementing natural water retention measures that restore natural water storage, for example inundating flood plains and constructing retention basins; • restoring the natural water flow regime through, for example, setting minimum flow and ecological flow requirements; • developing master or conservation plans for restoring the population of threatened fish species.

References

Reports: 4

1.19 Degrading water and sanitation systems in sprawling metropolises

Type: Trend/Driver **Categories:** Social Economic

Present and future developments

A quarter of all city inhabitants are projected to live in informal settlements by 2030 – accompanying the rapid expansion of megacities in emerging economies. While centralized water and sanitation systems may have worked for some cities in the past, such approaches are often not feasible in today's sprawling metropolises and informal settlements.

References

Reports: 3, 8

1.20 De-oxygenation of seas, threatening ecosystems

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

De-oxygenation. A combination of nutrient-rich pollutants entering the sea, and rising sea temperatures is increasing the prevalence of excessive blooms of algae that can both smother intertidal habitats and also deplete underwater oxygen levels. This can have severe consequences for marine biodiversity and fisheries, causing population declines, reduced reproduction and reduction of suitable habitat.

Actions needed

Effects of ocean acidification, de-oxygenation and warming require long-term aligned research, concerted monitoring effort and modelling. This must be based on common methods and protocols. Efforts must be scaled up in under-sampled areas, such as the deep-sea, to understand the impacts on ecosystems. Work towards a long-term monitoring programme to address the effects of ocean acidification and warming, to strengthen our knowledge of the combined effects of warming and acidification and de-oxygenation on marine ecosystems.

References

Reports: 3, 10, 22

1.21 Digital certification for easier administrative processes (at sea)

Type: Trend/Driver **Categories:** Technological Economic

Present and future developments

People still use paper certificates to ‘prove’ their skills or for legal purposes. A different way for receiving and managing maritime certificates is an app titled myCert; instead of actually printing them, putting them in an envelope and sending them by post to the other side of the world. Developed as a digital ecosystem, the app is connecting the three key players in this field: the issuers of certificates, the holders and the verifiers.

Seafarers can, for example, upload their certificates and sail away without worrying about losing valuable documents, while for issuing companies, this secure platform can improve efficiency with less operational costs. Moreover, the app allows for the verifier to connect more easily and work more efficiently throughout the certification management process.

All in one, this digital ecosystem resolves all the topics involving the processes that the issuers, holders or verifiers have, ensuring also higher trust levels between all parties involved.

References

https://safety4sea.com/5-digital-innovations-that-are-changing-the-maritime-industry/

1.22 E-learning to increase reach of programmes

Type: Trend/Driver **Categories:** Technological Economic

Present and future developments

Marine training is crucial for creating and developing a “healthy” industry. What goes beyond training, is effective online training methods, which when adopted in the maritime industry, bring benefits of substantial value both for the company as a whole and the individual seafarers. This is a demanding business with continuously changing training needs, and online training solutions make the processes easier, faster and more cost-effective.

Maritime organisations are already designing innovative distance e-learning solutions to allow seafarers to learn while they continue with their work. These are online platforms which connect individuals from all over the world, while using new age solutions such as virtual equipment simulation, 3D animated marine safety videos and Virtual Reality (VR) and enable seafarers to stay longer at sea, in order to continue to develop and improve the exact skills they need.

References

https://safety4sea.com/5-digital-innovations-that-are-changing-the-maritime-industry/

1.23 Global ocean observing system

Type: Trend/Driver **Categories:** Technological Ecological

Present and future developments

Established in 1991, GOOS is co-sponsored by the Intergovernmental Oceanographic Commission of UNESCO, the World Meteorological Organization, the United Nations Environment Programme, and the International Science Council. In its first decades, GOOS designed and coordinated the development of a global ocean observing system to support climate science and to serve as the observational backbone for operational forecast systems. In 2012, this success, coupled with growing concerns about the health of oceans and demand for information products to help nations manage their ocean economies, sparked development of the visionary Framework for Ocean Observing: a guide to meet the needs of multiple stakeholders. GOOS has since led the implementation of this framework by the ocean observing community, with the goal of serving users across climate, operational services and ocean health, increasingly with a focus on coastal areas and regional seas. By working together on observing tools and technology, the free flow of data, information systems, forecasts, and scientific analysis, this global community can leverage the value of all these investments. The system does not cover biodiversity and the complexity of ecosystem functioning, hence it needs a thorough upgrade in this direction.

Impacts in society

The ocean is changing. Climate change is shrinking ice cover and warming the oceans. It is provoking sea level rise, ocean acidification, deoxygenating large parts of the marine environment, and amplifying weather and climate extremes.

Economic losses associated with extreme weather and natural catastrophes are at record levels, and these are expected to increase with climate change. Extreme weather events, natural disasters, and the failure of climate change mitigation and adaptation are seen as the three greatest risks for nations in the coming decade. Human pressure on the ocean is degrading habitats, increasing plastics and other pollutants, over-exploiting fish populations, and causing the death of coral reefs and wider declines in marine biodiversity. In addition to supporting sustainability, ocean knowledge and information have the power to generate profits and jobs in the marine economy. By 2030, the ocean economy, buoyed by growth in tourism, mariculture and renewable energy, is predicted to be a much larger component of our national economies.

Actions needed

Use the network of Marine Stations to set up a biodiversity observation system, together with Marine protected areas, etc. Use genomics and traditional taxonomy to set up a standardized and highly technological system to assess the presence of species. Link this information to the assessment of ecosystem functioning. Identify the Cells of Ecosystem Functioning, based on connectivity, as the natural volumes where to act in our management efforts. Invest on capacity building so as to operationally cover these actions that require competence in Physical and chemical oceanography, taxonomy, genomics, ecology, economics, social sciences, the capacity building system, the health care system, food industry, tourism, etc. The greatest innovation is to pass from reductionistic to holistic approaches, integrating disciplines that, so far, have been developed in isolation from each other.

References

Reports: 28

1.24 Growing blue economy leading to busier seas

Type: Trend/Driver **Categories:** Economic

Present and future developments

Doubling of the global 'ocean economy' to $3 trillion by 2030, including strong growth in emerging sectors. Busier seas, including a doubling of global trade by 2031 and new infrastructure related to marine resource extraction (The Government Office for Science, 2018). Facilitated by innovations in offshore energy, aquaculture, and seabed mining (The Government Office for Science, 2018). Growing use of water systems for food production. Busier seas, including a doubling of global trade by 2035 and new infrastructure related to marine resource extraction. (The Government Office for Science, 2018) Economic activity in the ocean is expanding rapidly, mainly driven by developments in global population, eeconomic growth, trade and rising income levels, climate and environment and technology (OECD, 2016)

Impacts in society

Ocean mining, while relatively small, has expanded since 1981 to ~ 6,500 offshore oil and gas installations worldwide in 53 countries (60 per cent in the Gulf of Mexico by 2003) and likely will expand into the Arctic and Antarctic regions as the ice melts.

Actions needed

Identify and work with key sectors to create a long-term platform to capitalise on growing global opportunities for goods and services. These include maritime business services, high-value manufacturing, autonomy and robotics, satellite communication, marine science, and hydrographic surveying and mapping. Support mechanisms to address insufficient join up between the diverse sectors of the marine economy around common research, infrastructure and skills needs. This includes encouraging a collaborative approach to find technological responses to shared needs and to develop shared uses for space and infrastructure. Support actions towards the exploitation of genetic resources, including bio- prospecting, identification, and the valuation of biological resources.

Research to enhance knowledge of taxonomy and genomics to provide policy advice for Blue Growth and GES. This action will include genome bioinformatics and computational biology, sequence and structure analysis, molecular evolution and omics technologies.

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.

Implications of (non)action

If the actions are not taken there is a risk of facing major lack of qualified human resources in the blue bioeconomy.

References

Reports: 8, 10, 5, 12, 21, 22, 32

1.25 Growing frequency of floods in Europe and the world

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

Growing frequency of floods in Europe and the world. The effects of droughts and floods, the increasing levels of human pressure in cities due to urban sprawl, the emergence of new contaminants and the overexploitation of water for agricultural purposes will, among other factors, probably exacerbate the risk of water shortages in the years to come.

Actions needed

Developing and setting up technological (e.g. a smart city approach to integrating sensors and EWSs) and integrated systems for the prediction and risk management of urban floods (overflows in advanced wastewater treatment facilities, urban hydrology, surrounding river flow, hydrodynamics, internet of things, drainage design, social sciences and climate change analysis). o Design of new green infrastructure, nature-based solutions and ecological engineering methods to avoid or mitigate flood damage.

References

Reports: 3

1.26 Growing importance of pollutants such as plastics and pharmaceuticals

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Although awareness of the issues related to these two pollutants is growing, there is a severe lack of data on the scale and scope of the problem and thus limited evidence on impacts. Pollutants of emerging concern, such as plastics and pharmaceuticals, exemplify the wicked nature of water quality issues: they are complex and multifaceted, have no single solution, and attract divergent views from different stakeholders.

Although far fewer data are available on freshwater plastic pollution compared with marine systems, existing studies highlight that plastics, including microplastics, are ubiquitous throughout all freshwater systems.

Although awareness of the issues related to these two pollutants is growing, there is a severe lack of data on the scale and scope of the problem and thus limited evidence on impacts.

Optimal and efficient solutions to date are uncertain. Even when technology exists, removing pharmaceuticals and micro- and nanoplastics from water is costly and at times nearly impossible. Thus, prevention is key, as is a better understanding of the drivers of contamination from this heterogeneous group to clarify entry pathways into aquatic environments and define reliable methods for exposure and hazard assessment.

References

Reports: 17, 32

https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108964/potential_chemical_contaminants_in_the_marine.pdf

1.27 Growing use of offshore renewable energy

Type: Trend/Driver **Categories:** Economic

Present and future developments

Under the EU's blue growth strategy, new marine goods and services, such as marine renewable energy, are seen as important sources of employment, economic security and sustainble development.

Actions needed

Capitalise on the significant potential of the offshore renewable energy sector, building on and learning from experiences in offshore wind. Promote innovation and growth in the sector to generate economic growth, build a supply chain, reduce emissions to meet climate change ambitions, and support local communities. A minimum understanding of the environmental impacts of emerging sectors, to facilitate adequate regulation.

References

Reports: 10, 12, 30

1.28 Holistic / integrated marine governance

Type: Trend/Driver **Categories:** Political Economic

Present and future developments

Over the last 20 years, marine governance has moved beyond the sectoral management of marine activities that emerged during the second half of the 20th century to promote a holistic and integrated appraoch to management of the seas, recognising that the collective human footprint on marine ecosystems needs managing. The ecosystem approach is a key aspect, which was originally defined internationally under the UN Convention on Biological Diversity.

Actions needed

A coherent and long-term research effort is needed to support evidence based governance of the deep-sea biological, mineral and energy resources.

Bringing multidisciplinary teams of natural, social, behavioral, and engineering scientists together o break down barriers and find new ways of better integrating data, analysis, models, and redictions into decision-making for sustainable development.

Accelerating the development of more integrated, comprehensive, and accurate models to assess and redict the impact of societal feedback loops on ocean systems. This “whole earth” approach to cean modeling will allow communities to better account and plan for the complex and often nonlinear rocesses that drive ocean systems and impact society.

References

Reports: 12, 22, 31

1.29 Increase in activities around Arctic coastal zones

Type: Trend/Driver **Categories:** Economic

Present and future developments

Chemical pollution is an ongoing issue, as pollutants can persist in the oceans for decades after their use is restricted by legislation. The list of chemicals deemed to be persistent organic pollutants (POPs) continues to grow.

References

https://services-webdav.cbs.dk/doc/CBS.dk/Arctic%20Shipping%20-%20Commercial%20Opportunities%20and%20Challenges.pdf

https://earthsky.org/earth/climate-change-warming-arctic-means-for-the-rest-of-us

1.30 Increase of chemical and persistent organic pollutants

Type: Trend/Driver **Categories:** Ecological Social

Present and future developments

Chemical pollution is an ongoing issue, as pollutants can persist in the oceans for decades after their use is restricted by legislation. The list of chemicals deemed to be persistent organic pollutants (POPs) continues to grow.

Actions needed

Research on critical pollutants in the marine environment is needed to inform future GES assessments.

References

Reports: 3, 10, 22, 32

1.31 Increasing deep sea exploration (and associated issues of appropriation)

Type: Trend/Driver **Categories:** Technological Ecological

Present and future developments

The growing trend for exploration of resources in the deep sea, which may require new legal instruments.

Impacts in society

Act as a hub to address acute risks (including emergencies) and disasters (e.g. related to pollution risks of dumped munitions, shipwrecks etc.) inside and outside the EU by putting in place temporary panels of experts to assess the issues and propose solutions.

References

Reports: 10, 2, 22

1.32 Increasing evapotranspiration of soil moisture due to climate change

Type: Trend/Driver **Categories:** Economic Ecological

Present and future developments

Climate change could impact evapotranspiration of the soil. This will increase the frequency of agricultural droughts and increase the irrigation water demand, while decreasing the flow in rivers and cereks, which are the dominant sources of irrigation (JRC, 2015)

Impacts in society

Food scarcity, decline of fresh water ecosystems

References

Reports: 6

1.33 Increasing use of automation in the marine environment for various activities

Type: Trend/Driver **Categories:** Technological

Present and future developments

Autonomation and robotics improving our understanding of the marine environment, facilitating new and more-efficient economic activity, and posing new challenges for communication at sea and the skills base. Autonomy is likely to be the single most important marine technological development. There are a range of challenges associated with introducing autonomy, including a need for improved battery technology, electric propulsion technology, data transfer and inter-device connectivity.

Actions needed

Technologies are to be developed that enable modern communication at sea, and improve data transfer and battery power.

References

Reports: 10, 2

1.34 Lack of awareness on healthy ocean and its impact on our activities

Type: Trend/Driver **Categories:** Social

Present and future developments

The vast majority of humanity is unaware of the many benefits they derive from the ocean and its ecosystems, or how their actions affect ocean health and how changes in ocean health in turn affect their well-being and survival.

Actions needed

Promote a programme of Ocean Literacy that will raise awareness of the services provided by ahealthy ocean ecosystem, the ways in which those services are currently under threat, the scienceneeded to redress those declines, and the ways in which stakeholders and citizens can act to improvethe health of the ocean and the planet, and

Transform how we communicate ocean science by (1) simplifying the language used to communicateocean science and sustainable development issues, (2) ensuring free, open, comprehensible andwide access to sound knowledge, (3) targeting future generations and taking into considerationtheir technological means of communication and their creative minds, (4) reaching out to newcommunities through innovative channels of communication such as major news media outlets,high-profile foundations and NGOs, or partnering with personalities from the business orentertainment world, and (5) communicating complex issues across cultures and languages.

References

Reports: 31

1.35 Larger temperature extremes, water excess and/or drought

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Larger temperature extremes and associated water excess and/or drought. This issue evaluates observed and projected changes in the frequency, intensity, spatial extent, and duration of extreme weather and climate events. This physical basis provides a picture of climate change and extreme events. But it does not by itself indicate the impacts experienced by humans or ecosystems. For example, for some sectors and groups of people, severe impacts may result from relatively minor weather and climate events. To understand impacts triggered by weather and climate events, the exposure and vulnerability of humans and ecological systems need to be examined.

References

Reports: 14

https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap4_FINAL-1.pdf

1.36 Long-running leaks in water distribution

Type: Trend/Driver **Categories:** Technological Economic

Present and future developments

Producing billions of kilowatt-hours of electricity to pump water through breaks in the world's water-distribution networks—rather than into homes or businesses—is expensive. It also produces unnecessary emissions. By minimizing leaks and losses, both energy and water are saved.

Improving the efficiency of water distribution largely depends on management practices. The torrential bursts that cut off service and submerge streets are not actually the worst from a waste perspective: They demand attention and immediate remediation. The bigger problem is with smaller, long-running leaks that are less detectable. Vigilant, thorough detection and speed to resolution are key.

Addressing leaks requires financial investment, but doing so is the cheapest way to source new supply and serve growing urban populations. Those same practices make municipal water systems more resilient to water shortages.

Impacts in society

Pumping water from source to treatment plant to storage and distribution requires enormous amounts of energy. Utilities use the phrase "non-revenue water" to describe the gap between what goes into a municipal water system and what ultimately comes out the tap. The World Bank calculates that 8.6 trillion gallons are lost each year through leaks, split roughly in half between high- and low-income countries.

References

https://www.drawdown.org/solutions/buildings-and-cities/water-distribution

1.37 Marine early warning systems become interconnected

Type: Trend/Driver **Categories:** Ecological Social

Present and future developments

Data management of more than 130000 monitoring sites. New or better ecological and chemical monitoring programmes and sites. Scientific monitoring and early warning systems increasingly used also for anticipating societal crisis and emergengies.

Impacts in society

Early detection and real-time alert systems.

Actions needed

Support e-infrastructures for computing, modelling, forecasting, and early warning systems.

References

Reports: 2, 4, 22, 31

1.38 Nitrogen pollution due to fertilizer runoff

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Much of the nitrogen that is applied as a fertilizer eventually enters rivers, lakes and oceans, fertilizing blooms of algae that deplete oxygen, creating hypoxic or dead zones where little can survive.

Actions needed

A three-pronged approach is called for to tackle nitrogen pollution:

1) in the context of air, water and biodiversity policies, manage the risks of local pollution by better understanding the nitrogen pathways between sources and impact (the “spatially targeted risk approach”);

2) in the context of climate change mitigation and ozone layer protection policies, take into account global atmospheric concentrations of nitrous oxide (the “global risk approach”); and

3) monitor remaining nitrogen surplus (through a national nitrogen balance) and assess the most cost effective ways of maintaining it at a level acceptable to society (the “precautionary approach”).

References

Reports: 17, 32

1.39 Non-indigenous species altering the functioning of ecosystems (due to shipping and transport)

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Progress in ballast water treatment in ships, to combat the spread of (alien) marine species.

Impacts in society

The establishment of Non-Indigenous Species that alter negatively the functioning of ecosystems (e.g. noxious algae, jellyfish, aggressive predators, toxic species) - (4: biodiversity is declining). The establishment of Non-Indigenous Species may also alter positively the functioning of ecosystems (e.g. coral reefs, high value species, etc)

Actions needed

Research to understand impacts of climate change on ocean circulation, biogeochemical processes and the effects on ecosystem dynamics and pelagic ecosystems. This should include primary production trophic web interactions and distribution, abundance of marine organisms, changes in biodiversity and the spread of invasive species.

References

Reports: 4, 22, 30, 32

1.40 Ocean absorption of increased atmospheric heat and carbon dioxide

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

Factor that will deepen the challenge of achieveing marine sustainbility. An intensification of climate change and acidification of the oceans can be expected to have stark consequences for marine biodiversity and productivity at regional and global scale (JRC, 2016)

Impacts in society

This will make other challenges bigger.

Actions needed

European policymakers must use all opportunities to drive the transformation to a carbon free economy by advancing carbon emission mitigation measures, enforcing carbon emission reductions and stimulating alternative technologie (JRC, 2016)

References

Reports: 12

1.41 Rapid decrease of ice sheet extent in the Arctic

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Changes in sea-ice extent and volume are important for several aspects of ocean and climate monitoring, as well as for safe marine operation in and close to ice-covered regions. Sea ice is an integrated part of the climate system through its effect on surface albedo and heat and momentum flux between the ocean and the atmosphere. Sea-ice thickness, being a crucial parameter for sea-ice volume, is important for the freshwater content and cycle in the Arctic, and also has an impact on the ice drift speed. Sea-ice thickness affects the opening of leads and biological production below the sea ice. The Arctic is warming twice as fast as the planetary average, and models show that it's on track to become ice-free during the summer as soon as 2030. Globally, ice has been rapidly disappearing, evidenced by declining trends in minimum summer Arctic sea ice, Greenland and Antarctic ice sheets, and glacier thickness worldwide.

References

Reports: 9, 19, 21

https://www.wired.com/story/the-arctic-carbon-bomb-could-screw-the-climate-even-more/

https://www.sciencedaily.com/releases/2019/09/190926105836.htm

1.42 Rapid melting of a large portion of the Greenland ice sheet and mountain glaciers

Type: Trend/Driver **Categories:** Ecological

Present and future developments

Globally, ice has been rapidly disappearing, evidenced by declining trends in minimum summer Arctic sea ice, Greenland and Antarctic ice sheets, and glacier thickness worldwide.

References

Reports: 19, 21

https://www.sciencedaily.com/releases/2019/09/190926105836.htm

1.43 Remote sensors and monitoring systems are increasingly deployed

Type: Trend/Driver **Categories:** Technological Economic

Present and future developments

New technologies to measure and monitor the ocean including, but not limited to, the use of remotesensing, micro- and nano-satellites, acoustic and electromagnetic sensors, environmental "e-DNA"techniques, autonomous platforms and shared infrastructure.

The identification and routine measurement of essential variables related to the ocean, climate, andecosystems that can serve as sentinels of ocean function and health, and will facilitate globalscientific coordination and communication by reaching consensus on common classificationsystems for ocean attributes. Technologies such as remote sensing (satellite imagery and drones), IoT and AI can collectively help monitor the health of water systems in different geographies. Better insight into the quality and quantity of available water can in turn lead to more accurate and responsive pricing mechanisms for water that scale conservation, reuse and recycling. Artificial intelligence and machine learning can provide context to historical data, making it easier to predict infrastructure risks and inform replacement plans in real time, optimizing capital, revenue, operating costs and services. Activities may focus on the development of new sensors to monitor physical, chemical and biological parameters by integrating knowledge on marine environmental research, nano-materials, electronics, biotechnology and ICT.

Impacts in society

Remote sensors and IoT-enabled monitoring systems can improve the accuracy and speed with which centralized utility systems can detect and repair leaks and ensure water quality. Autonomous vehicles allow for more regular data collection and greater access to the deep sea and other inhospitable marine environments. This has implications for our understanding and modelling of the marine environment, and for the economy.

References

Reports: 3, 8, 10, 2, 31

1.44 Resilient agriculture to overcome climatological changes

Type: Trend/Driver **Categories:** Technological Ecological

Present and future developments

Resilient agriculture to global change will permit a wider portion of the population to be able to overcome extreme events as droughts and also to be able to cultivate using less water in the long term, but for its achievement a technological advancement is necessary, also in different fields as biotechnologies and a better understanding of traditional agriculture practises. Promising agricultural land uses are worldwide foreseen in revising the complex and efficient rural systems adopted in the past, towards multifunction and resilient agroforestry systems to be adopted in the future. Considering that 70% of water use is for agriculture (AQUASTAT, 2016) and that the growth in population needs to increase agriculture production, optimising water consumption in agriculture will represent a big step towards sustainable use.

References

Reports: 7

1.45 Restoring coastal wetlands is getting increasing attention

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

Wetlands face a myriad of threats, but thanks to research and advocacy efforts, awareness is growing about the role they play in curbing climate change and coping with its impacts. It is vital to preserve healthy coastal wetlands—keeping a lid on the carbon they contain—while also rehabilitating and restoring those that already have been degraded. Along the fringes of coasts, where land and ocean meet, lie the world's salt marshes, mangroves, and sea grasses. These coastal wetland ecosystems are found on every continent except Antarctica.

They provide nurseries for fish, feeding grounds for migratory birds, a first line of defense against storm surges and floodwaters, and natural filtration systems that boost water quality and recharge aquifers. Relative to their land area, they also sequester huge amounts of carbon in plants aboveground and in roots and soils below.

Coastal wetlands can store five times as much carbon as tropical forests over the long term, mostly in deep wetland soils. The soil of mangrove forests alone may hold the equivalent of more than two years of global emissions—22 billion tons of carbon, much of which would escape if these ecosystems were lost.

Impacts in society

Of the 121 million acres of coastal wetlands globally, 18 million acres are protected today. If an additional 57 million acres are protected by 2050, the resulting avoided emissions and continued sequestration could total 3.2 gigatons of carbon dioxide. While limited in area, coastal wetlands contain large carbon sinks; protecting them would secure an estimated 15 gigatons of carbon, equivalent to over 53 gigatons of carbon dioxide if released into the atmosphere.

References

https://www.drawdown.org/solutions/land-use/coastal-wetlands

1.46 Satellite earth observation providing new insights on water systems

Type: Trend/Driver **Categories:** Technological Ecological

Present and future developments

Satellite imagery and other earth observation tools are delivering profound new insights on water supply in parts of the world where conventional ground-based methods to measure water supply are not feasible or practical. Advanced satellite monitoring technologies, such as Interferometric Synthetic Aperture Radar (InSAR), are also helping to fill in data gaps relating to groundwater management. InSAR is a mapping technique that identifies earth surface deformations using radar imagery from orbiting satellites.

Impacts in society

In cases where groundwater is being over-extracted or recharged, InSAR can observe the development, and potentially use artificial algorithms to fill in data gaps, thereby enabling water managers to understand the status of an aquifer better. This degree of hydrological insight can provide an unprecedented understanding of groundwater usage, helping to address issues of neglect, over-extraction and assumptions about capacity.

Actions needed

Ocean economy satellite accounts could offer a way forward. Building up on existing data collection efforts, satellite accounts offer a robust framework for monitoring aspects of a country's economy not shown in detail in the core national accounts, while allowing for greater flexibility for those industries not covered by industrial classifications. Satellite accounts for the ocean economy would provide a highly organised method for collecting consistent ocean economy data. Should a critical mass of countries develop such accounts then international comparability would be enhanced.

References

Reports: 2, 3, 8, 17, 30, 31

1.47 Scattered data on water resources and use making analysis difficult

Type: Trend/Driver **Categories:** Technological Political

Present and future developments

Where data on water resources and use does exist, it is often scattered across multiple government departments and stakeholders, and is also not readily compatible (or interoperable) with other data sources.

Impacts in society

From rural communities to multinational corporations to city planners and national governments, decision-makers struggle with the confines of isolated and fragmented information.

Actions needed

Develop accurate and useful valuations of the marine environment through the goods and services it provides (including food, capturing carbon, mitigating flooding, and supporting human health) so that environmental externalities can be made clear and their value incorporated into decision making.

Systems for sustained ocean observations are an essential part of worldwide efforts to better understand the ocean and its functioning. These observing systems comprise fixed platforms, autonomous and drifting systems, submersible platforms, ships at sea, and remote observing systems such as satellites and aircraft, using increasingly efficient technologies and instruments to gather, store, transfer and process large volumes of ocean observation data. The data derived from such instruments are crucial for many different scientific communities and for a wide range of public and commercial users active in the ocean economy.

Implications of (non)action

Sustained long-term observations are required to understand the interactions between the marine environment, climate change, human activities and the combined effects of these on the oceans. Physical, chemical, biological, ecological, and geological data need to be integrated to form a holistic understanding of hazards, risks and changes in the marine environment.

References

Reports: 3, 8, 17, 20, 22, 30

1.48 Seawater rising globally

Type: Trend/Driver **Categories:** Ecological Technological

Present and future developments

A combination of melting polar ice and, more significantly, water expansion due to warming led to a global sea level rise of around 20 cm between 1901 and 2010. This is projected to continue rising. Current estimates suggest a further rise of 0.25–1 m by 2100 depending on emissions. For marine systems, impacts are expected to be geographically variable, with many fish populations projected to move poleward due to ocean warming, meaning that local species extinctions are expected in the tropics-

Impacts in society

Global flood losses in 136 of the world’s largest coastal cities have been estimated to rise from US$ 6 billion per year in 2005 to US$ 60–63 billion per year in 2050 (European Marine Board, 2019). Sea level rise is likely to shift coastlines and in some cases threaten the existence of small island states.

Marine and terrestrial biodiversity in boreal, subpolar and polar regions is projected to decline mostly because of warming, sea ice retreat and enhanced ocean acidification.

Climate change alone is projected to decrease ocean net primary production by between 3 and 10 per cent, and fish biomass by between 3 and 25 per cent (in low and high warming scenarios, respectively) by the end of the century.

Actions needed

Improved modelling of sea level rise and coastal flooding, to inform planning of infrastructure and reduce uncertainty for coastal communities. Research to understand impacts of climate change on ocean circulation, biogeochemical processes and the effects on ecosystem dynamics and pelagic ecosystems.

Establish a long-term monitoring programme to follow changes in the thermohaline circulation (THC) and deep water mass formation processes. Develop better models to predict future changes to the system and the potential for cooling and sea level rise in Western Europe.

Research to understand past environmental changes in connection to climate variability.

Implications of (non)action

Sea level rise threatens coastal settlements, and also transitional waters that can be invaded by the sea. Coastal defenses are the usual remedy but they also represent a problem, especially if the coast is sandy, since they transform soft bottom habitats into rocky habitats, changing the composition of natural communities and also the dynamics of the coast, also in terms of possible beach replenishment from natural sources.

References

Reports: 1, 3, 5, 9, 10, 12, 13, 14, 21, 22, 23, 32

https://www.euronews.com/2019/09/25/watch-live-ipcc-releases-key-report-on-world-s-oceans-and-ice-sheets

https://www.ipcc.ch/srocc/home/

1.49 Seawater temperature rising

Type: Trend/Driver **Categories:** Ecological Economic

Present and future developments

Ocean warming of 1.2–3.2°C, depending on emissions, is projected by 2100. Evidence shows that this causes decline in cold-water fish species, coral bleaching. Marine heatwaves are predicted to increase dramatically in frequency and magnitude as a consequence of global warming. Surface and subsurface Chlorophyll-a concentration variation (effect).

Impacts in society

Rinsing temperatures alter the ecological conditions for biological communities. This changes the composition of biodiversity and, eventually, also ecosystem functioning. In the Mediterranean Sea, for instance, hundreds of tropical species entered the basin and many of them developed important populations that, in some cases, interact with human activities. Jellyfish, for instance, can clog the cooling systems of industrial plants, they sting people, eat fish eggs and larvae and impact on fisheries. The indigenous species, furthermore, can suffer from massive mortality events that can span over hundreds of Km, as it happened for sponges and sea fans in the Ligurian sea.

Actions needed

Increasing temperatures have the local - regional impacts that I highlighted in the previous cell, but they have also global impacts, first of all the melting of polar ice. This causes sea level rise, as evidenced in the cells above, which, in its turn, affects the regular functioning of the Great Ocean Conveyor that is triggered by the "cold engines" of the poles. Cold and salty water sinks and generates the conveyor. If, instead, polar ice melts the ensuing cold and low-salinity water floats above the saltier water below and it can stop incoming currents such as the Gulf Stream that mitigates the climate in Northern Europe. Paradoxically, then, global warming can lead to regional increases in phenomena linked to lower temperatures. The impairing of the Great Ocean Conveyor has impacts on the global climate, with increases in extreme events such as hurricanes, floods, droughts etc. These phenomena have enormous social and economic impacts. It is universally agreed that global warming is due to current systems of production and consumption and especially to energy production linked with the burning of carbon based fuels which implies oxygen consumption and carbon dioxyde production. These production and consumption modes must evolve into different technologies that are not based on combustion.

Implications of (non)action

Policy inaction is not uncommon in low-income countries or where there is uncertainty about the effects of pollutants. Boero: many high-income countries have delocalized their polluting production systems into low-income countries that, to improve their status, accept ecological degradation while hoping for economic upgrades. Having delocalized polluting practices, however, has a low efficiency in terms of environmental quality in high-income countries du to the global bearing of this kind of environmental alteration. Furthermore, the environmental degradation of low income countries is causing crises that push people away, with great migration fluxes towards high-income countries. The more the environment will be altered (and especially global warming) the more Europe will be exposed to waves of immigration. Good practices must be exported, so as to replace the bad practices that we removed from our countries.

References

Reports: 3, 10, 13, 14, 21, 22, 32

https://www.sciencedirect.com/science/article/pii/S0303243418301016

1.50 Shifting towards multistakeholder governance models

Type: Trend/Driver **Categories:** Political Economic

Present and future developments

Mainstreaming new technologies and approaches cannot be left to accelerators and investors alone. Governments, as the ultimate custodians of water resources, must remain at the centre of the innovation agenda. Allowing government officials to make the most of the Fourth Industrial Revolution will require new solutions that can help them better navigate the complexities of resource-management decisions. How, for example, might technological advancements help local officials better understand and synthesize disparate sources of water-related information in real time? Could the creation of new platforms lower these transaction costs for governments and facilitate more confident and agile decision-making across ministries.

Despite clearly having potential benefits for decision-makers, the Fourth Industrial Revolution also raises important questions about the future of water governance. As governments are ultimately responsible for ensuring that technologies are developed and scaled responsibly, they will need to develop new policy frameworks and protocols for how emerging technologies are tested and refined.

Impacts in society

Ocean economy innovation networks

Actions needed

Ocean economy innovation networks are initiatives that strive to bring together a diversity of players (e.g. public research institutes, large enterprises, small and medium sized enterprises, universities, other public agencies) into flexibly organised networks. They work on a range of scientific and technological innovations, in many different sectors of the ocean economy (e.g. marine robotics and autonomous vehicles, aquaculture, marine renewable energy, biotechnologies, offshore oil and gas). Such networks are springing up in many parts of the world in response to changes in the national and international ocean research environment, and leveraging their organisational and skill diversity to benefit their partners and research in the ocean economy more generally.

The United Nations Decade of Ocean Science for Sustainable
evelopment (2021-2030) will bring together scientists and stakeholders from all relevant sectors to enerate the scientific knowledge and to develop the partnerships needed for informing policies to support well-functioning, productive, resilient, and sustainable ocean.

References

Reports: 8, 30

1.51 Surface water temperature rising in rivers and basins

Type: Trend/Driver **Categories:** Economic Ecological

Present and future developments

Warming trend in river water temperature have been observed in the Danube. Average water termperature has increased by more than 1ºC. The formation of ice on the river surface has also been observed to dissapear.

References

Reports: 6

1.52 The impairment of the cold engines of oceans and seas due to global warming

Type: Trend/Driver **Categories:** Ecological

Present and future developments

The impairment of the cold engines of the oceans and seas, e.g. in the Mediterranean Sea, and the disruption of Gulf Stream. Continued global warming and associated ice decline, with consequent impacts on the polar cold engines that fuel the great ocean conveyor and that regulate the global climate.

Impacts in society

The great ocean conveyor, triggered by polar cold engines, determines the climate of the planet. The clouds in the sky are made of water that evaporated from the ocean! The ocean is also above us. The extreme events that are causing problems worldwide, from fires to floods, are due to climate change, and the driver of climate is the ocean. If ocean dynamics change, the climate changes. The solution to this problem resides in a radical change in our systems of production and consumption. We still burn carbon and are in the age of fire. We must abandon the age of fire and start a new era.

Actions needed

This implies a radical change in our systems of production and consumption. Plastic is just one of the problems, but not the largest... We must invent new technologies that will guarantee the availability of goods and services without destroying the premises of our well being, because this is what we are doing now. Some states are moving in this direction without waiting others to do so (e.g. New Zealand). This is offering enormous opportunities of economic development (not growth) linked to technological innovation. People are ready to change their habits if this will improve their standards of life.

Implications of (non)action

If we will continue with business as usual, the alteration of the grand ocean conveyor will disrupt our climate drastically. This is not a wild card, this is a prediction that is happening already. China is starting to understand the importance of this issue, and will invest lots of resources so as to find solutions. Those who will find these solutions first will be leading the economy, those who will not will lag behind. Europe has the potential to become a leader in this field.

References

Reports: 1, 13, 29

https://scripps.ucsd.edu/news/climate-model-suggests-collapse-atlantic-circulation-possible

1.53 Virtual reality for (safety) training purposes

Type: Trend/Driver **Categories:** Technological Economic

Present and future developments

This comes as no surprise that VR training programs are available to the market. They can be used for crew entertainment or, as mentioned earlier when in need to develop new skills. To further enhance onboard crew safety, operator-owners are beginning to investigate developments in cyborg crew - wearable technology – which can be used to monitor heart rates, accumulated steps or sugar levels, etc., in real-time, to ensure the health and wellbeing of their crew on board.

References

https://safety4sea.com/5-digital-innovations-that-are-changing-the-maritime-industry/

2 Weak signals

2.1 Adaptation of North Atlantic Albacore fishery to climate change

Type: Weak signal **Categories:** Ecological Political

Present and future developments

Fisheries are constrained by ecosystem productivity and management effectiveness. Climate change is already producing impacts on marine ecosystems through overall changes in habitats, productivity and increased variability of environmental conditions. The way how these will affect fisheries is under debate and, also there is uncertainty on the best course of action to mitigate climate change impacts on fisheries. Harvest control rules are sets of pre-agreed rules that can be used to determine catch limits periodically and describe how harvest is automatically controlled by management in relation to the state of some indicator of stock status. In 2017, the International Commission for the Conservation of Atlantic Tunas adopted a harvest control rule for North Atlantic albacore.

References

https://www.frontiersin.org/articles/10.3389/fmars.2019.00620

2.2 Affordable desalination innovations

Type: Weak signal **Categories:** Technological Economic

Present and future developments

In the past 30 years alone, drastic improvements have been made in the desalination process, with new technology and enhanced operating systems. According to the Water Desalination Report, current operating plants require only a quarter of the energy compared to systems in the 1980s, due primarily to efficient pumps, membranes and energy- recovering devices. Sun-rich countries, such as Abu Dhabi, are also starting to integrate renewable sources of energy into desalination plants, thereby reducing energy costs and potentially offsetting the energy demand during peak hours.65 The future of desalination is not only bright in terms of technological advancement reducing cost, but the ability to use natural resources to produce potable water in water-scarce regions is also promising.

Actions needed

The high costs of energy need developing low-costs desalinisation technologies as well as coupling desalinisation to green energy production.

References

Reports: 3, 7, 8

2.3 Autonomous Ships

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Over the past few years, companies like Rolls-Royce Marine and Japanese shipping giant Nippon Yusen have shared plans to send remote and autonomous ships to sea. These ships will remain crewed to begin with, but as the technology advances, some of the ships may be crewless by as early as 2020.

Certain companies are building fully autonomous ships from scratch, while other start-up businesses are developing semi-autonomous systems to be used on existing vessels. What is certain is that "autonomous" is likely to become a vital part of the day-to-day onboard operations.

Impacts in society

Global shipping is responsible for approximately 30%of total global nitrogen oxide (NOx) emissions. Theseemissions have been linked to thousands of prematuredeaths in coastal areas.

Ships account for approximately2.5% of total global greenhouse gas (GHG) emissions.Other environmental impacts from shipping includebiodiversity impacts related to ballast water and theeffect of noise pollution on ocean wildlife. Global policyefforts have recently focused on sulphur and GHGemissions from ships and ballast water management,but efforts could be intensified with respect to NOx andparticulate matter (PM) emissions.

References

Reports: 32

https://safety4sea.com/5-digital-innovations-that-are-changing-the-maritime-industry/

2.4 Autonomous solar-powered ship that cleans oil spills and other pollution

Type: Weak signal **Categories:** Technological

Present and future developments

In the future, a swarm of autonomous robots might be able to handle oil spill cleanup. That's the idea behind a new solar-powered robot prototype equipped with nanotechnology designed by researchers at MIT. They say that a giant swarm of these robots could be able to clean a Gulf of Mexico size area in one month.

References

http://www.nbcnews.com/id/38883221/ns/technology_and_science-science/t/solar-powered-robot-swarm-could-clean-oil/

2.5 Blockchain in water management to improve administration and maintenance

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Blockchain offers potential opportunities for municipalities to record water-quality information in a transparent and openly accessible manner that is protected from third-party tampering. The addition of blockchain- based smart contracts could automatically trigger repairs by (and payments to) pre-approved suppliers, overcoming the long processing times and bureaucracy that can hinder repairs in some jurisdictions. By enabling peer-to-peer trading of water allocations among users in an open and transparent manner, blockchain-backed smart contract systems can help optimize water use and encourage better stewardship.

References

Reports: 8, 2

2.6 Coastal living linked with better mental health

Type: Weak signal **Categories:** Social Values

Present and future developments

Researchers used survey data from nearly 26,000 respondents in their analysis, which marks one of the most detailed investigations ever into the well-being effects of being beside the sea. After taking other related factors into account, the study revealed that living in large towns and cities near to England's coastline is linked with better mental health for those in the lowest earning households.

References

https://www.sciencedaily.com/releases/2019/09/190930214514.htm

2.7 Co-management for sustainable common pool resources

Type: Weak signal **Categories:** Economic Political

Present and future developments

The research explores the potentials of co-management and the state of its implementation in, which is an economy in transition and highly dependent on tourism. The study will focus on multi-level governance structure/behavior in the public sector and quasi-governmental institutions, private sector, and the role of NGOs in relation to local-level commons. Tourism is an energy intensive industry with a high carbon footprint, which immensely affects the common pool resources (CPR) and ecosystems. With such combative relation between tourism and CPR, co-management offers a solid platform for institutions and resource users to share power and collaborate to reconcile the strife between tourism and ecosystems.

References

https://www.sciencedirect.com/science/article/pii/S096456911930328X?dgcid=rss_sd_all

2.8 Conflicts over offshore drilling and use of resources

Type: Weak signal **Categories:** Economic

Present and future developments

After a long dispute between the EU and Turkey regarding the latter's activities which EU comments as "illegal", EU sanctions against who are involved in offshore drilling activities in the Eastern Mediterranean within Cypriot territorial waters.

References

https://safety4sea.com/eu-imposes-sanctions-against-turkey/

2.9 Decentralized water collection and treatment systems for households and communities

Type: Weak signal **Categories:** Technological Political

Present and future developments

Development of sustainable and resilient water infrastructure is an urgent challenge for urban areas to secure long-term water availability and mitigate negative impacts of water consumption and urban development. A hybrid system that combines centralized water infrastructure and household decentralized water facilities, including rainwater harvesting and greywater recycling, may be a solution to more sustainable and resilient water management in urban areas. Understanding household and community preferences for decentralized water facilities is important to inform the design and ultimately the promotion and adoption of such systems.

References

https://www.sciencedirect.com/science/article/pii/S004313541930908X?dgcid=rss_sd_all

2.10 Disaster risk reduction for transboundary river basins

Type: Weak signal **Categories:** Political Ecological

Present and future developments

A recent UNESCAP disaster risk-focused report has identified transboundary river basins in South Asia as disaster hotspots. One such area in the Hindu Kush Himalayan region is the Koshi basin.

References

http://www.iwmi.cgiar.org/2019/10/disaster-risk-reduction-hub-for-koshi-river-to-be-developed/

2.11 Diversification in stock use, shifting the burden

Type: Weak signal **Categories:** Economic

Present and future developments

Declining fish stocks lead to the search for other stocks to replace the functions / needs that were fulfilled by the declining ones. This shift overexploitation from one stock to another and leads to innovative use of previously undervalorised stocks.

Actions needed

Technological developments in aquaculture production including research on innovative feeds, and research based on DNA sequencing brood stock, new species and stock baselines adapted to climate change impacts.

References

Reports: 14, 22

https://www.researchgate.net/profile/Gabriella_Caruso/publication/284625083_Fishery_Wastes_and_By-products_A_Resource_to_Be_Valorised/links/565584c908ae1ef9297723b1/Fishery-Wastes-and-By-products-A-Resource-to-Be-Valorised.pdf

2.12 Drought considered a national security issues for trade and geopolitical relations

Type: Weak signal **Categories:** Political Technological

Present and future developments

There is now a recognized need to move away from reactive to proactive approaches to drought risk management, said Goodman, suggesting that American early warning systems and information sharing be improved to assist in risk response planning. Countries important to US strategic interests are experiencing drought and heightened tensions over the competition of resources. The Syrian civil war illustrates one of the starkest examples of how a prolonged drought has helped fuel conflict.

References

https://www.circleofblue.org/2019/water-climate/understanding-and-responding-to-the-role-of-drought-in-national-security/

2.13 Ecological ocean farming focusing on seaweed and shellfish

Type: Weak signal **Categories:** Ecological Economic

Present and future developments

A small group of ocean farmers and scientists are charting a different course—developing small-scale farms where complementary species are cultivated to provide food and biofuel, clean up the environment, and reverse climate change. Instead of finfish, the anchor crops of green ocean farms are seaweed and shellfish, two organisms that may well be Mother Nature’s Rx for global warming.

How so? Among other benefits, oysters filter nitrogen out of the water column. Seaweed pulls carbon from the atmosphere and the water, with some varieties capable of absorbing five times more carbon dioxide than land-based plants. Seaweed farms also have the capacity to grow massive amounts of nutrient-rich food and provide a clean replacement for biofuels.

References

https://www.drawdown.org/solutions/coming-attractions/ocean-farming

2.14 Farmed oysters able to protect themselves from acidification

Type: Weak signal **Categories:** Ecological Economic

Present and future developments

Oysters bred for fast growth and disease resistance are able to adapt their shell growth to protect themselves from environmental acidification, according to new research.

References

https://www.sciencedaily.com/releases/2019/09/190926112640.htm

2.15 Floating wind energy digital twin (virtual replica)

Type: Weak signal **Categories:** Technological Economic

Present and future developments

The US Department of Energy Advanced Research Projects Agency-Energy (ARPA-E) issued a 3.6 million grant to Principle Power and partners for the development, validation and operation of the world’s first digital twin software for floating offshore wind applications.

A digital twin is a digital replica of a living or non-living physical entity. By combining the physical and the virtual world, data is provided enabling the virtual entity to exist at the same time with the physical entity. Specifically, it replicates physical assets that can be used for various purposes. This digital representation provides the elements and the dynamics of how an Internet of Things (IoT) device operates and lives throughout its life cycle.

The technology known as DigiFloat will be a real-time representation of the WindFloat Atlantic (WFA) project. DigiFloat will be installed off the coast of northern Portugal.

References

https://safety4sea.com/partners-receive-grant-for-worlds-first-floating-wind-digital-twin-project/

2.16 Inadequate water safety standards may lead to health risks

Type: Weak signal **Categories:** Political

Present and future developments

Health risks persist even for pollutants that are widely monitored and regulated. Worse, regulations guiding safety standards are often fragmented across countries and agencies. Prescribed pollution limits safe.

References

Reports: 17

2.17 Integrated risk assessment is incrasingly used in the emerging blue economy

Type: Weak signal **Categories:** Social Political

Present and future developments

A study discusses six key insights from the long history of risk research in the social sciences that can inform integrated assessments of risk: (1) consider the subjective nature of risk, (2) understand individual social and cultural influences on risk perceptions, (3) include diverse expertise, (4) consider the social scales of analysis, (5) incorporate quantitative and qualitative approaches, and (6) understand interactions and feedbacks within systems. Finally, the study shows how these insights can be incorporated into risk assessment and management, and apply them to a case study of whale entanglements in fishing gear off the United States west coast.

References

https://www.frontiersin.org/articles/10.3389/fmars.2019.00609

2.18 Legal barriers for the blue bioeconomy due to focus on traditional industries

Type: Weak signal **Categories:** Political

Present and future developments

Novel / innovative activities in the blue bioeconomy are hindered by underdefinition of these activities. Current legal frameworks insufficiently address these developments and thus stifle them.

References

Reports: 14

2.19 Melting of the Antarctic ice sheet

Type: Weak signals **Categories:** Ecological

Present and future developments

In contrast to the melting of the Arctic sea ice, sea ice around Antarctica has been expanding. Satellite measurements indicate an increasing sheet thickness above the continent, outweighing the losses at the edge. Suggestions include the climatic effects on ocean and atmospheric circulation of the ozone hole, and/or cooler ocean surface temperatures as the warming deep waters melt the ice shelves. At the same time, a tipping point in the Antarctic ice sheet may be crossed if global temperatures are allowed to rise by more than 2℃. This could result in large parts of the ice sheet being committed to melt-down over the coming centuries, reshaping shorelines around the world.

References

https://phys.org/news/2019-10-antarctica-ice-sheets-seas-meters.html
http://www.antarcticglaciers.org/
https://www.nasa.gov/feature/goddard/nasa-study-mass-gains-of-antarctic-ice-sheet-greater-than-losses

2.20 Microplastic fibres found around the world

Type: Weak signal **Categories:** Social

Present and future developments

Microplastic fibres found in tap water around the world.

Actions needed

Extensive ban on plastic packaging should be considered. Waht is needed is to recollect and reuse plastics, even the possibilities to convert plastics to 'oil' again.

References

Reports: 14

https://www.reddit.com/r/Futurology/comments/dy7z28/plastic_waste_converted_back_to_oil/

2.21 Nanotechnology innovation may unleash new water sources at scale (e.g. desalination)

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Nanotechnology holds the potential to unleash new water sources at scale, and in doing so, it can bring benefits across multiple industries, including water decontamination, infrastructure development and monitoring systems. The global economy has already recognized the potential impacts of this technology, with expected investments in the nanotechnology market – which is expected to exceed $125 billion by 2024.60 Given that nanotechnology can manipulate and manufacture new materials, devices and systems at an atomic level with a fundamentally new molecular organization and function.

References

Reports: 8

2.22 New catalyst efficiently produces hydrogen from seawater

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Seawater is one of the most abundant resources on earth, offering promise both as a source of hydrogen and of drinking water in arid climates. Now researchers have reported a significant breakthrough with a new oxygen evolution reaction catalyst that, combined with a hydrogen evolution reaction catalyst, achieved current densities capable of supporting industrial demands while requiring relatively low voltage to start seawater electrolysis.

References

https://www.sciencedaily.com/releases/2019/11/191111180111.htm

2.23 New Celtic Sea Alliance launched to promote floating wind energy

Type: Weak signal **Categories:** Technological Political

Present and future developments

Next steps for the Alliance include the formation of a Celtic Sea Offshore Wind industrial cluster. Additionally, the Alliance will focus on policy engagement to secure a pipeline of at least 1GW worth of floating wind turbines in the Celtic Sea before 2030. The alliance claims that this could attract over of £2 billion worth of regional investment and generate new jobs.

References

https://safety4sea.com/new-celtic-sea-alliance-launched-to-promote-floating-wind/

2.24 New kelp forests of marine permaculture to enhance ecosystem and capture carbon

Type: Weak signal **Categories:** Ecological Economic

Present and future developments

The oceans absorb half of the carbon dioxide recaptured from the atmosphere, which causes acidification, and over 90 percent of the heat from global warming. Ocean deserts are expanding. Von Herzen wants to restore marine life in subtropical waters with thousands of new kelp forests—what he calls marine permaculture.

The key technology involves marine permaculture arrays (MPAs), lightweight latticed structures roughly half a square mile in size, submerged 80 feet below sea level, to which kelp can attach. Attached buoys rise and fall with the waves, powering pumps that bring up colder, nutrient-rich waters from far below. Kelp soak up the nutrients and grow, establishing a trophic pyramid rich in plant and animal life.

Plants that are not consumed die off and drop into the deep sea, sequestering carbon for centuries in the form of dissolved carbon and carbonates. Floating kelp forests could sequester billions of tons of carbon dioxide, while providing food, feed, fertilizer, fiber, and biofuels to the world.

References

https://www.drawdown.org/solutions/coming-attractions/marine-permaculture

2.25 New maritime platform to optimize supply chain (data sharing)

Type: Weak signal **Categories:** Economic Technological

Present and future developments

BHP's Maritime and Supply Chain Excellence team and Klaveness Digital informed that they are cooperating in order to drive the development of new shipping and logistics platforms. These aim to improve the way the industry works together and shares scheduling and vessel information.

The concept aspires to facilitate BHP and its partners to access the same shipping information in real-time, while those who will use the platform will also be able to see the shipping schedule and calculate impact on their inventory and production.

References

https://safety4sea.com/new-maritime-platform-to-optimize-supply-chain-to-be-created/

2.26 Pacific islands aim for zero carbon shipping emissions

Type: Weak signal **Categories:** Technological Economic

Present and future developments

An alliance of Pacific island nations hopes to acquire USD 500 million aiming to a zero-carbon emissions shipping, a plausible scenario in the Pacific Ocean by the middle of the century, given that the Pacific islands rely on transportation in their everyday lives.

The coalition which was announced by the governments of Fiji, the Marshall Islands, Samoa, Vanuatu, the Solomon Islands and Tuvalu, on Tuesday, September 24 aims for a complete decarbonization by 2050 and has further set an emissions reduction target of 40% by 2030.

According to the Guardian, the partnership is willing to raise money through grants from multinational corporations, concessional loans, direct private sector investment and registering regional blue bonds. The money could be used to refurbish already existing passenger and cargo vessels with lower-carbon technologies or even assist in the acquisition of newer zero-emissions ships.

Impacts in society

Pacific Islands firmly rely on imported fossil fuels and can be severely affected in the possibility of price shocks or supply disruptions.

The Pacific Islands are highly dependent on shipping transportation for travel, medicines, employment and wider connections to the world. Therefore, a lack of communication and sea travel between the islands would have major implications on the domestic, social and economic development as well as international trade, due to the many small populations being spread throughout the archipelago. The region imports 95% of its fuels, with the transport sector being the biggest user and imported petroleum contributing to an average of 40% of GDP in Pacific island states.

References

https://safety4sea.com/pacific-islands-aim-for-zero-carbon-shipping-emissions/

2.27 Researchers use drones for monitoring fauna

Type: Weak signal **Categories:** Technological Ecological

Present and future developments

(Woods Hole Oceanographic Institution) Researchers from Aarhus Institute of Advanced Studies (AIAS) in Denmark and Woods Hole Oceanographic Institution (WHOI) in the US devised a way to accurately estimate the weight of free-living whales using only aerial images taken by drones. The innovative method, published in the British Ecological Journal Methods in Ecology and Evolution, can be used to learn more about the physiology and ecology of whales.

References

https://www.eurekalert.org/pub_releases/2019-10/whoi-rud100119.php

2.28 Smart and ecologically ambitious floating cities

Type: Weak signal **Categories:** Technological

Present and future developments

Smart and ecologically ambitious floating cities. Masaki Takeuchi wants Singapore to dream big. Specifically, the Japanese architect and civil engineer believes a floating city, created off the shores of the Southeast Asia's smallest country, could provide enough land for an additional 50,000 people and produce enough food, water and energy to sustain them without the need for land reclamation.

References

https://www.eco-business.com/news/future-or-fantasy-are-floating-cities-the-next-stage-of-singapores-urban-development/
https://www.shimz.co.jp/en/topics/dream/content03/

2.29 Solid-state wave energy

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Because water is nearly one thousand times denser than air, aqua turbines are technically more efficient than wind turbines. The problem with wave energy technologies is economic inefficiency. They require moving parts that can withstand the stress and corrosion of the sea. The raw energy found in the ocean can easily become wave power's downfall.

A company in Seattle, Oscilla Power, has created a wave-energy technology that converts the kinetic energy of the ocean without external moving parts. Compression and decompression within Oscilla's wave energy converter create electricity.

Solid-state wave energy eliminates some of the key issues that have plagued other start-ups in the field of marine energy. It may be the breakthrough, if it can capture ocean energy affordably.

Impacts in society

Oceans remain the largest untapped source of renewable energy on earth, surging with roughly 80,000 terawatt hours of power. A single terawatt is the equivalent of 1 trillion watts and sufficient to provide electricity to 33 million U.S. homes.

References

https://www.drawdown.org/solutions/coming-attractions/solid-state-wave-energy

2.30 Stimulating trade-offs in the water-energy-food nexus

Type: Weak signal **Categories:** Economic Political

Present and future developments

In the Omo-Turkana and Zambezi basins in Africa, complex relationships emerge from the balances struck among hydropower generation, irrigated agriculture, water quality and environmental flows.

References

http://www.iwmi.cgiar.org/2019/10/simulating-trade-offs-in-the-water-energy-food-nexus/

2.31 Superconducting light weight wind turbine generator to provide power to ships

Type: Weak signal **Categories:** Technological Ecological

Present and future developments

For the time being, the project partners discuss with wind turbine manufacturers the possibility of a follow up project and commercial product development.

They also are discussing the application of the technology for ship propulsion using much smaller and lighter motors and generators.

The team behind the project states that the benefit is the superconductors, which are able to produce electricity without resistance. Also, on the contrary to copper, they are able to carry 100 times the current density, making electrical machinery compact and lightweight.

References

https://safety4sea.com/worlds-first-superconducting-light-weight-wind-turbine-generator-to-provide-power-to-ships/

2.32 Water innovation ecosystems to promote technological solutions

Type: Weak signal **Categories:** Economic Technological

Present and future developments

Building a strong and diverse culture of innovation is critical for the water community's ability to fully harness the Fourth Industrial Revolution. Without this, technology-enabled solutions will still be developed, but likely by a select few and not necessarily in a way that gets to the root of water challenges. However, by identifying and targeting vital levers of influence, an entire new innovation ecosystem, can arise that incubates ideas from the ground up and encourages the next generation of technology-savvy water leaders.

References

Reports: 8

2.33 Water saving at home

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Using water at home—to shower, do laundry, soak plants—consumes energy. It takes energy to clean and transport water, to heat it if need be, and to handle wastewater after use. Hot water is responsible for a quarter of residential energy use worldwide. Efficiency can be improved household-by-household and tap-by-tap.

In the United States, 60 percent of home water use occurs indoors, primarily for toilets, clothes washers, showers, and faucets. Low-flush toilets and efficient washing machines can reduce water use by 19 and 17 percent respectively. Low-flow faucets and showerheads and efficient dishwashers can also contribute. In total, these technologies can reduce water use within homes by 45 percent.

30 percent of home water use occurs outdoors, while another 10 percent is lost to leaks. Water use for irrigation can be reduced or eliminated by using captured rainwater, shifting to plants that do not require it, installing drip irrigation, or turning off the spigot entirely.

Local restrictions on water consumption and policies requiring efficient plumbing are highly effective. Product labeling can inform consumer choices, while incentives, namely rebates on purchases of efficient appliances and fixtures, can encourage voluntary action.

References

https://www.drawdown.org/solutions/materials/water-saving-home

2.34 Wave and tidal energy becomes mainstream

Type: Weak signal **Categories:** Technological Economic

Present and future developments

Wave- and tidal-energy systems harness natural oceanic flows—among the most powerful and constant dynamics on earth—to generate electricity. A variety of companies, utilities, universities, and governments are working to realize the promise of consistent and predictable ocean energy, which currently accounts for a fraction of global electricity generation.

While the ocean's perpetual power makes wave and tidal energy possible, it also creates obstacles. Operating in harsh and complex marine environments is a challenge—from designing systems to building installations to maintaining them over time. It is more expensive than producing electricity on solid ground.

Despite decades of work, marine technologies are still in early development and lag well behind solar and wind. Tidal energy is more established than wave, with more projects in operation today. Across the world, a variety of wave-energy technologies are being tested and honed, in pursuit of the ideal design for converting waves' kinetic energy into electricity.

Wave and tidal energy is currently the most expensive of all renewables. Still, the opportunity of marine-based energy is massive. Proponents believe wave power could provide 25 percent of U.S. electricity, for example. Realizing it will require substantial investment and expanded research.

Impacts in society

There are not many projections of wave and tidal energy to 2050. Building on those few, we estimate that wave and tidal energy can grow from .0004 percent of global electricity production to .28 percent by 2050. The result: reducing carbon dioxide emissions by 9.2 gigatons over thirty years. Cost to implement would be $412 billion, with net losses of $1 trillion over three decades, but the investment would pave the way for longer-term expansion and emissions reductions.

References

https://www.drawdown.org/solutions/coming-attractions/marine-permaculture

2.35 Water problems becoming a national emergency (e.g. Zimbabwe)

Type: Weak signal **Categories:** Social Ecological

Present and future developments

Harare is reeling from a serious water crisis as the city's main sources of potable water have virtually dried up, with the only remaining source being so heavily polluted making it costly to purify at a time the local authority is buffeted by massive foreign currency shortages.

References

https://allafrica.com/stories/201909270187.html

3 Wild cards

3.1 *Atmospheric river mega storm*

Type: Wild card **Categories:** Ecological

Present and future developments

A winter storm scenario called ARkStorm (for Atmospheric River 1,000). Experts have designed a large, scientifically realistic meteorological event followed by an examination of the secondary hazards (for example, landslides and flooding), physical damages to the built environment, and social and economic consequences. The hypothetical storm depicted here would strike the U.S. West Coast and be similar to the intense California winter storms of 1861 and 1862 that left the central valley of California impassible. The storm is estimated to produce precipitation that in many places exceeds levels only experienced on average once every 500 to 1,000 years.

References

https://tos.org/oceanography/assets/docs/24-3_machlis.pdf
https://pubs.usgs.gov/of/2010/1312/

3.2 *Major diplomatic crisis on debated areas*

Type: Wild card **Categories:** Political Economic

Present and future developments

The growing value of marine territory linked to growing demand for marine resources and new technology to extract and identify them create the risk of growing global tension over disputed areas, e.g. in the South China Sea.

References

Reports: 10

3.3 *Massive earthquakes on northern sections of the Cascadia Subduction Zone*

Type: Wild card **Categories:** Ecological

Present and future developments

A new analysis by researchers in Oregon, Spain and British Columbia suggests that massive earthquakes on northern sections of the Cascadia Subduction Zone, affecting areas of the Pacific Northwest that are more heavily populated, are somewhat more frequent than has been believed in the past. The Cascadia Subduction Zone runs from Northern California to British Columbia, and scientists say it can be roughly divided into four segments. There have been 43 major earthquakes in the past 10,000 years on this subduction zone, sometimes on the entire zone at once and sometimes only on parts of it. When the entire zone is involved, it's believed to be capable of producing a magnitude 9.1 earthquake.

References

https://www.opb.org/news/series/unprepared/cascadia-subduction-zone-earthquake-big-one-oregon-state/
https://pamplinmedia.com/pt/9-news/317781-197175-research-says-big-one-could-rattle-state-sooner-than-we-thought

3.4 Mercury pollution of oceans, rivers, and lakes due to runoff from thawing permafrost

Type: Wild card **Categories:** Ecological

Present and future developments

Researchers have estimated the amount of natural mercury stored in perennially frozen soils (permafrost) in the Northern Hemisphere. Permafrost regions contain twice as much mercury as the rest of all soils, the atmosphere, and ocean combined. As global temperatures continue to rise, the thawing of permafrost is accelerated, and mercury trapped in the frozen ground is now being released. The mercury is transforming into more mobile and potentially toxic forms that can lead to environmental and health concerns for wildlife, the fishing industry and people in the Arctic and beyond.

References

https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017GL075571
https://www.sciencedaily.com/releases/2019/10/191016124557.htm

3.5 Multiple oil platform spills/failures

Type: Wild card **Categories:** Ecological

Present and future developments

Oil spills have produced measurable effects on ecosystems that have not been readily predictable from laboratory studies on isolated organisms. However, ecosystemlevel interactions are poorly understood even without the complications resulting from effects of pollution. These generalizations emerge: oil regularly reaches sediments after a spill; oil in anoxic sediments is persistent; oil regularly contaminates Zooplankton and benthic invertebrates; fish are also contaminated, but to a lesser extent; oil contamination decreases the abundance and diversity of benthic communities.

Actions needed

Act as a hub to address acute risks (including emergencies) and disasters (e.g. related to pollution risks of dumped munitions, shipwrecks etc.) inside and outside the EU by putting in place temporary panels of experts to assess the issues and propose solutions.

References

https://tos.org/oceanography/assets/docs/24-3_machlis.pdf

3.6 Ocean piracy

Type: Wild card **Categories:** Ecological

Present and future developments

Illegal maritime arrivals, exploitation of natural resources, illegal activity in protected areas, marine pollution, prohibited imports and exports, biosecurity risks, and maritime terrorism have all been listed as additional dangers to the marine economy by the Australian Department of Home Affairs. But it is maritime piracy that continues to be the greatest fear and steal the headlines.

References

https://tos.org/oceanography/assets/docs/24-3_machlis.pdf
https://www.raconteur.net/finance/maritime-piracy

3.7 Political shift towards more regionalised economies

Type: Wild card **Categories:** Political

Present and future developments

Political shift towards more regionalised economies could dramatically hamper the global efforts. While many countries today benefit from sophisticated, cutting-edge scientific infrastructure, technology, andhuman capacity for science and innovation, major disparities exist in the capacity around the world to undertake the marine scientific research or the collection of ocean data required for proper management of human activities that can affect the marine environment.

Actions needed

Actively promote the equitable sharing of science and knowledge, work to fill gaps in the global distribution of scientific capacity, and accelerate the transfer of marine technology. It will do so byfacilitating new partnerships to improve access to data, equipment and expertise, thereby providingpathways for new knowledge production needed to fill current gaps. With this new knowledge andcapacity, communities will be better able to harness new science-based services in order to enhanceresource management, food security, hazard mitigation, and resilience.

Create new processes and dialogues to help build the capacity of decision-makers to understand anduse ocean knowledge and to push for institutional change in order to allow for more evidence-basedpolicy making. These partnerships will be developed through early engagement in those regionswhere gaps exist, ensuring that scientific capacity needs are identified during the planning processfor the Decade. Increasing scientific and technical capacity so that all nations can participate in, and benefit from, developments in ocean science and technology, in particular the most vulnerable: smallisland developing states and least developed countries.

Implications of (non)action

References

Reports: 14, 31, 32

3.8 Reassignment of rights to genetic resources

Type: Wild card **Categories:** Political

Present and future developments

Reassignment of rights to genetic resource and support actions towards the exploitation of genetic resources, including bio-prospecting, identification, and the valuation of biological resources. Activities will 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.

References

Reports: 14, 22

3.9 Subsea premafrost and methane hydrates

Type: Wild card **Categories:** Ecological

Present and future developments

The Arctic contains much of the world's permafrost, which holds what the report calls a "sleeping giant" made of greenhouse gases. In addition to the most common type found in soil on land, there is high-carbon permafrost under the seafloor of shallow coastal shelf areas that were flooded as sea levels rose about 11,650 years ago. Estimates vary, but 1.5 trillion tons of carbon dioxide are said to lurk beneath the Earth's permafrost. That's more than 40 times as much CO2 as humans released into the atmosphere last year, and double the amount of the gas in the atmosphere today.

References

https://www.wired.com/story/the-arctic-carbon-bomb-could-screw-the-climate-even-more/
https://phys.org/news/2018-12-arctic-permafrost-giant-world-carbon.html

ANNEX 2: FOCAL AREAS

1 Climate-resilient coastlines

Scope: Sea-level rise and coastal vulnerability

Clear target(s)

By 2030, to adapt to an unavoidable sea-level rise across Europe and related extreme events.

By 2030, to propose a comprehensive plan for sea-level rise adaptation, including strategic withdrawal, at the scale of Europe.

By 2030 scale up the best practices to improve the efforts of climate change mitigation through the specific role of the coastal wetlands.

Present and future developments

Trends and drivers	Weak signals	Wild cards
Declining coastal economic activities due to environmental and economic pressure Evapotranspiration of the soil moisture due to climate change Growing blue economy leading to busier seas Growing frequency of floods in Europe and the world Growing use of offshore renewable energy Rapid melting of the Greenland ice sheet and mountain glaciers. Seawater rising globally Seawater temperature rising Virtual reality for training	Affordable desalination Blockchain in water management to improve administration and maintenance Coastal living linked with better mental health Disaster risk reduction for transboundary river basins Ecological ocean farming - focusing on seaweed and shellfish New catalyst efficiently produces hydrogen from seawater New kelp forests of marine permaculture to enhance ecosystem and capture carbon New maritime platform to optimize supply chain (data sharing) Smart and floating cities	Atmospheric river mega-storm Major diplomatic crisis on debated areas Political shift towards more regionalised economies

Sea-level rise is an unavoidable phenomenon through 2100 and beyond. Its velocity and intensity will depend on global warming. It has accelerated over the twentieth century and will increasingly affect the coastline and coastal areas where many populations and economic activities are concentrated. This land-sea interface is very vulnerable to the rise in water level and to periodic submersions during storms or floods. Deltaic areas, islands and low-lying coastal areas are particularly vulnerable to marine submersion and damage during storms (Clark *et al*., 2016). Furthermore, the coastal zone with an altitude of less than 10 m (or low elevation coastal zone, LECZ) will accommodate more than 900 million inhabitants in 2030 and pass the billion in 2060, an increase of 50% compared to the year 2000 (Neumann *et al*., 2015). Combined with the rise in sea-level and continental subsidence in some areas, flood vulnerability is expected to affect between 300 to 400 million people in 2060, particularly in Asia but also in several regions in EU countries such as the Netherlands (notably Rotterdam) or Italy (notably Venice) and the Great Britain (notably the Thames estuary).

Another important element to consider is the frequency and intensity of extreme events such as marine submersion, temporary flooding (Leal Filho, 2015) and hurricanes. Combined with rising sea-levels, these extreme events can increase the magnitude of impacts. The European Atlantic coasts are more frequently exposed to stronger storms, probably because of the climate change.

Given the huge investments needed to adapt coastal areas, and to secure their populations in **the medium and long-term, anticipating these risks is a major public policy issue**. Research in the environmental sciences helps to inform choices in these public policies to anticipate changes and assess risks. The globalisation of efforts to understand the climate system, in particular via the IPCC since 1988, has made it possible to first define the routes of climate forcing, then to script their causes and finally to make projections of their consequences (IPCC, 2013). International decision-makers at the economic and political level have gradually taken the results of these projections seriously. The projections in the latest IPCC report (SROCC, 2019) envisage a likely increase (> 66% prob) in the average sea-level at the timeline of 2100 of 29 cm (RCP 2.6) through to 110 cm (RCP 8.5) (Oppenheimer *et al*., 2019).

Given the assumption of a high rise in global average temperature and melting of a significant share of the polar ice caps**, the total rise could reach 2 m in 2100 or more** (Bamber *et al*., 2019). Managing the rise in sea level depends on the control of global warming. At local scales, there are significant differences in terms of the exposure of coastal areas and effects related to specific vulnerabilities, as well as unequal adaptive capacities across territories, notably in Europe. The environmental, social and economic consequences will therefore depend on the scale of the phenomenon, current and future characteristics and uses of the coastal areas under consideration and, above all, the ability to anticipate, react and coordinate actions. It is, therefore, necessary to anticipate the challenges and consequences of rising sea-level according to various scenarios. This approach thereby offers a conceptual framework for the development of research programmes.

Wetlands face a myriad of threats, but thanks to research and advocacy efforts, awareness is growing about the role they play in curbing climate change and coping with its impacts. It is vital to preserving healthy coastal wetlands - keeping a lid on the carbon they contain - while also rehabilitating and restoring those that already have been degraded. Along the fringes of coasts, where land and ocean meet, lie the world's salt marshes, mangroves, and seagrasses. These coastal wetland ecosystems are found on every continent except Antarctica. They provide nurseries for fish, feeding grounds for migratory birds, the first line of defence against storm surges and floodwaters, and natural filtration systems that boost the water quality and recharge aquifers. Relative to their land area, they also sequester huge amounts of carbon in plants aboveground and in roots and soils below. More research is needed to secure as much as possible their multiple ecosystem services.

Coastal towns and the related infrastructures and economic activities are the heart of the political and economic value of the coastal regions. They are the gates of the international trade and gather several roles notably to be the interface with the hinterland and the other non-oceanic countries. The cost of adaptation to sea level rise (SLR) is still low for the coming decade for most of the European coastal cities but the existing trends justify envisaging a partial withdrawal. Actually, dams and pumps can protect for years, but not for decades, and certainly not at the 2050 horizon. Situations differ all along the European coastline (Ireland vs the Netherlands as an example) but this diversity has to be anticipated realistically. Several technologies are available, but the political will and the involvement of the local population remain the key drivers. There will not be a dynamic "blue economy" without a concrete strategy to face this slow but unbearable phenomenon. As an example, the Indonesian government is preparing the move of its capital, Djakarta (10 million inhabitants), from Java to Borneo, another island, 800 km from the city. The SLR will strongly impact coastal tourism. While the traditional sun and beach tourism will be highly affected, alternative cultural and sports activities or offshore cruise with « floating cities » may offer new opportunities for tourism.

The oceans absorb half of the carbon dioxide recaptured from the atmosphere. Over the last ten years, 25% of anthropogenic emissions of carbon dioxide as well as 90% of additional warming due to the greenhouse effect have been absorbed by the oceans. This causes acidification and absorption of over 90 percent of the heat from global warming. If priority is given to seaweeds and shellfish in **coastal and offshore aquaculture, a number of advantages would be gained**, including carbon sink, biodiversity support, increase of resilience and multi-use potential notably with wind energy parks. Plants that are not consumed die off and drop into the deep sea, sequestering carbon for centuries in the form of dissolved carbon and carbonates. Macroalgae of kelp forests could sequester billions of tons of carbon dioxide while providing food, feed, fertilizer, fibre, and biofuels to the world.

Current, wave and tidal energy systems that harness natural oceanic flows are among the most powerful and constant dynamics on earth to generate electricity. A variety of companies, universities, and governments are working to **realize the promise of consistent and predictable ocean energy**, which currently accounts for a small fraction of global electricity generation. Operating in harsh and complex marine environments is a challenge—from designing systems to building installations to maintaining them over time. It is more expensive than producing electricity on solid ground, today. Despite decades of work, marine technologies are still in early development and lag well behind solar and wind. The potential for reduction of carbon dioxide emissions, however, is considerable. If the investments remain high, they may pave the way for scaling up activities and major GHG emission reductions.

Societal Impacts

Sea-level rise projections at 2100 are alarming although most of the decision-makers deny its speed and magnitude. It will impact the majority of the Member States and numerous countries in other continents; more than 0.6 Billion people are directly exposed to risks of flooding and submersion. Towns, infrastructures, and several economic activities will be affected; sooner or later, **a strategic withdrawal, when justified, will have to be planned** and explained to populations.

Because of huge impacts on society and policy in Europe, this trend is a major issue. Its consequences will be out of control if not anticipated. Migrations from Africa (Egypt for ex.) or South East Asia will be increased dramatically. It is admitted that anticipation and strategic planning help reducing cost and crises. In addition, several nature-based solutions can be explored.

Actions needed

Although the majority of EU coastal nations have sea-level rise (SLR) plans, there is very little work done on the ways and means to prepare the adaptation of European coastal zones to the SLR, including research. Flooding and submersion ignore borders and vulnerable countries have to anticipate these multi-impact trends. **This work has to be designed as a trans-national programme** to facilitate all the required components of a long term adapted strategy: interactive and consistent national observation systems, pooling of data and process methods, alert network, long-term withdrawal strategies, ranking of vulnerable populations, infrastructures, industries, natural resources and polluted zones.

Anticipation requires research to reduce risks and costs and to protect the economy and lives. Both state and local decision-makers need to be confronted with alarming and at the same time reliable sea-rise values and timeframes before taking adaptation measures, which can be radical and unpopular. Indeed, the major challenge is managing population, goods and services in vulnerable coastal regions. Some coastal areas, such as large deltas like the Nile, show much faster apparent increases due to continental subsidence, a phenomenon most often of anthropogenic origin. These highly vulnerable regions are, therefore, 'ahead of the curve' compared to stable low regions. Their study makes it possible to better anticipate what could be probable scenarios for other regions that will experience submersion later, such as the delta of Ebro, Rhône, Rhine or Po in four European countries.

Therefore, **any projection of the SLR through the middle of the century, or even less, has to integrate the consequences** on natural environments, economic activities, societies and governance in the broadest sense. This helps to outline the type of priority research that is necessary to best meet the challenges to come. The approach is necessarily reflective because political, economic and societal choices will themselves determine the trajectories of changes in sea-level.

While limited in area, coastal wetlands contain large carbon sinks; protecting them would secure an estimated 15 gigatons of carbon, equivalent to over 53 gigatons of carbon dioxide if released into the atmosphere. Of the 121 million acres of coastal wetlands globally, 18 million acres are protected today. As an example, if an additional 57 million acres were protected by 2050, the resulting avoided emissions and continued sequestration could total 3.2 gigatons of carbon dioxide.

EU-added value and implications of (non)action

Sea-level rise is not a weak signal but a mega-trend. Its speed and magnitude cannot be defined precisely because it is highly variable according to location and strongly linked with human activities and policies. All the watersheds are involved, even in Central Europe, as the management of river flows is depending on uses and policies upstream. The impacts of sea-level rise are not necessarily negative. As an example, brackish water aquaculture can replace rice culture in deltaic areas (Nile, Mekong...) which provides high-quality proteins and export opportunities.

These scenarios show that a change of adaptation strategies is needed, because of both the irreversibility of the current changes but also because of the limits of the technological solutions available to combat them. Interdisciplinary research needs to be conducted involving all actors, from civil society to better understand, quantify and project the phenomenon over time, assess its impacts, initiate coastal and urban transitions, specify and implement ways to reduce or offset the effects of flooding, limit inequalities in risk and to manage crises.

There is a clear and obvious need for cross-disciplinary, cross-sectoral and cross-actor research. The "Dutch model" of continuously increasing coastal and river defence is not sustainable after 2075 (Deltares, 2018). The European research community must be proactive and prepare relevant programmes. The demand from the Member states and other countries has to be anticipated, or governments will have to face stronger extreme meteorological events and damages, which will be out of the umbrella of insurance.

2 Clean water for the blue planet

Scope

Clean water cycle

Clear target(s)

By 2030 cut half industrial nutrients, plastics, pharmaceuticals and pesticides in European aquatic systems.

The ultimate goals: Aquatic systems free of fossil and industrial waste (incl. plastics), pharmaceuticals; pesticides; industrial nutrients; macro litter that end up in the sea by rivers and torrents; micro litter that end up in the sea through the wastewater treatment plants.

Present and future developments

Trends and drivers	Weak signals	Wild cards
Accumulation of plastics Degradation of drinking water quality Global ocean observing systems Growing importance of pollutants such as plastics and pharmaceuticals Increase of chemical pollutants Lack of awareness on healthy ocean and its impact on our activities Marine early warning systems Nitrogen Pollution Resilient agriculture Scattered data on water resources and use	Autonomous solar-powered robot swarms that clean oil spills Decentralized water collection systems for households and communities Inadequate water safety standards a health risk Microplastic fibres found around the world	Mercury pollution of oceans, rivers, and lakes due to runoff from thawing permafrost Multiple oil platform spills/failures Ocean piracy

Healthy water and oceans have always been important to mankind as all life depends on them. Nowadays, **chemical pollutants, industrial and agricultural nutrients, pharmaceuticals and marine litter can be found widespread in the water environment**, in all waterways and marine regions, posing one of the most significant threats both for the marine ecosystems and humans.

Currently, there is very scarce information regarding the lifespan of litter and other pollutants, like pharmaceuticals, pesticides industrial nutrients, in the freshwater and marine environment as well as their fate after their introduction, as well as their source. Recent publications produce evidence, for instance, that, when the thawing of permafrost is accelerated, mercury, trapped in the frozen ground, is being released. Indeed, the whole issue of pollution and litter is a serious, complex and multi-dimensional problem with significant implications for the marine and coastal environment and human activities and health all over the world.

Litter and other pollutants originate from many sources and have a wide spectrum of negative environmental, economic, safety, health, and cultural impacts. For instance, the growing accumulation of plastics and microplastics has alarmed most of the countries around the globe, as its consequences on human health have yet to be defined in detail.

A big part of marine pollution and litter comes from rivers and torrents especially after rainfalls that wash away debris from household goods, construction, packaging, as well as food and drink packaging. How much of this material enters the ocean is not known and will be dependent largely on the extent and effectiveness of wastewater and solid waste collection and management. Better management and knowledge are required, even if society is already responding and reacting.

Microplastics, in particular, come into the sea from land-based sources; cosmetics and personal care products, textiles and clothing (synthetic fibres), terrestrial transport (particle matter from tyres) and plastic producers and fabricators (plastic resin pellets used in plastics manufacture). These are only some of the already known products that can deliver microplastics to the water and through the waterways of rivers and torrents are entered in the marine environment. Currently, and depending on the sophistication of the equipment and procedures adopted in different regions, a significant proportion of microplastics passes through wastewater treatment plants and ends up in the marine waters. Sea-based sources, although they appear to be dominated by the fisheries industry (e.g. gear, packaging material, strapping bands); and shipping (garbage, hull scrapings, containers, spoilt cargo, greywater, ropes and cargo nets) also include aquaculture discards (e.g. cages, buoys, netting, packaging materials structures); dumping waste from shipping and other matter at sea, derelict fibre-glass vessels etc. Commercial fishing and aquaculture, two of the Blue Growth sectors, seem to be the major contributors, for marine plastic from sea sources, mainly through discarded fishing gear, including monofilament lines, nylon netting and Styrofoam buoys.

The connection with humankind's activities, the need to change the current way of thinking and associated behaviours are needed in all parts of the world for land, rivers and coasts. There are many initiatives all over the world, but none of these is devoted to coordinating the actions, engaging science, industry, policy and society, all together and the same time.

Citizens, coming from land-locked countries with rivers, lakes, but without coasts and marine waters, and irrespectively of the regions and place, face similar problems of pollution. So, in fact, the problem of litter, arriving into the sea is not only a problem of the good environmental status of marine environment but also a problem of providing the required ecosystem services in all waterways and coastal and marine waters and avoid potentially harmful effects on human health. As the societal momentum is gradually addressing litter and other pollutants at sea, it is fundamental at the European or even at the global scale to support and engage all actors from across the entire societal spectrum.

The issue of litter pollution is immense in terms of the policy, more so because we are still not aware of its effects in the marine environment addressed also by the G20 in its Action Plan to Combat Marine Litter in its 2017 meeting in Hamburg. The UN Sustainable Development Goals, and especially SDG14, describe marine pollution which comes from land-based sources, reaching alarming levels, in case of plastics with an average of 13,000 pieces of plastic litter that can be found in every km^2 of ocean. Pollution and plastic are also prominent as an entire action in the EU "International Ocean Governance: an agenda for the future of our ocean (Action 9)" and both are mentioned explicitly in the Regional Research and Innovation Agendas, such as that of the Mediterranean, the Baltic Sea, the North Sea and the Black Sea.

Societal Impacts

In the First UN World Ocean Assessment, one of the significant barriers in addressing marine litter is the absence of adequate science-based monitoring and assessment programmes. The hotspots of marine litter on global, regional and local scale should be determined and communicated to a broader range of stakeholders to promote understanding and effective mitigation. **Science and technology could turn the problem for opportunity for a positive impact in society in Europe and beyond.**

Using science and technology as a driver and involving policy and industry in a unique target-oriented approach that everybody understands, could create a new culture in Europe and worldwide. **The change of thinking and behaviour is probably the biggest gain within this task.** Directives and legal issues for marine and freshwater environment pollution (including plastic-MFDS) are in place, however the way to tackle the issue at the source, as well as public education and industry engagement for investment, to drive society beyond these legal country requirements that, unfortunately, do not yet exist.

Science can play the leading role and work with both policymakers and industry to achieve what European citizens want: "water to drink, to use without fear and to swim in". An exemplary policy for clean water from the snow to the sea in Europe could become a model for the rest of the world. Public participation in issues especially related to marine litter management is quite widespread in Europe, but what is missing is the stimulus to involve society in transforming collective clean-up campaigns.

Poor water availability detracts human resources from development and increases the national public health budget. Equal access to water resources distribution is a key aspect that must be guaranteed for all.

Actions needed

All disciplines of science and all parts of society can, and should, be engaged. The idea is to use the multidisciplinary science to connect many scientific disciplines like **toxicology, biodiversity, water and benthic research** in rivers, lakes and marine coastal and open sea waters oceanographic modelling, and river flow addressing the creation of new monitoring systems and remote sensing capabilities. R&I&D actions must define and identify approaches and tools to trade-off ecological dynamics and socio-economic needs, taking into account marine ecosystems goods and services and their environmental, economic and social value, to inform and improve adaptive planning and management scenarios.

Promotion of innovative technologies and services for efficient collection, management and reuse of plastics as well as protection of coastal areas and seas from the impacts of man-made pollution have to be developed further. Starting from the resilient agricultural pollution and minimisation of nitrogen pollution, to recycling of materials and behaviour and cultural change, **actions could be planned based on existing governance structures**, albeit in a more coordinated way to achieve results and engagement.

Technology is well placed, including multiple innovative approaches that must be both effective and operational (like for example floating booms, Plastic Sea Sweeper trash wheel, ocean cleaner and others). Technology can help address in many ways the litter and pollution problems. For instance, green nanotechnology-based coatings that encourage microplastic polymer degradation in water under natural or artificial sunlight is still in a prototype form but could prove useful. Finally, monitoring technologies (for example, scanning technologies, Ferrybox, use of drones, cameras, image analysis, etc.) could also be improved in the future and probably give rise to start-ups and engage entrepreneurs.

Policy, on the other hand, must be largely involved through the local, regional and national governments with decisions to be taken, for the first time, in a highly coordinated way, bringing together both the science community and the industry. This will enable the social, economic and regulatory aspects to work together towards the implementation of the targets. In terms of funding and investment, this action should **raise private and public/national funds**, which can be added to the scope, at all levels and directions (e.g. rivers, lakes and sea- coastal waters and open sea; regional, government and private funding), enhancing the Public-Private Partnership (PPP) and leverage the funding from EU sources.

This focal area is also open to all educational levels, life-long learning organisations and centres, NGOs, International organisations, Universities, Research Institutes, national governments and to making the citizens aware of the problem. Citizens should be invited to contribute to accomplishing this and be engaged throughout the process, while the results should be given back to society. There are several initiatives, work programmes and projects that, if coordinated properly, could turn the wheel much faster. School children from primary schools to senior citizens in all countries, land-locked or coastal states, from coastal areas and riverbanks, to rivers mouths and to open sea, can be equally engaged to contribute. Most professional skills from scientists to policymakers, from inhabitants to tourists and from professionals to workers can be engaged.

EU-added value and implications of (non)action

Science and technology can lead this effort from the start and involve all major players and stakeholders in all aspects of freshwater and marine environments in the European countries. Engaging citizens and proposing solutions could be part of the guided mission. The EU-added value could be great, given that despite the efforts made internationally, regionally, and nationally, there are indications that the problem of marine litter is actually becoming even more severe. On the contrary, non-action will create more problems in the freshwater/drinking/marine water systems and the degradation of rivers, lakes, and coastal and marine waters will be evident in some years.

The engagement of EU as a leading partner in the process will help in coordinating all actions in Europe on water and plastic/microplastic pollution, in a way that has not been accomplished before, at any scale. It will not only create knowledge but also link this knowledge with the industry, research, education and policy communities, with having clusters of active knowledgeable citizens who will be, in a way, also responsible about the health of the marine and freshwater environment. As "every second breath comes from the sea", a healthy European marine ecosystem could give Europe the ability to show the world that, indeed, Europe and European citizens have made it a priority to achieve the best for the European Seas.

Creating a water resilient society requires a complex and interconnected system of management of water resources able to act on several levels: reuse – reduce – preserve quality; contribute to guarantee equal access and distribution; spread culture and knowledge to support informed decisions. Such management of the water resources would require a more ecologically sound governance model, including the deep sea and the seabed areas.

The marine and coastal waters are commons that need to be cared for. **This should not be seen only as a problem but also as an opportunity to increase the ecosystem service resources, which could, in turn, enhance the European citizens' well-being.** New business models can be developed to upscale the knowledge and strengthen the blue growth momentum, as a product, promising innovative technologies in the service of society, considering the existing legal and policy frameworks.

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3 Vital aquatic ecosystems

Scope

Biodiversity and sustainable ecosystem productivity

Clear target(s)

Harmonize aquatic ecology and economy in decision making processes (2030)

Start to adopt holistic approaches at all decision levels, passing from tactics to strategy (2020)

Introduce biodiversity and ecosystems in all school curricula, including universities (2021)

Complete the census of marine life in European Waters and set up a pan European observatory for biodiversity (2030).

Use the state of water ecosystems and biodiversity as a sensor of the efficacy of economic sustainability (2030).

Present and future developments

Trends and drivers	Weak signals	Wild cards
Altered biodiversity and species distribution Coastal erosion and changes in Arctic Ocean biogeochemistry due to thawing permafrost. Declining biodiversity Declining fish stocks Global ocean observing system Growing blue economy Growing importance of pollutants such as plastics and pharmaceuticals Holistic/integrated marine governance Lack of awareness on healthy ocean and its impact on our activities Rapid melting of the Greenland ice sheet and mountain glaciers. Seawater temperature rising The impairment of the cold engines of oceans and seas	Co-management for sustainable common-pool resources Drought in National Security Ecological ocean farming Farmed oysters able to protect themselves from acidification Floating wind energy digital twin Integrated risk assessment processes in the emerging blue economy Lack of infrastructure for developing the blue bioeconomy Legal barriers for the blue bioeconomy	Atmospheric river mega-storm Major diplomatic crisis on debated areas Massive earthquakes on northern sections of the Cascadia Subduction Zone Melting of the Antarctic ice sheet Multiple oil platform spills/failures Ocean piracy Political shift towards more regionalised economies

Despite the widely recognized primacy of biodiversity and ecosystem functioning as a pre-condition to our well-being, action to describe the structure (biodiversity) and function (ecosystem functioning) of vital systems is not considered a priority *de facto*. Our impacts on the natural capital cannot be properly assessed since we do not have a sufficient understanding of either biodiversity or of ecosystem functioning, i.e. the core of the natural capital. The exploration of biodiversity in terms of species description is not considered a priority, and marine systems are often approached by considering surfaces (the surface of the ocean, or the surface of the ocean floor) and not volumes.

Even if this focal area is centred on aquatic systems, many problems affecting these systems come from land, since we are terrestrial animals: our waste, from plastic to chemicals, is produced and used mostly on land but they eventually end up in aquatic systems.

The complexity of aquatic systems is addressed in bits and pieces, leading to a lack of understanding and inefficient management. In spite of a widely invoked ecosystem approach, single problems are tackled in isolation from each other (from plastic to overfishing), with a tendency to still adopt reductionistic approaches, when a holistic view is badly needed. Agricultural fertilizers are recognized as being conducive to eutrophication, but the impact of agricultural pesticides on aquatic systems is neglected. If the ultimate causes are not removed, the problems will persist. Global warming, for instance, is the ultimate cause of multiple stressors that have proximate effects. **The melting of glaciers**

and polar ice sheets causes sea-level rise, but also the impairment of the 'cold engines' that trigger the great ocean conveyor that regulates the circulation of air and water in the atmosphere and of water in the oceanic systems. The Great Ocean Conveyor is triggered by sea ice formation at the poles. Marine ice is made of freshwater and the salinity of the water on which it floats becomes very high. High salinity and low temperature increase the density of the water below the ice, which makes the heavy water sink. The cold engines, then, determine the global ocean circulation. If the ice melts, freshwater is liberated that floats over the high salinity water below. Artic water deriving from ice melting can stop the Gulf Current, with severe impacts on European climate. **Overall, the alteration of the ocean conveyor has even greater effects on our well-being than sea-level rise**, since it will lead to increased drought and floods, severe storms, alteration of ecosystem functioning and a huge cascade of the effect that will pose severe threats to our way of life, from social to economic security.

In more general, as a consequence of anthropogenic CO2 emissions oceans are becoming warmer (global warming) and more acidic (ocean acidification), and the sea-level rises, with severe threats to human settlements, with Venice as a paradigmatic example.

Cumulative impacts cannot be treated by focusing on single stressors. A timely shift from compartmentalized science to a global approach to ecosystem understanding is urgent, and this must be linked with economic decisions. The available knowledge can be assembled to first define natural units of management and conservation to overcome unnatural political borders, even within the European Union, whose directives and recommendations require harmonization.

Societal Impacts

Our planet is alive thanks to the presence of the water and our society cannot be healthy and wealthy if water in all its forms (solid, liquid, vapour) is not considered as a primary source of well-being. Complex aquatic ecosystems providing goods and services to human societies calls for a holistic strategy that builds on our dependence on the nature.

There cannot be a healthy society in an unhealthy environment. To survive and increase economic capital we have to protect natural capital. We have limited economic and social data on impacts of ecosystem change on society, for instance impacts of natural disasters on fisheries, aquaculture and tourism. Only few non-market valuation studies have explored marine ecosystems in providing human health benefits. To determine the socio-economic impacts and trade-offs, much greater collaboration among economists, natural and social scientists is required.

The ecological transition towards a sustainable way of life is a great economic and social opportunity, that is conducive to lead to technological innovation in the production of energy of all types, from power to food, of new recyclable materials that will not invade our ecosystems as plastic is currently doing, not to speak about nuclear waste, pesticides and all types of pollutants. The current crises (climatic, economic, migration, etc.) calls for an urgent change in our lifestyle.

Actions needed

To develop interdisciplinary expertise across the natural, physical, social, economic and health sciences is critical for global capacity building, sustainably managing marine resources, addressing key uncertainties relating to the climate and the marine environment, and developing the technologies needed for the future global economy.

Introducing courses on the natural capital from primary school to universities can trigger shared awareness to change. This should not be limited to focused courses on natural history. An interdisciplinary and transdisciplinary program should lead to a shift from reductionistic to a holistic vision of complex systems. It would mobilize representatives of all disciplines.

In the field of science, we need to **assess the state of the natural capital in terms of both biodiversity and ecosystem functioning**, setting up an observation system that covers not only physics, geology and biogeochemistry but also the living component in its intricacies. This will require a huge effort in technological innovation, with the development of new sensors for biodiversity, mainly while coupling genomics and traditional taxonomy. Europe has a significant network of marine stations that might be the nodes of the observation system and the agents of innovation. Besides exploring biodiversity, we need to understand the role of species in making ecosystems function, from viruses and bacteria to whales, from the coast to the deep sea, in conjunction with freshwater systems as a link between the atmosphere, land systems and the ocean.

The interfaces between science, policy, and industry, should be strengthened. The realization of this strategy requires professionals. In the field of jurisdiction, we need to harmonize conventions, directives, and national laws to reach a coherent regulation based on the ecosystem approach. Non-professional stakeholders can be involved in initiatives such as **citizen science** and interviews to test the efficacy of initiatives aimed at increasing the awareness of the importance of natural systems for our well-being.

Our impact on natural systems is leading to **'tipping points'**. The shift from a fish to a jellyfish ocean is an example of a tipping point. Marine Protected Areas can help assess whether the removal of a human impact (e.g. overfishing) can lead the system to recover from projected damage.

Meteorological models are powerful in so far as they are fed with a huge amount of real-time data that leads to a continuous refinement of the models. The same accuracy is needed to develop ecological, economic and social models since the three domains are deeply intertwined. These models will lead to wiser policies based on better control of complex situations, based on continuously improving science. ICT infrastructures should store information on traditional and biodiversity-ecosystem focused observing systems to develop models for predicting the outcome of management options of dynamic ecological systems.

The awareness that this change in paradigm is needed can be summarized with a sentence from Navigating the Future IV of the European Marine Board: "To truly progress this knowledge, European scientists across a broad range of disciplines and domains must make a quantum leap towards holistic approaches and integrated research on a scale which will help us to much better understand, protect, manage and sustainably exploit the seas and oceans which surround us". This is a Grand Challenge; not just for Europe, but for human society as a whole.

EU-added value and implications of (non)action

Europe has the most advanced sustainability legislation at the global level, but it is not sufficiently enforced due to lack of consistent governance. This is an occasion to become prominent worldwide and show the way to other countries. Europe is complex enough to test efforts towards harmonized enforcement of its rules: The Marine Strategy Framework Directive, for instance, prescribes that Good Environmental Status is reached in all EU waters by 2020, but every state can decide how to do it, with lack of consistency. Furthermore, the Mediterranean Sea is mostly European in its Northern Sector, but the Southern and Eastern portions are under the influence of African and Asian countries. The shared space must be managed in a shared fashion, with international agreements such as the Barcelona Convention. The Mediterranean Sea represents a unique opportunity since its ecosystems are regulated by three cold engines that recall the cold engines that determine the great ocean conveyor. The North Adriatic cold engine has already stopped once, luckily replaced by the cold engine of the Northern Aegean, leading to significant changes in ecosystem structure and function. The Mediterranean, furthermore, is subjected to an unprecedented "biological invasion" of tropical species and mass mortalities of indigenous species, both determined by global warming.

Non-action, i.e. the continuation of business as usual models, would lead to further increases of extreme events due to global warming, habitat destruction, overexploitation and degradation of natural resources. This would lead to conflicts over the possession of limited resources or to severe environmental conditions (from desertification to floods and inundations) that will push people to abandon their countries and move towards better conditions: first of all, to Europe. The damages of increasingly frequent extreme events will cause enormous economic costs due to the destruction of production systems, infrastructures, urban settlements. The impairment of the cold engines is already changing the climate of the planet, with heath waves and rigid winters that require costs that will lead countries into social and financial crises.

The situation cannot be coped with through the enforcement of limited projects that alleviate the symptoms of some stressors. The gravity of the situation require that we reorganize our production and consumption systems, i.e. our culture and our priorities.

Aquatic systems, and especially oceanic spaces, are commons, as are their resources, and suffer for the tragedy of the commons. What we do on land, furthermore, reaches the sea through riverine systems and then spreads with currents.

4 Digital twin of oceans and waters

Scope

Observation and early warning

Clear target(s)

By 2030 create an open digital twin of European aquatic systems.

Open digital twin of oceans, seas, coastal areas and inland waters for observation and early warning by 2030 in Europe and by 2040 globally.

100 000 citizen scientists engaged by 2030.

Present and future developments

Trends and drivers	Weak signals	Wild cards
Advances in virtual water sensors Cyber Security E-learning Lack of awareness on healthy ocean and its impact on our activities Marine early warning systems Remote sensors and IoT-enabled monitoring systems Increasing deep sea exploration Satellite earth observation providing new insights on water systems Scattered data on water resources and use Shifting towards agile multi-stakeholder governance models Virtual Reality	Blockchain in water management Floating wind energy digital twin Researchers use drones to weigh whales Stimulating trade-offs in the water-energy-food nexus	Major diplomatic crisis on debated areas Ocean piracy Political shift towards more regionalised economies

Most of humanity is unaware of the many benefits they derive from the aquatic systems or how their actions affect, for instance, ocean health and how this, in turn, affects their well-being and survival. This is partly because, where data on aquatic systems, water resources and their use do exist, they are often scattered across multiple government departments and stakeholders and are, hence, not readily compatible (or interoperable) with other data sources creating **fragmented information and limited societal awareness on aquatic ecosystems and impacts of human activities on them**.

Many countries today benefit from sophisticated, cutting-edge scientific infrastructure, technology, and human capacity for science and innovation. However, major disparities exist in the capacity around the world to undertake the aquatic scientific research or the collection of ocean data required for proper management of human activities that can affect the marine environment, for instance, plastic pollution.

Comprehensive observation of aquatic systems from the surface to the seabed would require not only the automated collection of physical data but also the extensive engagement of the scientific community and other stakeholders to provide systematic information on biological ecosystems and socio-economic activities to allow the analysis of their diverse forms of interaction. As our aptitude to scrutinize the aquatic systems will enhance understanding of ecosystem functions, so will our ability to anticipate significant events, including super-storms, heat waves, tsunamis, harmful algal blooms, jellyfish blooms, invasions of non-indigenous species and their impacts on indigenous species and ecosystems as well as on human activities and settlements. **Scientific monitoring and early warning systems are the key for anticipating ecological and societal crisis and emergencies.**

If observation systems are advanced for physics, chemistry and geology, they are almost non-existent for biodiversity and ecosystem functioning. The growing trend for exploration of resources in the deep sea may also create new disputes and need for better data and understanding for suitable design of societal responses including political and legal instruments. Furthermore, the growing value of marine territory (linked to the growing demand for marine resources and new technology to extract them) create the risks of growing global tensions over disputed areas, e.g. in the South China Sea or in the Arctic.

Digitalization techniques open major opportunities through the deployment of sensor networks that will boost a ‘Big Data’ revolution in the ocean and other water system science like that observed in atmospheric science. Still, no sensors are available to assess biodiversity, a key element of ecosystems. Among other advances, **a digital twin is a digital replica of a living or non-living physical or biological entity.** By combining the physical and the virtual world, data are provided enabling the virtual entity to exist ‘at the same time’ with the physical entity. Specifically, it replicates physical assets that can be used for various purposes. This digital representation provides the elements and the dynamics of how, for instance an Internet of Things (IoT) device operates and lives throughout its life cycle, for instance the development, validation and operation of the digital twin software for floating offshore wind applications already exist and many other areas of application are considered, including the observation of aquatic systems.

The coverage of diverse observation and digitalization initiatives need to be mapped and integrated. The gaps need to be identified, too, in particular, the observation network and the basic knowledge on biodiversity are largely missing, today. Applying the digital twin in the aquatic observation systems can readily build on physical data on meteorology and ocean observation and gradually integrate also biological data on living organisms. While some biological data collection can be automated and thus also potentially used in real-time, other data are collected ‘manually’, for instance by relying on citizen science for systematic nature observation.

While remaining open for a wide set of stakeholders to share data, such digital twin platforms need to transmit trust in dealing with the data security. The first step in preventing cyber-attacks is identifying threats and vulnerabilities, assessing the risk exposure attached to these matters and developing both protectionary measures and contingency plans to neutralise these risks as much as possible.

Such platforms can take advantage of a range of new technologies to measure and monitor aquatic systems including, but not limited to, the use of remote sensing, micro- and nano-satellites, acoustic and electromagnetic sensors, environmental “e-DNA” techniques, autonomous platforms and shared infrastructure with advances in Internet of Things (IoT). Innovative methods are used to learn more about the physiology and ecology of aquatic life. For instance, aerial images taken by drones are used to accurately estimate the weight of free-living whales. Autonomous vehicles, in turn, allow for more regular data collection and greater access to the deep sea and other inhospitable marine environments. This has implications for our understanding and modelling of the marine environment, and the economy.

Machine learning and artificial intelligence (AI) are increasingly used to process and analyse the collected data, which can provide context to historical data, making it easier **to predict ecosystem or infrastructure risks** and inform mitigation, adaptation and replacement plans in real-time and also to optimize operating costs and services. Virtual sensors employ artificial intelligence (AI) software that uses deductive reasoning to process information from various machines to determine what a physical sensor output would be. The results are transcribed in a real-time configuration that is understandable and accessible for water managers and stakeholders alike. The training and in more general awareness raising on the aquatic ecosystem may also benefit from the advances in virtual and augmented reality (VR and AR) technologies.

Societal Impacts

From rural communities to multinational corporations to city planners and national governments, decision-makers struggle with the confines of isolated and fragmented information not only in Europe and globally. The observation system can help adapt to and mitigate diverse crises with major economic benefits. Improved understanding provides gradually improved capacity for better management of ecosystems. Extreme event scenarios (droughts, floods, intense precipitation, erosion) must be taken into account and must inform predictions on water needs as well as management strategies and policies at local and global levels, also for resolution of conflicts on water.

For instance, Europe needs to be better prepared for how climate change may drastically affect the Gulf stream and subsequently Northern Europe. Another example is how groundwater is being over-extracted or recharged; the systems can observe the development, and potentially use artificial algorithms to fill in data gaps, thereby enabling water managers to understand the status of aquifers better. This degree of hydrological insight can provide an unprecedented understanding of groundwater usage, helping to address issues of neglect, over-extraction and assumptions about capacity. The developed systems can act as a hub to address acute risks (including emergencies) and disasters (e.g. related to pollution risks of dumped munitions, shipwrecks etc.) inside and outside the EU also by putting in place temporary panels of experts to assess the issues and propose solutions.

The digital twin of aquatic systems can also stimulate new processes and dialogues to help build the capacity of decision-makers to understand and use the knowledge and to push for institutional change to allow for more evidence-based policymaking. Partnerships can be developed through early engagement in those regions where gaps exist, ensuring that scientific capacity needs are identified. Increasing scientific and technical capacity of all Member States is needed to ensure their participation and ability to benefit from the developments.

Actions needed

Developing an **integrated and sustained observing system** even beyond Europe is needed together with the synthesis of observation products to respond to scientific and societal demands. Further harmonization of European legislation and directives towards integral management of aquatic systems is one of the first steps needed. The more coordinated identification and routine measurement of essential variables related to the function and health of aquatic ecosystems would also help reach international consensus on common classification systems for aquatic system attributes. This offers also unique opportunities for technological innovation. The industry, in collaboration with the scientific community, will be a key player to develop existing and new **services for better-informed, aware and crisis-ready society**. Europe can develop accurate and useful valuations of the aquatic environment through the goods and services it provides (including food, capturing carbon, mitigating flooding, and supporting human health) so that environmental externalities can be made clear and their value incorporated into decision making.

Systems for sustained ocean observations are an essential part of worldwide efforts to better understand the ocean and its functioning. **These observing systems comprise fixed platforms, autonomous and drifting systems, submersible platforms, ships at sea, marine stations, and remote observing systems** such as satellites and aircraft, using increasingly efficient technologies and instruments to gather, store, transfer and process large volumes of ocean observation data. The data derived from such instruments are **crucial for many different scientific communities and a wide range of public and commercial users active in the ocean economy**.

Ocean economy satellite accounts could offer a way forward. Building upon existing data collection efforts, satellite accounts offer a robust framework for monitoring aspects of a country's economy not shown in detail in the core national accounts while allowing for greater flexibility for those industries not covered by industrial classifications. Satellite accounts for the ocean economy would provide a highly organised method for collecting consistent ocean surface data. Should a critical mass of countries develop such accounts then international comparability would be enhanced?

The collected data can be turned to active use by **developing an open digital twin of European aquatic systems** including oceans, seas, coastal areas and inland waters for observation and early warning. Such a system would require e-infrastructures for computing, modelling, forecasting and early warning systems, based on a constant input of data from observation systems. Also, citizens need to be engaged as **citizen scientists to make standardised observations** of water ecosystems and to empower the use of data widely in society to create awareness for action. Citizen science can play a crucial role in areas that are not covered by current instruments (e.g. jellyfish blooms, mass mortalities, plastic accumulation, harmful blooms).

Such highly ambitious targets may require innovation networks that strive to bring together a diversity of players (e.g. public research institutes, large enterprises, small and medium-sized enterprises, universities, NGOs and public agencies) into flexibly organised partnerships. They work on a range of scientific and technological innovations, in many **different sectors of the economy** (e.g. marine robotics and autonomous vehicles, aquaculture, marine renewable energy, biotechnologies, offshore oil and gas). Such networks are springing up in many parts of the world in response to changes in the national and international ocean research environment and leveraging their organisational and skill diversity to benefit their partners and research in the economy more generally.

Mainstreaming new technologies and approaches around digital twin of aquatic systems cannot be left to accelerators and investors alone. **Governments, as the ultimate custodians of water resources, must remain at the centre of the innovation agenda**. Allowing government officials to make the most of the digital twin will require new solutions that can help them better navigate the complexities of resource-management decisions. How, for example, might technological advancements help local officials better understand and synthesize disparate sources of water-related information in real-time? Could the creation of new platforms lower these transaction costs for governments and facilitate more confident and agile decision-making across ministries?

EU-added value and implications of (non)action

Beyond clearly having potential benefits for European decision-makers, the digital twin also raises important questions about the future of water governance. As governments are ultimately responsible for ensuring that measures such as new technologies are developed and scaled responsibly, they will need to develop new policy frameworks and protocols for how new solutions are tested and refined to avoid new problems. Such analyses require data, but without strong and comprehensive observations systems the interactions between the systems and new solutions cannot be understood. This relates also to the broader need **to treat aquatic systems as commons and search for effective governance** models building on shared and trusted data.

This focal area helps increase the understanding of water ecosystems, their biodiversity and productivity as well as create an ability to anticipate significant events and their impacts on aquatic systems and society. In this area, Europe can actively promote the equitable sharing of science and knowledge, work to fill gaps in the global distribution of scientific capacity and accelerate the transfer of marine and other water systems technologies. Europe can do so by **facilitating new partnerships** to improve access to data, equipment and expertise, thereby providing pathways for new knowledge production needed to fill current gaps. Without this new knowledge and capacity, communities in Europe and beyond will not be able to harness new science-based services to enhance resource management, food security, hazard mitigation, and resilience.

5 Human at sea

Scope

Human settlements and operations at sea

Clear target(s)

By 2030 establish a smart and sustainable autonomous village at sea.

By 2025 start with different prototypes and experiment with combinations of units.

By 2035 establish a permanently inhabited deep-sea base.

Present and future developments

Trends and drivers	Weak signals	Wild cards
A growing proportion of humankind living close to the sea Changes of temperature and precipitation (climate change) and weather extremes Growing blue economy leading to busier seas Growing use of offshore renewable energy Holistic / integrated marine governance Increasing use of automation in the marine environment for various activities Shifting towards multi-stakeholder governance models	Autonomous Ships Conflicts over offshore drilling and use of resources Ecological ocean farming - focusing on seaweed and shellfish New catalyst efficiently produces hydrogen from seawater New kelp forests of marine permaculture to enhance ecosystem and capture carbon New maritime platform to optimize supply chain (data sharing) **Smart and ecologically ambitious floating cities** Solid-state wave energy Stimulating trade-offs in the water-energy-food nexus Water innovation ecosystems to promote technological solutions Water saving at home	Major diplomatic crisis on debated areas Political shift towards more regionalised economies Reassignment of rights to genetic resources

While land use increases across Europe, there lies an enormous opportunity in **living at sea**, and possibly, under the sea. Such a “new frontier” could create momentum to learn from the sea and to truly seek better ways of sustainable living in and among the waters. It is a test of combined European ingenuity. The knowledge required for this may also be learnt from carefully observing existing communities living extremely close to the sea across the globe.

Whereas a self-supporting village in European seas may first and foremost be focused on the scientific and/or operational objectives linked to the other focal areas, such a village would need to be designed that it provides basic survival needs (food, water, energy) **with minimal exchange with onshore activities** (self-sustaining) whilst not harming its environment. Another requirement would be that such a community would be scalable (replicable) in due time.

As the oceans cover 2/3 of our planet and sea-levels are still expected to rise, this focal area is to investigate the feasibility of establishing communities at sea. Doing so could also relieve the pressure of land-based activities. The idea is that these communities are not only floating cities or marinas but also represent **a new way to live and work** at the interface of our water-dominated world.

There is a range of trends that point towards more intensive but also a more efficient use of available resources at sea; most of these (technical) developments are singular advances that have not been tried in integrated systems. Automation is increasing but would need to deal with multi-space use at sea. **Developments in aquaculture, permaculture, ocean farming, aquaponics, water innovation and desalination, energy generation (offshore renewables), would have to be adjusted to work in**

unison and would have to be tested in harsher environments than previously tried. Circularity would have to be further developed to avoid loss of precious resources.

Governance is certain to play a role in such future living areas. Whereas Europe has a significant amount of coast and national waters, an extrapolation of the possibilities of villages or cities at sea would need to address ownership or appropriation issues. **Under current legal conditions, the creation of aquatic villages beyond national jurisdiction would take place in a lowly governed zone**. To think about expansion and multiplication of aquatic villages would also need to address "good governance" and how the holistic governance by aquatic villages of the surrounding areas can be assessed and enforced. Such developments could be hampered by diplomatic crises concerning rights to debated areas or resources.

Such an undertaking is of a scale that cannot be borne by single countries or even regions – there is an added value in a European approach through the pooling of resources and expertise. Conversely, a more regionalised approach would hamper this ambition.

Societal Impacts

As overpopulation, intensive land use, coastal degradation, pollution, threaten land-based communities, it is an option to turn towards the sea. Europe has different seas and oceans (and overseas territories) that could allow for such sea-based strategies.

Such an ambitious project would guide towards **new options for dealing with the inevitable consequences of sea-level rise**. Due to its relatively secluded nature, a sea-borne community would need to be extremely innovative in its daily (survival) activities, providing possible innovations that will be relevant for land or coastal communities. As such, the societal impacts depend also heavily on the replicability of the goal – one community may just be a proof of concept, but if multiplication is achieved, new societal forms – sea communes – may emerge that will be different societies. Once that happens, sea communities may also become attractive places for leisure and learning activities.

It is clear that although seafaring nations with strong maritime/civil engineering traditions would be closely linked to preparatory activities in the sea communities, participation and contribution is not limited to nations with a coastline. **Cooperative contributions** similar to the building of the International Space Station can be envisaged as several technical components can be developed and contributed **by a range of engineering fields** (wind, solar, desalination, energy storage, food storage, material re-use) and **experience with and knowledge of living under extreme circumstances** (cold, heat, drought) would all be required contributions.

Actions needed

Ensuring that such communities would be feasible would require large efforts in systems planning and feasibility studies as well as possibilities for testing and demonstration. The environmental (physical) constraints would **require large research advances** in aquatic production, materials development, civil engineering, circular design, and sustainable living.

To come to a grand design, many design options remain open. The concept of living labs seems very appropriate in this context: small(er) trials with semi-permanent structures that stay afloat for longer periods would be the first step. Such structures would need to be designed in a standardised way so that recombination and multiplication are possible. An **evolutionary approach with adaptation, selection and retention of good practices** is advisable.

Moving from design principles to actual demonstrations would require intensive cooperation of research and industry to combine and adapt existing solutions. The generation of solutions could be stimulated by organising a design competition that is partially funded by grants and leads to ever more specific blueprints through different stages. Involvement of industry would not only be a matter of prestige but also of innovation and creating **new business in a more aquatic world**.

EU-added value and implications of (non)action

The European Union is experiencing further ecological and population pressures on land. Especially coastal areas are already densely populated and different sectors are competing for space. The proposed mission to create a community at sea is a bold commitment that would not be undertaken (at the required speed) without the commitment of the European Commission. The clout of Horizon Europe would truly enable the required pan-European efforts in organising skills, knowledge and know-how.

This focal area can be compared to the archetypical "putting a man on the moon" - although this can be achieved for more Europeans at a lower cost. It could also be compared to missions for developing a "Biosphere 2" in Arizona, to study the possibility of permanent residence on the Moon and/or planets. It is a bold undertaking that **could not be achieved without public intervention**, but at the same time offers opportunities to businesses to showcase technologies and ingenuity, and thus incentivise larger and smaller enterprises to contribute (in-kind) to realising this vision. Europe can become a **frontrunner in sustainably exploiting the seas**, which not only promotes European values of good stewardship but also offers a platform for research and industry in Europe to work together.

This should be seen as a challenge to test human ingenuity and the will to go beyond what has been tried before. It is an enormous opportunity to try out the design capabilities of many different (engineering) research institutions and businesses. It requires a systems-of-systems approach in which many different disciplines are required to work together and adjust single solutions to work more effectively in a grand design.

Working together in European academia and industry networks can provide **new options for humanity to deal with a changing world** – climate and sea-level rise – and thus open up a whole range of fields of research and business in which Europe can excel.

ANNEX 3: REAL-TIME DELPHI SURVEY TOPICS

1 Oceans and water ecosystems

1.1 By 2030, the EU reduce the chemical pesticide runoffs to water ecosystems by 80%.

Background

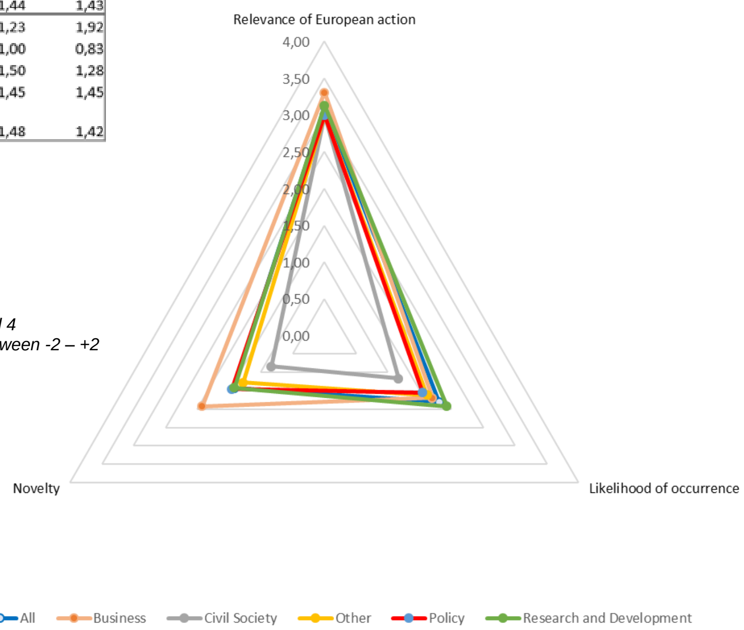
Chemical pesticides are widely used in all agricultural practices throughout the world and reach the seas and oceans via terrestrial runoffs. They are used to free crops from either competitors (other plants), or predators and parasites (animals). A lot of studies have been carried out on the impact of fertilizers as a cause of eutrophication, whereas little research has been done on pesticides and their impact on water ecosystems. Reducing runoffs can be achieved by banning and/or replacing some chemical pesticides with biological alternatives and establishing wider areas for natural protection between the cultivated lands and water courses.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (148)	3,11	1,80	0,58	1,44	1,43
Business (13)	3,31	1,69	0,31	1,23	1,92
Civil Society (6)	3,00	1,17	0,00	1,00	0,83
Other (18)	3,00	1,61	0,72	1,50	1,28
Policy (11)	3,00	1,55	0,18	1,45	1,45
Research and (100) Development	3,13	1,92	0,67	1,48	1,42

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The reduction of pesticides runoffs to water ecosystems is rated as very important in relevance for EU actions by the majority of participants. Whereas the topic appears to be quite new for stakeholders in the business sector, the civil society is already more aware. Regarding the likelihood of occurrence, the participants seem, except for the Civil Society group, to agree on a probable occurrence.

Comments of RTD Participants

1 ***Water quality policies** have existed in all European countries **since the 1970s.** Some reclaiming of territorial waters is to the credit of the Basin Agencies. However, in 50 years, it can be seen that **efforts have been largely insufficient** to treat the causes, despite the industrial decline of many countries. I think that **agricultural practices** will take **small and insufficient steps** towards the reduction of amendments and the use of pesticides. The **number of molecules of agricultural and industrial** origin present in water **is considerable** and it seems to me that, until now, **Europe has mainly worked to classify these molecules and not to reduce or ban them.***

2 *I feel this is a relevant topic from **the environment point of view**. However, it can only be implemented with a **ban on chemical and synthetic pesticides** and a proper **promotion and development of biodegradable** and **non-harmful bio-based** alternatives.*

3 *It's urgent to change the agricultural practices in order to **limit the impact of the environment.** Unfortunately, because **of lobbying and misinformation**, the **chances** that it happens are **quite low**.*

4 *Agricultural practices have an important **impact in freshwaters, estuaries, coastal and offshore systems and biodiversity** and their effects must be minimized*

5 *The missions area created to define **Research and Innovation topics**. This area of intervention is important but is more linked to **legislative developments** than to research and Innovation.*

6 **Requires urgent joint action** for **regulation and effective monitoring/control** and clear enforcement. If not tackled jointly, it may create unfair market access etc.

7 Such an action should include **research on eutrophication**.

8 Maybe 80% is a very high percentage. The **agricultural lobby is quite powerful,** and the socio-economic changes are quite big - it also requires a **change in mentality**. In addition why only to focus on chemical pesticides? **What about the fertilizers**?

9 Also needed to **reduce all chemical effluents** such as **pharmaceutical**, **cosmetics**, **detergent**

10 80% seems high but why not being ambitious. **without strong political support it's unlikely to happen** as the economic consequence can be important

11 In the late 80's of the last century, the **Black sea became almost dead**. In many ways, thanks to **the mass use of pesticides in vineyards**, near the coastal zone. In the early 90's, **after the disintegration of the Soviet Union**, the economic activity of the population around the sea fell sharply, **and the mass use of pesticides proved too expensive. As a result, after 5 years, the ecological state of the sea has improved dramatically**. Unfortunately. currently, the **degradation of the ecosystem continues** again.

Expert team reflections on findings

The answers reflect a high level of uncertainty that might lead to a vast array of positions. This indicates that the problem has not been tackled seriously, with the aim of reaching an informed consensus in the various societal components.

Some respondents highlight other contaminants (fertilizers, pharmaceutical, cosmetics, detergents), others say that it is only a matter of legislation. Others say that the effects of agricultural practices have important effects that must be minimized, but the effects are well studied for some stressors and not for others. Some respondents say that it is a matter of legislation and not of research and innovation. Research is, however, needed to ascertain the effects of stressors on aquatic systems that, in the case of pesticides, are not clear at all. Innovation is needed also to replace the current agricultural practices with alternative ones, if current practices are recognized as unsustainable.

In past decades, research on eutrophication led to minimize the impact of fertilizers or, at least, to focus on their potential impacts on aquatic systems. A parallel wealth of research did not occur for pesticides and, especially, on their effects on aquatic systems.

1.2 Trend - By 2030 the status of all marine species in the EU waters is assessed, and actions have been taken to truly maintain marine biodiversity.

Background

The estimated number of species inhabiting the planet is eight million. Only two millions have been named. Most of marine biodiversity is still unknown. Designed to conserve Europe's marine life, the 1st descriptor of Good Environmental Status of the Marine Strategy Framework Directive requires the exploration and assessment of biodiversity, so as to effectively manage the natural capital of Europe.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (145)	3.08	1.69	0.69	1.39	1.45
Business (13)	2,69	1,62	0,23	1,15	1,77
Civil Society (6)	2,50	0,83	0,33	0,83	0,33
Other (17)	2,94	1,59	0,71	1,47	1,47
Policy (11)	2,73	1,45	0,36	1,18	1,18
Research and Development (98)	3,23	1,80	0,81	1,46	1,50

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2

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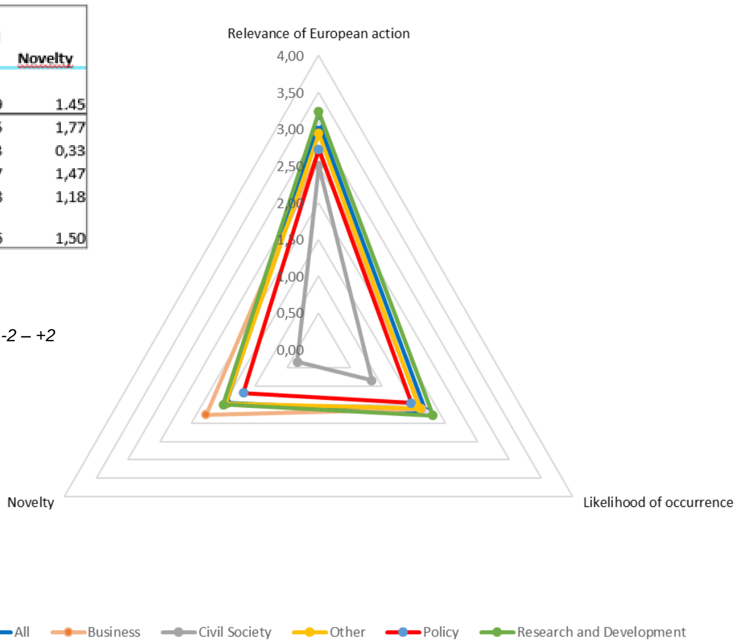


The assessment of all marine species within the EU is considered as very important for EU actions by the participants. Whereas the topic is quite new for stakeholders of the business sector, however, the civil society and the policy sector are aware of this need for action. The Civil Society has less trust in the likelihood of occurrence than.

Comments of RTD Participants

1. There are two issues: the **status of all marine species** in EU waters is **assessed**, and **measures** have been taken **to effectively maintain marine biodiversity**. For the first aspect, it is possible to **carry out an inventory before 2030** if fundamental knowledge such as taxonomy is given a real boost. As far as biodiversity is concerned, I doubt that progress can be made without **changing the economic paradigm**.

2 This trend is indeed a **wishful trend**, however it has a **major bottleneck** - we **only know about 5-10%** of all marine biodiversity so I do not believe **we will know the remaining 90% in the next 10 years**, as a lot still needs to be done and **bioprospecting** and **taxonomic sciences** need to be further **boosted**. On the other hand, the second part of this trend implies a much larger area of marine protected areas, with pre-defined time limits and a close engagement between sustainable exploitation measures with restauration and protection measures. Ultimately if we **foster sustainable exploitation,** we can achieve somewhat **a better balance for the marine ecosystem usage and maintenance.**

3 Of course we **need to know more** about the marine biodiversity that is for the moment unknown. Nevertheless, **we don't have to wait for the results of such study to protect the aquatic life.**

4 This is certainly a must, but requires **social engagement and clear leadership**, to make the necessary decisions

5 Needs coherent **action at global level.** Ocean is one and **highly interconnectedness** especially for **migratory species, but also impact of habitat** with current techniques and new techniques, and establishing **SUSTAINED (biological) ocean observation**, we can move at **increased pace in describing and assessing marine species** (the other 6 million), but maintaining biodiversity is another story; **MSFD focuses on BD in general** but sometimes **unclear reference conditions**, CFP and Natura2000 focus on reference/target conditions for just a few species and habitats.

6 This **cannot be achieved without citizen Science and novel monitoring methods** (aerial and submarine drones, DNA assessment methods, satellite, automatic sensors and cameras, etc.), investing sufficiently

7 1.2 The **United Nations** are just completing the **"decade of biodiversity". Action is not very timely.**

8 I hope they will take into consideration also **marine microorganisms fungi, bacteria**, etc

9 There are two issues in this question: "Status" - **The status of "all marine species" is very difficult** to reach in 10 years as the species are still not known. It would require a massive work. If the **species have an industrial value the socio-economic impact** could also be massive. "Actions" - actions are not enough. **We need to monitor in order the actions are effective in the long-term.**

10 This will require **substantial increase of research funding**, which is not the current trend...

11 The problem with this statement is that no **economic resource is really allocated to support taxonomic studies** and to promote collection and identification of marine and aquatic species, including the **description of new still unknown species**. We urgently need to **prioritize taxonomic inventories of species while promoting actions for their protection**. Papers in the last decades and years highlight that a large number of species deserve to be described even in the "relatively well known" Mediterranean Sea, and that to **describe all estimated new species a relevant effort** is needed for several taxonomists working for several decades ... but recent calls do not include the possibility to feed taxonomic projects. This is a non-sense from my point of view.

12 **Funding is a critical issue here**, because a strong support to taxonomic studies is a must.

13 Unfortunately, in addition to the negative impact on the ecosystem of human activity, there are **many impacts of natural factors**. For example, the **appearance of various**

universes in the sea that adversely affect biodiversity. It seems to me that in some cases a person is powerless to fight them.

Expert team reflections on findings

There is a great hiatus between what is considered as a stringent priority (know biodiversity, assess its status, enforce actions so as to protect it) and what is actually done to fulfil it. And most respondents appear resigned that the situation will not change, in spite of the urgency of action. Today, the greatest majority of aquatic biodiversity is poorly known, and its status is assessed with models and assumptions but not with the acquisition of solid data.

International treaties, from the Rio Convention to all the other conventions, thereafter, recognize the importance of biodiversity protection; the European Union, with the Marine Strategy Framework Directive, prescribes that within 2020 the trend towards a Good Environmental Status is to be triggered in all EU waters. Biodiversity status is the first descriptor of GES. The protection of biodiversity is the first aim of Marine Protected Areas and of their networks. With this very clear scenario, the expertise and the research efforts in knowing, assessing and protecting biodiversity should be strengthened heavily.

1.3 By 2030, economists emphasise precautionary minimum standards and the future value of ecosystems.

Background

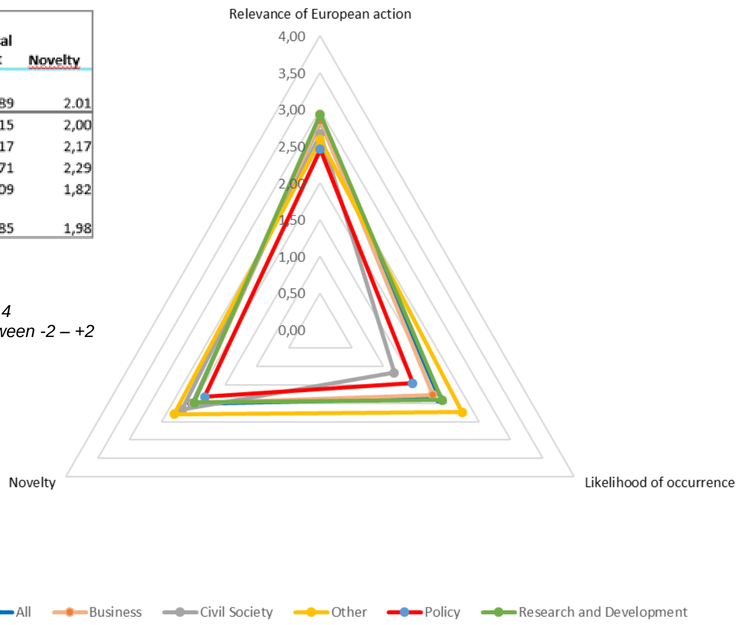
Willingness to pay can be applied to items that are for sale and that can be bought with money. If a coral reef is worth 10 billion dollars, is it right to destroy it if the revenue is 11 billion dollars? Can we design new ways of assessing the value of the natural capital, without using monetary prices and their absurd implications? Attention could be paid to ecosystem functioning characterised by extensive uncertainty, by irreversibility and by non-linearities that generate potentially large negative effects from ecosystem loss or degradation, the focus shifts to how to behave with precaution in the face of this combination of features.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (140)	2.84	1.87	0.71	0.89	2.01
Business (13)	2,85	1,77	0,77	1,15	2,00
Civil Society (6)	2,67	1,17	0,67	1,17	2,17
Other (17)	2,59	2,24	0,29	0,71	2,29
Policy (11)	2,45	1,45	1,09	1,09	1,82
Research and Development (93)	2,94	1,91	0,73	0,85	1,98

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



Regarding precautionary minimum standards and the future of value of ecosystems, there is the largest divergence in relevance for EU actions between the participants from the Policy sector compared to the Research and Developments sector. In general, the concept seems quite novel to all participants. The opinions for evaluating the likelihood of occurrence are more diverse compared to the other evaluation criteria.

Comments of RTD Participants

1 **The sustainability of ecosystems** remains an element that has **no monetary value.**

2 One important issue is the **valuation of degraded areas** and the study of recovery of **value and ecosystems services after restoration**

3 Required in national accounts, but we will have to accept its **imperfectness as method**; will always need **additional assessment and valuation techniques**; action can be taken at global (methods) and national level (accounting). **European level is relevant but not crucial.**

4 1.3 Great Action!

5 "Emphasize" is a start but **we need more than that** in order to protect the marine environment. **Actions are needed by governments** and that may require **a long time to be implemented.**

6 An important issue is to **increase public awareness about conservation** and to **imagine/prioritize values** other than money in guiding general chooses.

7 **The economic valuation of water ecosystem** would bring much **more value** to European citizens **than the CO2 reduction**. CO2 reduction is a**) approached by technologies** which have heavy side impact on ecosystems both at production and even more at decommissioning and b) **we have no control of the CO2** production **outside Europe**.

Healthy water ecosystems ranging from glaciers, through soils, wetlands, rivers down to the oceans, **may be achieved by much simpler techniques**, energetically sustainable, and the whole action has **localised impact clearly seen by European citizens**. The water ecosystem valuation was approached in the past but never in a complex way.

Healthy water ecosystems mean also **carbon fixation in marshlands, peatbogs, soils** etc. as well as **higher albedo in glaciers and lower surface temperature in forests**, both competing the climate change.

Expert team reflections on findings

Respondents agree that this issue is important, but they feel that the EU cannot play a significant role in the absence of action from the rest of the world. What was asked is to rethink the valuation of natural systems so as to avoid pure monetary accountings. If this objective is recognized as valid (and most respondents agree about its relevance) then research must be carried out so as to reach it. The EU can lead providing alternatives that might be followed by the rest of the world. If we wait for a global consensus we will never act.

1.4 By 2030, the EU develops integrated approach to marine governance following the functions and structures of ecosystems beyond political boundaries.

Background

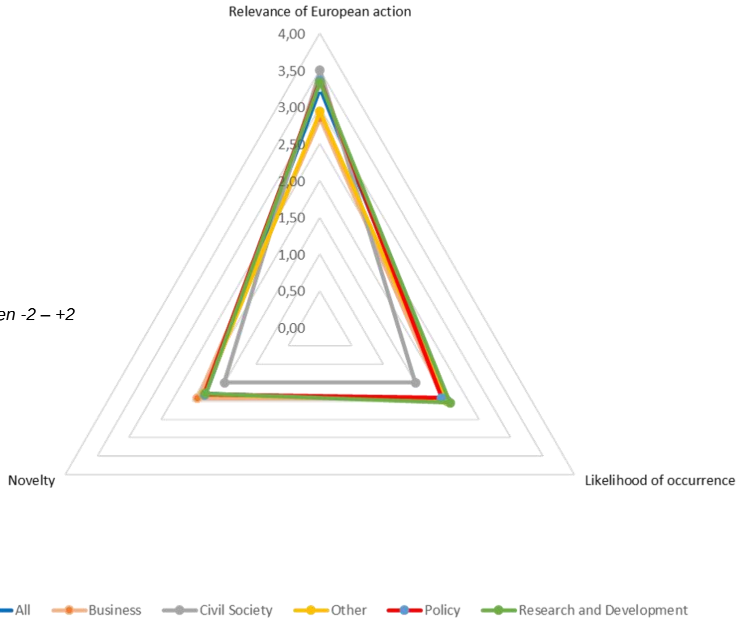
Integrated Coastal Zone Management, Maritime Spatial Planning, The Natura 2000 Network, the Networks of nationally designated Marine Protected Areas, the Water Framework Directive, the Marine Strategy Framework Directive and many other national and international measures apply on the same space, in different ways and from different perspectives that rarely consider the structure and function of ecosystems in defining spatial units of management and conservation. Understanding connectivity and boundaries is a precondition to sustainability. Oceanic ecosystems do not recognize political boundaries and human actions must be managed on ecologically meaningful spatial units, assessing connectivity. This insight may lead to a unified approach to marine governance.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (139)	3.25	1.99	0.91	1.09	1.80
Business (13)	2,85	1,92	0,62	0,69	1,92
Civil Society (6)	3,50	1,50	0,83	1,17	1,50
Other (17)	2,94	2,00	0,71	0,82	1,82
Policy (11)	3,36	1,91	1,00	1,27	1,82
Research and Development (92)	3,34	2,04	0,98	1,16	1,79

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



An integrated approach to marine governance shares an almost equal evaluation almost all the participants. They see the topic as very important in relevance for European action, quite new, and likely of occurrence. Only the Civil Society sees the concept as less likely and less novel compare to the rest. Additionally, the participants from other non- defined sectors, see it less relevant.

Comments of RTD Participants

1 It is indeed **a scientific solid approach to measure ecosystems** using its **owns limits and not the geographical or political ones.** However, given the current state of the art in defining such ecosystem-based units **it seems hard to have it defined and implemented by 2030**

2 This is the way to do things, but **knowing the current implementation of many directives and legislation**, it is **difficult** to see this implemented, since **member states do not collaborate** each other, in general**: a change of culture** is necessary, going **beyond the 'national interests**'

3 As in a previous comment, it is a relevant topic, but I **miss a direct link with the importance of research and innovation** linked to this topic. The key novelty of missions should be more clearly directed to research and innovation.

4 **Great progress** made in EU waters, **at least in concept**, but still need **further alignment and interoperable**; further progress needed in **regional sea basins** and **with third countries (non-EU)** e.g. in Mediterranean, Black Sea, Atlantic. Missions need **governance**, but as a means to deliver. Not as a purpose by itself (concepts & standards & procedures)

5 Great progress made but still **a lot to develop**

6 1.4 Great Action!

7 The development of an integrated approach is a start, but we **need implementation in order the approached** developed is effective. **Actions are needed by governments** and that may require **a long time to be implemented**.

8 ... that's why I've launched with experts **the appeal for the Ocean to be recognized as a common good of humanity** www.oceanascommon.org. France supports the notion in the bbnj negotiation framework. The European parliament has voted in that way in the COP15 Resolution.

9 It would be great, but I think **we are still far**.

10 Only an **integrated approach** to the management of marine resources **in accordance with the functions and structures of ecosystems** can have a real positive effect.

Expert team reflections on findings

The respondents provide conflicting answers. The urgency of this action, however, is recognized by the majority of the respondents. As with biodiversity, however, it is claimed that we are far from achieving such operational knowledge so, again, we are confronted with actions that are urgent but that will not be enforced properly if the current trends will prevail. Obviously, the hint is that in order to achieve these results we must change current trends and dedicate our efforts to fulfil what is universally recognized as important. Recognizing the natural spatial boundaries of large ecosystems (as is done with the proposal of Cells of Ecosystem Functioning) requires lots of research in terms of both biodiversity and ecosystem functioning, and this will require also lots of innovation in the way the systems are defined, managed and protected.

1.5 By 2030, the farming of bivalves for food quadruples in the EU providing a sustainable food source.

Background

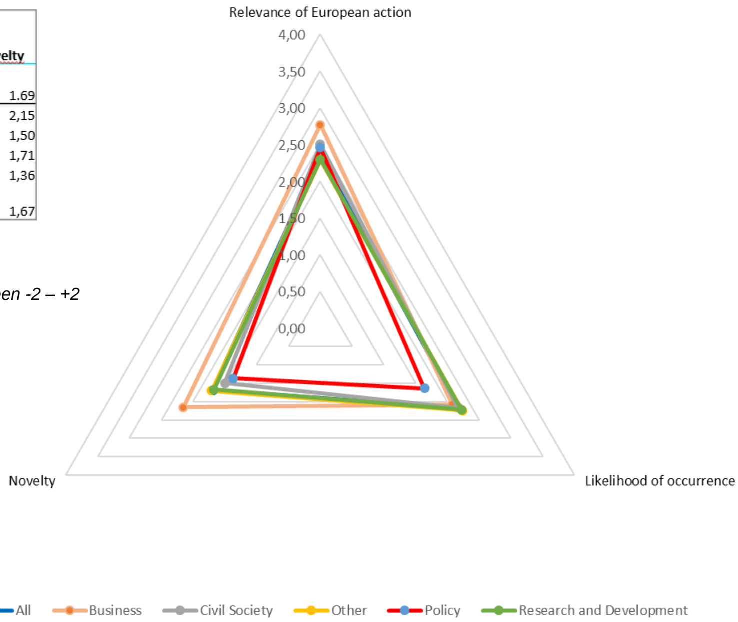
Marine aquaculture is increasing but it must reduce its pressure on environment. One way to do this is to farm animals lower on the food web that require little to no feed, such as freshwater carps, tilapia, and bivalves. Bivalves (oysters, mussels and clams) and other low trophic level seafood offer access to rich nutrition. Bivalves appear to have minimal ecological impact while minimizing concerns around welfare in captivity.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (138)	2.36	2.16	0.74	0.51	1.69
Business (13)	2,77	2,08	0,62	0,77	2,15
Civil Society (6)	2,50	2,17	0,83	0,67	1,50
Other (17)	2,29	2,24	0,82	0,06	1,71
Policy (11)	2,45	1,64	0,55	0,36	1,36
Research and Development (91)	2,30	2,22	0,76	0,56	1,67

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The farming of bivalves for food has spread the opinions of the participants, especially the ones from the Policy and Business sector. The latter sees the topic as higher relevant, newer, and more likely than the rest of the experts. Research and Development sees the occurrence of the topic as more likely compare to Policy. In total, the topic is seen less relevant compared to the other analysed statements.

Comments of RTD Participants

1. Provided that the **potential negative ecological impacts** (e.g. **sedimentation** under cages and possible **organic loading,** changes in the existing **underlying habitats** and **communities**) are taken into account.

2. This can be truly a **positive measure to solve SDG related to protein supply and hunger**, but needs to be achieved under **strict control of negative ecological impacts minimization**.

3. **Inland farming of marine organism** should also be considered in order **to reduce environmental impact.**

4. **I cannot see novelty here** and the statement that **bivalves aquaculture** has minimal impacts is not true: in addition to organic matter enrichment, they **attract invertebrate predators (e.g. sea stars),** sometimes invasive species.

5. I do not understand **why** the mission focus (broad) is **focusing only on bivalves**. **Sustainable aquafarming** will indeed be important (and should be achieved). A **broader approach** is needed here, and the industry is ready to develop solutions. However, the R&I investments from the industry are not sufficient to reach the objective, and therefore **leverage of additional investments will be key**.

6. Innovation in aquaculture is not only about the target species, it is also and **even more about sustainable and innovative approaches**: combining multi-trophic levels,

innovation in feeding, harvesting, circular economy, energy etc. **Monoculture is not the approach.**

7 **Ecological impact** still to be checked.

8 Not sure how much effort it takes to quadruple the farming of bivalves. Important to have **measures and regulations addressing the massive production of bivalves**.

9 Also s**pirulina production** should have a **strong contribution to nutrition**.

10 This could be done minimizing environmental impact. But I think that bivalve farming must be done under **very controlled conditions**. My big concern is the **occurrence of micro-plastics i**n natural environments and the high uptake by filter **-feeding organisms and the transmission to tissues and in the trophic chain**.

11 **x4 in 10 years is not realistic**. These are **small businesses with need to access wide areas**. Need many people ready to do it, financing, development of markets and **strong reduction of administrative burden** and/or possibility for rich retired to oppose economic development on the seashore.

12 **Filter-feeders collect contaminants** (e.g. micro plastics) so as the seas become more polluted, they become less appetising.

Expert team reflections on findings

Lots of concern about pollution under the rearing structures that some respondents identify as "caging", whereas bivalve aquaculture is not using cages. It is true that microfaeces are a source of pollution, but bivalves do not require the provision of food and they remove microbes from the environment, transforming them into proteins.

Among respondents, some give it for granted that microplastics will be incorporated and transferred to consumers. Recent research papers[1], however, indicate exactly the opposite. Hence, research and innovation can help in disentangling this issue.

The denial of the efficacy of monocultures is very valid. Some investigations[2] have revealed sustainability of these practices but, of course, potential impacts should be properly assessed at each location. No respondent expressed concern about the health problems linked with bivalves in terms of pathologies such as cholera, hepatitis and other less acute syndromes. This is of course linked with the relaying procedures before the product is marketed. Especially if animals are eaten without cooking and practically alive (e.g. oysters).

[1] https://doi.org/10.1016/j.envpol.2018.11.038

[2] https://doi.org/10.1016/j.marpolbul.2004.02.038

2 The recovery of healthy oceans and waters

2.1 By 2030, the EU together with international partners reverse the decline of healthy fish stocks in all its seas

Background

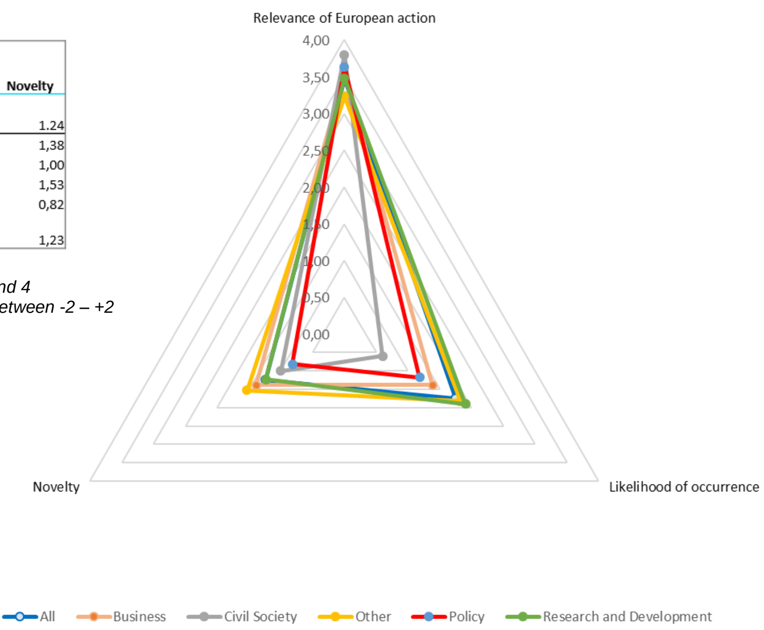
Sustainable fisheries management addresses depleted stocks and gather ocean stakeholders behind a common framework. ‘Fishery’ refers to activities involved in catching a species of fish or shellfish, or a group of species that share the same habitat. A sustainable fishery has sufficient spawning fish to produce the next generation, while allowing fishing to take place. This ensures we can secure our fish and aquatic fish resources for the future. Furthermore, combating, monitoring and sanctioning for illegal, unreported and unregulated (IUU) fishing, by using new available and emerging technologies will help the ocean stewardship to recover our oceans.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic Impact	Ecological impact	Novelty
All (140)	3.48	1.74	1.12	1.48	1.24
Business (13)	3,54	1,38	1,31	1,62	1,38
Civil Society (5)	3,80	0,60	0,80	2,00	1,00
Other (17)	3,24	1,82	0,94	1,18	1,53
Policy (11)	3,64	1,18	1,00	1,45	0,82
Research and Development (94)	3,48	1,90	1,16	1,49	1,23

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



Among all the statements, the participants ranked reversing the decline of healthy fish stock as the most relevant topic for European action. Further, this topic seems equally recognised by all stakeholders and only somewhat new to them. The highest divergence in opinions appears regarding the likelihood of occurrence: whereas the Civil Society rates it as unlikely, the Research and Development Sector thoroughly sees it as likely. All other sectors diverge in between.

Comments of RTD Participants

1. While this is an **extremely important action** for marine ecosystems, in my opinion **10 years are too short** a time frame to successfully implement sufficient actions, and **many exploited stocks** will likely be depleted or **critically overexploited** before that happens.

2. This is an **extremely important action** to the current status of the ocean and towards **achieving higher health and restoration** of marine ecosystems. The **definition of fishing quotas MUST be sustained** by clear **scientific data on stocks, state of growth** and other relevant information for decision making. If the **quotas are**

maintained under strict scientifically recommended boundaries this is achievable within the next 10 years.

3 It probably **takes 10 years for the stock of a species to recover** if the pressure on the stock in question ceases. That's not believable.

4 **Sustainable fishery** must be developed if we want to preserve the ocean biodiversity. **Controls and sanctions** have to be made. Nevertheless, **fighting against fishery lobby will be difficult.**

5 One of the problems is the **subsidies to fisheries**, which should be **removed or transformed, giving subsidies** to sustainable fisheries and removing those to impacting fisheries.

6 Knowledge base is there. EU needs political will to implement and enforce. **requires EU coherence action also outside EU waters.**

7 While this is an **extremely important action** for marine ecosystems, in my opinion **10 years are too short** a time frame to successfully implement sufficient actions, and **many exploited stocks** will likely be depleted or **critically overexploited** before that happens.

8 This is an **extremely important action** to the current status of the ocean and towards **achieving higher health and restoration** of marine ecosystems. The **definition of fishing quotas MUST be sustained** by clear **scientific data on stocks, state of growth** and other relevant information for decision making. If the **quotas are maintained under strict scientifically recommended bounda**ries this is achievable within the next 10 years.

9 It probably **takes 10 years for the stock of a species to recover** if the pressure on the stock in question ceases. That's not believable.

10 **Sustainable fishery** must be developed if we want to preserve the ocean biodiversity. **Controls and sanctions** have to be made. Nevertheless, **fighting against fishery lobby will be difficult.**

11 One of the problems is the **subsidies to fisheries**, which should be **removed or transformed, giving subsidies** to sustainable fisheries and removing those to impacting fisheries.

12 Knowledge base is there. EU needs political will to implement and enforce. **requires EU coherence action also outside EU waters.**

Expert team reflections on findings

Many express concerns about the feasibility of this objective within 10 years. Many respondents bring about subsidies to impacting fisheries as an obstacle to achieving this objective. Furthermore, they refer to an (industrial) fisheries lobby resisting against such actions.

However, research model findings indicate that in well managed Marine Protected Areas, fish stocks recover in less than 5 years. The recovery of tuna has been rapid when the quotas were established.

Most of the needed measures are already suggested by the scientific community also in terms of innovation in the use of fishing gear. The problem is not to find the right thing to do, the problem is to actually do it.

This issue is directly linked with the sustainable aquaculture issue. Fish aquaculture requires artificial feeding and since most fish are carnivores and eat other fish, the food comes from natural populations of species that have lower commercial value than those of aquaculture, which exacerbates the impact of fisheries, if devoted to carnivores. Also, aquaculture is commonly subsidized, with the exception of herbivorous fish (such as Tilapia) or filter feeders.

2.2 By 2030, the detrimental impact of marine litter (especially plastics) on human health and the ecosystems is reduced by 60 percent in European waters.

Background

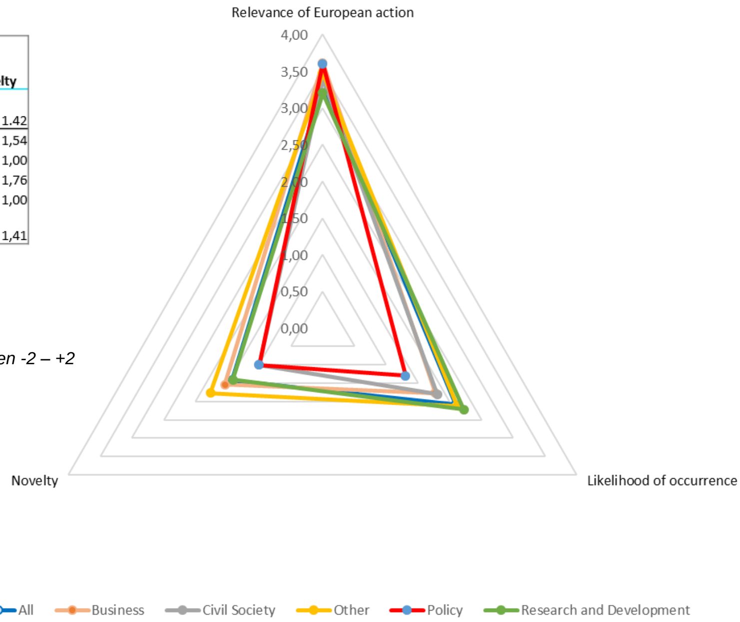
Litter, accumulating in our seas and coasts is impacting marine ecosystems, causing problems to human activities that use and depend on the sea and raising human health concerns. European Member States are developing measures to tackle marine litter (especially the plastics) with the Marine Strategy Framework Directive, but the information base is still insufficient, especially on the impacts of marine litter on biota and on human health, including the potential for actual accumulations in the food chain. We need to identify hotspots areas for marine litter and use innovative and cost-effective technologies that are able to reduce the amount and impact of litter pollution at the sources (rivers input, Waste Treatment Plants); including developing new methods for treating microplastics.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (140)	3.31	2.09	0.86	1.55	1.42
Business (13)	3,62	1,77	1,00	1,77	1,54
Civil Society (5)	3,40	1,80	0,80	1,60	1,00
Other (17)	3,47	2,12	1,06	1,65	1,76
Policy (10)	3,60	1,30	1,00	1,80	1,00
Research and Development (95)	3,20	2,22	0,80	1,47	1,41

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The participants ranked the impact of marine litter as highly relevant to European actions. The likelihood of occurrence differs from somewhat unlikely to likely; with the Policy Sector being the most incredulous party.

Comments of RTD Participants

1 Maybe not by as much as 60%, but **a reduction of marine litter in EU waters by 2030 seems possible.**

2 Again, I wish this could be achieve but honestly do **not believe we can reduce 60%**.... But **aiming for such goal** will surely provide **a massive reduction** compared to the actual state.

3 **Treating water** to remove microplastic and identifying how they impact human health **is not the solution**. **Changing the way we are producing and consuming it.**

4 **Change first attitudes and behaviour**, then implement technological solutions, especially for micro and nano-plastics, but be aware that, despite the media attention to this, **plastics are not the main problems of seas** (although it is for some megafauna).

5 Issue is **that there are no boundaries in the oceans** and when visiting Africa, one can see that for more that Europe can do, if the others don't do the same, the fight will be lost.

6 Extremely important but not just for (marine) litter, **all pollution to be tackled through joint regulation and strict enforcement**, together with regulation and support to 'first movers' advantage. innovate to use these **EU actions as competitive advantage** in market.

7 **60% might a very high percentage**. This trend also requires a **change in behaviours** (from all stakeholders) and this may take a long time.

8 This action is under way. The sources of plastics pollution must first be **addressed in the distribution of goods and then in the water basins.**

9 I think people is relatively aware about this and this very high percentage could be reached. However, we have to **change the industry behaviour in order to reduce packages**, promote the use of reusable/recycling packages, eliminate multi-material packages and **ask industries for clear statements about the material used** and the destination of particular packages in the recycling .... **Governments have to adopt more stringent rules.**

10 How will the reduced impact be measured? **What is the baseline?**

11 **Do we know the impact now?** The likely response is NO. So how can we reduce by 60%?

12 Do not reduce to plastic.

13 Important to **stop the littering first then commence with clean-up** - only a few percentage is visible - a lot should be left untouched **- key is prevention** - it is also not just plastics but chemicals, particles of all kind and ships etc.

14 **A balanced indicator for the impact of marine litter** across the entire ecosystem has not been devised, so **a KPI like this requires** a serious boost to assessment capacities.

15 **The impact is very difficult to measure**. It is even more difficult to assume that we are reducing 60% de impact/pressure/inputs of marine litter in the coming 10 years.

16 I would suggest broadening **the scope**. There is **much more marine litter** to be addressed. Secondly, addressing plastics would manly be facilitated by land-based measures.

Expert team reflections on findings

The reduction of both marine litter and of the melting of the cap of polar ice, was overall considered as having enormous positive ecological impact. However, we still do not know well the impacts, especially of micro-litter, on biota, ecosystem and humans. On the other hand, a good number of the respondents agreed that although marine litter is very high in the scientific agenda, it is probably a societal problem that needs change of behaviour from all stakeholders, including industry. As such it may require time beyond the decade. In addition, it may not even be the most pressing problem for marine ecosystems' health today, as compared, for example, with marine and freshwater pollution from chemicals.

Many respondents appear to believe that the impact is not known, so it is difficult to reduce it by 60%, since we do not know the 100%. There are many studies on the presence of macro and microplastics and their impact on animals that eat plastics, from cetaceans to reptiles and birds. The solution to the problem, as remarked by the respondents, is on land, in the production systems. Both the research and the innovation that aim at finding solutions to curb the litter must come mainly from land-based approaches.

2.3 By 2030, the EU achieves rigorous control of ships' ballast water.

Background

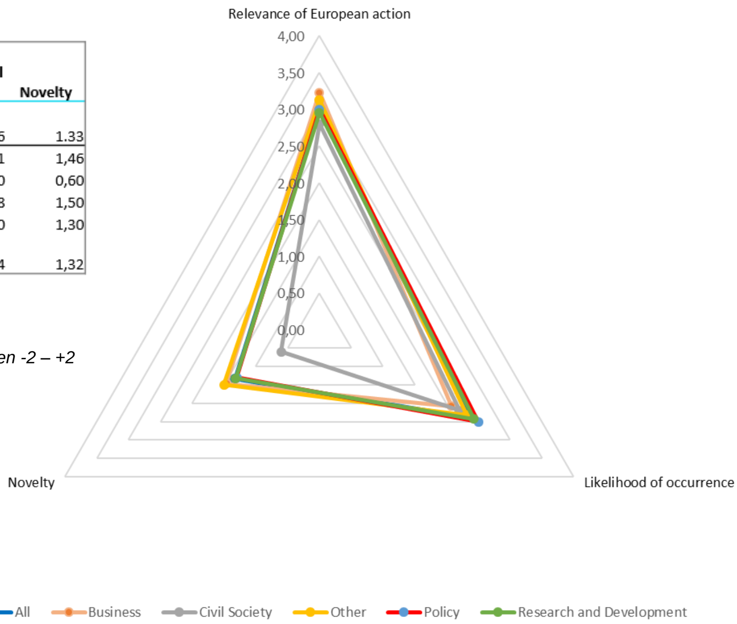
Ballast water may be taken onboard by ships for stability and can contain thousands of aquatic or marine microbes, plants and animals, which are then carried across the globe. Untreated ballast water released at the ship's destination could potentially introduce a new invasive marine species. Hundreds of such invasions have already taken place, sometimes with devastating consequences for the local ecosystem. The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM Convention) was adopted in 2004 to introduce global regulations to control the transfer of potentially invasive species. With the treaty now in force, ships should manage their ballast water and enforcement remains a major *challenge.*

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (135)	3.00	2.38	0.39	1.26	1.33
Business (13)	3,23	2,08	0,00	1,31	1,46
Civil Society (5)	2,80	2,20	0,40	1,20	0,60
Other (6)	3,13	2,31	0,69	1,38	1,50
Policy (10)	3,00	2,50	0,40	1,20	1,30
Research and Development (91)	2,96	2,43	0,40	1,24	1,32

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



Regarding the rigorous control of ships' ballast water there is a large consensus amongst the participants. Stakeholders, except the Civil Society find the topic new. In general, the topic is seen as likely in occurrence and very important in relevance of European action.

Comments of RTD Participants

1. The legal framework is in place, so this is just a **question of enforcement**. Also, additional **technology development for Ballast water treatment** on board is key to facilitate the implementation of such measures and must be considered here.
2. **Nothing new** here. Technologies to treat ballast water exist. It's just a **matter of enforcement.**
3. **Enforcement**, enforcement, enforcement + monitoring.
4. Not new. techniques are in place. needs **enforcement**.
5. 2.3 Ballast water is a problem but **considered second order**. There have been quite some advances recently.
6. Very important topic but not sure how it could be addressed by innovation actions as the enfor**cement seems to be the main issue**. **Government incentives** could be used.
7. Relevant but **government efforts** are needed.
8. **Globalisation means (very) cheap transport**; shipping sector has been rather good at avoiding internalising externalities so far.
9. Please note, that this topic could be covered by the **Co-Programmed Partnership zero-emission waterborne transport**. In addition to earlier comments, I **miss a clear mission and vision** for the mission regarding oceans. It seems to be **individual topics rather than a broad outlook** with further detailing. Why only ballast water, and not coatings for example?

Expert team reflections on findings

Ballast water treatment was also high ranked on ecological importance, but its importance to the society was considered minor. However, it is well documented that ballast waters can harm society and economy. For instance, the alien ctenophore *Mnemiopsis leidyi* reached the Black Sea via the ballasts of oil tankers coming from the USA. The gelatinous carnivore had a severe impact on fish populations, with enormous impacts on the local economy. Harmful algae can be transported via ballast waters, and they can cause severe impacts that have societal relevance. The lack of perception of the societal importance of alien species transport through ballast waters is another indication of the need of improving ocean literacy.

Many respondents have stretched that what is really missing for this action, is the enforcement of the existing international and national legislation. Apparently, most of the respondents think that the issue is not that novel and that the solutions are at hand, as is the legislation. Indeed, at present, it is crucial to enforce the rules and procedures that are already present.

2.4 By 2030, the multiplied effect of green consumer brand marketing and bottom-up social media campaigns generates major public response and environmental movement to clean the European water ecosystems.

Background

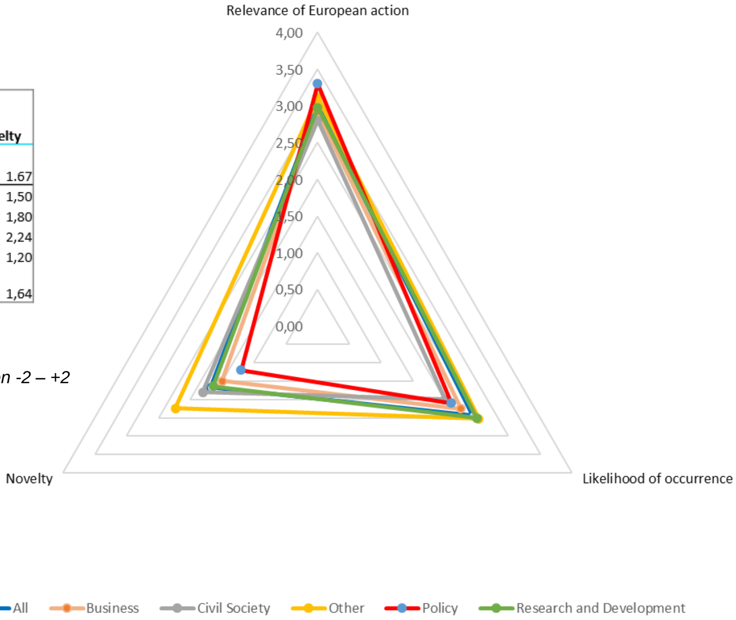
The role of advertising in driving behavioural change is well researched. However, the effective use of media to promote environmental action is less understood. For instance, why did a video of a turtle with a straw embedded in its nose inspire widespread public action to ban plastic straws, while many other information campaigns elicit little response? Research into social behavioural drivers has shown that perceived social norms can influence environmental behaviour; the upheaval in social and other media could present an opportunity for immediate action, transforming the way scientists, practitioners, and the general public collaborate.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (138)	3.01	2.43	0.86	1.00	1.67
Business (12)	2,92	2,25	1,00	1,33	1,50
Civil Society (5)	2,80	2,00	1,00	1,00	1,80
Other (17)	3,12	2,53	0,82	1,06	2,24
Policy (10)	3,30	2,10	1,10	1,20	1,20
Research and Development (94)	2,98	2,50	0,82	0,93	1,64

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The participants see the multiplied effect of green consumer brand marketing and bottom-up social media campaigns as very relevant for European actions and quite likely of occurrence. Of higher interest is the fact, that the Policy sector, in particular, is quite aware of this topic.

Comments of RTD Participants

1 Why don't we use all the **tools and data from marketing to promote environmental actions?** Instead of convincing people that they need to buy stuff, we should convince them to have a **better environmental behaviour**.

2 I'm not convinced that the 'Lutheran way of convince' (i.e. making people guilty) is the best way. **Be aware that you try to change the way of life of people who has a long cultural tradition.**

3 Nudging, transparent as **well-underpinned scoring and labelling can generate huge change in behaviour.** But it must be accompanied by **clear legislation and enforcement**. Public is not the only or ultimate responsible actor. Many processes such as market are **steered by 'anonymous' drivers.**

4 **Not a new issue**, technologies (however some of them could be improved) and regulations exist.

5 **Not new at all, still important**, but I'm not very optimistic that it will be very efficient.

6 Need to create an **emotional linkage between the Ocean and the society**, including those living in the countryside. Ocean literacy is crucial also.

7 **Avoid "easy" targets like aquaculture or farming.** Whatever you do production has some impacts. The point is to **choose productions that minimize impacts.**

8 **The appeal to citizens may be quite high** as the old as well as "new" water pollutants are discussed and understood by ordinary citizens. Also, nobody questions the **need of public action in this area**, so it is a **political question** by all means and it is easy to bring it up as an important election question. This may be successful.

9 Many movements are well intended **but badly coordinated or communicate -** a much better organisation should take place as in many cases all this is nice but does not bring much besides a good feeling and is **in a number of cases a total waste of money/funds**. So better **structuring and organisation with targeted topical programs.**

10 **Activists consumers are on their own** unable to shift goalposts if authorities/ governments don't consolidate the progress **made with toughening regulatory standards.**

11 This could be **combined with the topic on plastics**. But what is the R&I need here?

Expert team reflections on findings

The Green Consumer Brands were considered as important to change behaviour but do not carry any innovative or marine research potential. However, their connection with education, stakeholders awareness was considered important especially if this is done in a coordinated way at all societal levels.

The fishing industry is already moving in this direction, for instance by explicitly labelling own products as “dolphin friendly”. The application of the descriptors of GES, as specified in the MSFD, might become efficient measures of sustainability: if a production enhances GES, then it is sustainable; if it is worsening the state of some descriptors, then it is not sustainable.

2.5 By 2030, the automated monitoring and big-data analysis will cover 95% of global fishing fleets revolutionising the management of commons in the sea.

Background

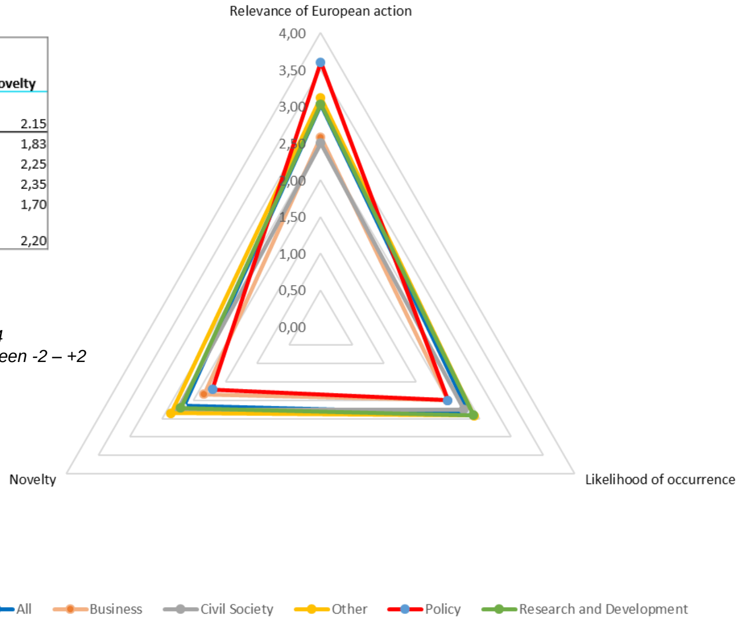
The impact of the internet of things, autonomous vessels and a big-data approach to ocean observation is emerging through products recently derived from access to Automatic Identification System. For the first time, these have allowed the mapping of global fishing activity and quantification of use of the High Seas, among other applications. The data generated by advanced technologies, however, is accessible only by fee, and while massive in scale it must be expanded, as it currently encompasses only 50–70% of the global fishing fleet. More pervasive ocean observation could permit more dynamic, responsive, and predictive fisheries management.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (137)	3.03	2.34	0.80	0.91	2.15
Business (12)	2,58	2,00	0,75	0,75	1,83
Civil Society (4)	2,50	2,25	0,50	0,50	2,25
Other (17)	3,12	2,41	0,88	0,94	2,35
Policy (10)	3,60	2,00	1,10	0,70	1,70
Research and Development (94)	3,03	2,40	0,77	0,96	2,20

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The automated monitoring and big-data analysis have its highest rating in relevance of European action by the Policy sector. The lowest relevance is rated by Business and Civil Society. While the Policy experts rated the topic highest in relevance, they a more modest with the other two rating criteria, in comparison to the other participants.

Comments of RTD Participants

1. On the paper it seems great, but we need to **be sure that the data collected are the real data.** In France, dolphin accidental capture is supposed to be very low but it's just because most of the **fishermen don't declare accidental catch.**

2. Again, these **measures must be linked to subsidies**: if you don't provide data, or not allow installing these technologies, you don't receive subsidies (or fishing permits).

3. **Data reliability** is of high importance.

4. Issue might be the **standardization of the metadata** allowing the data to be included in the same models.

5. As with agriculture, it is **unlikely that states will take binding measures for fishermen**. The paradigm shift for fisheries will wait at least a generation ...

6. **Reliability of data would be relevant**. I have concern about a really positive impact as similar actions in the past had no relevant results.

7. Very relevant topic. Representing the Waterborne Technology Platform, **I would not limit it to fishing vessels only.**

Expert team reflections on findings

The automated monitoring was considered overall as an emerging and relevant issue but some of the respondents were questioning the reliability of relevant data. We must be sure that the information we gather is reliable and is conducive to knowledge. Some states may belittle fisheries' yields because they do not want to avoid quotas and taxes, other states declare more, so as to show that the objectives of production have been met.

3 The role of oceans and waters in climate mitigation

3.1 By 2030, European ecosystem restoration efforts for capturing blue carbon attract multi-billion-euro investments

Background

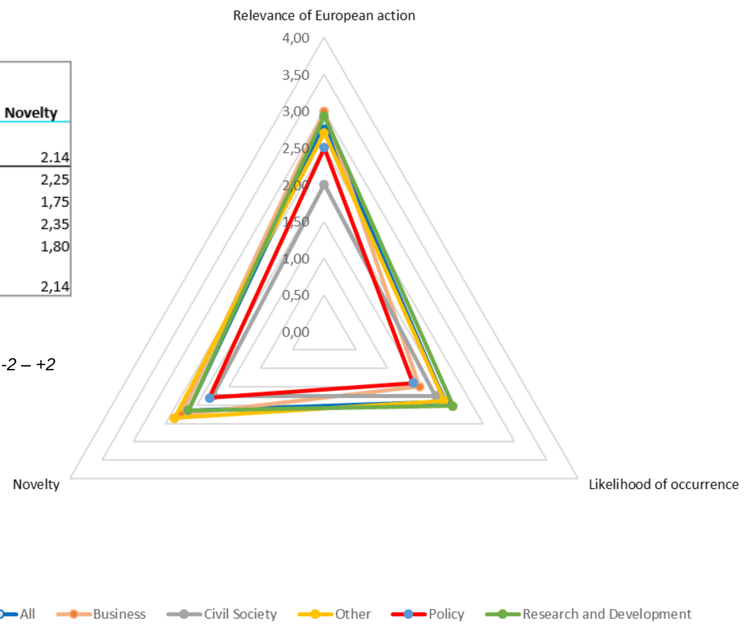
Blue carbon is the carbon stored in water ecosystems. Restoring coastal ecosystems such as mangroves, tidal marshes and seagrass meadows help sequester and store more carbon per unit area than terrestrial forests. Tidal marshes are being lost globally at a rate of 1-2% per year. They cover roughly 140 million hectares of Earth's surface. They have lost more than 50% of their historical global coverage. Seagrasses cover less than 0.2% of ocean floor globally, but store about 10% of the carbon buried in the oceans each year. Seagrasses are being lost at a rate of 1.5% per year and have lost approximately 30% of historical global coverage. When protected or restored, blue carbon ecosystems sequester and store carbon. When degraded or destroyed, these ecosystems emit the carbon they have stored for centuries into the atmosphere and oceans and become sources of greenhouse gases.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (135)	2.85	1.90	0.85	1.19	2.14
Business (12)	3,00	1,50	0,67	1,17	2,25
Civil Society (4)	2,00	1,75	0,75	0,75	1,75
Other (17)	2,71	1,88	0,65	1,24	2,35
Policy (10)	2,50	1,40	0,30	1,20	1,80
Research and Development (92)	2,93	2,02	0,98	1,20	2,14

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



For attracting multi-billion-euro investments for capturing blue carbon, the policy sector aligns largely with the Civil Society, while the Business sector aligns with Research and Development. The Research and Development stakeholders show overall higher ratings in all three criteria. The R&D and Business sector rate the topic as very important in relevance, quite new, and likely occurrence. The Civil Society sees the topic as less relevant than all other participants.

Comments of RTD Participants

1. There is a visible **increase in specialized blue investment funds and capital** and with these specialized investors associated with the increasing group of impact investors this can indeed be possible and should be **fostered by the EU as complementary action to the publicly funded projects.**

2. **Serious doubts that this will attract** private investors....

3 Private investors will not spend a cent if they can't bring out another 2 cents. **Corporations tend to see the ecosystem as something that is there to be used** and that **when spoiled, the state is there to recover**; can't see a profitable business that came out of it and unfortunately with no profit, no capital.

4 **EU action extremely important** in the sense of 'first mover' advantage. First movers and new technologies must be supported, within a **wider framework such as the Green Deal**. But action remains needed at **global level in order to make difference.** Assessment of the relative contribution to mitigate CO2 equivalent emissions show that potential is there, but **cannot make the difference at scale** and pace we need today. We **need bankable projects**, need to connect insurance companies: restoration and carbon capture is part of risk reduction strategies... hence insurance benefits.

5 The issue is **how to attract** private investors?

6 **Blue carbon** may be the GHG solution ...

7 The focus on sea and oceans is very short sighted. Water (and carbon) **retention in soils and inland wetlands is enormous** and the amount of carbon released from degraded soils and wetlands, in central Europe also by forest degradation, **has never been quantified.** Also, most European citizens live outside the coast and see the negative ecosystem impact. To mobilise them for action, **the inland water-related ecosystems have to be included.**

8 **The amount of carbon** that can be permanently stored in this way in European seas **is too small,** the justification for restoring marine habitats lies more in **their habitat and ecosystem functions rather than C retention**.

Expert team reflections on findings

Most respondents consider that capturing blue carbon is very important with a considerable impact on environment. For all stakeholders, the relevance, novelty and likelihood are equally weighted. EU could play the role of the “first-mover” but the attractiveness for private investment may remain poor. The involvement of countries without access to the sea could be high as the carbon retention in soils and wetlands is higher than in marine ecosystems. This challenge of carbon capture is crucial for climate change mitigation, but the concrete and efficient application is still depending on the will and action of several countries around the world. Respondents are clearly aware of this limitation.

3.2 By 2030, the EU together with principal polluter countries curb climate change and achieve slowing down the melting of ice on polar caps.

Background

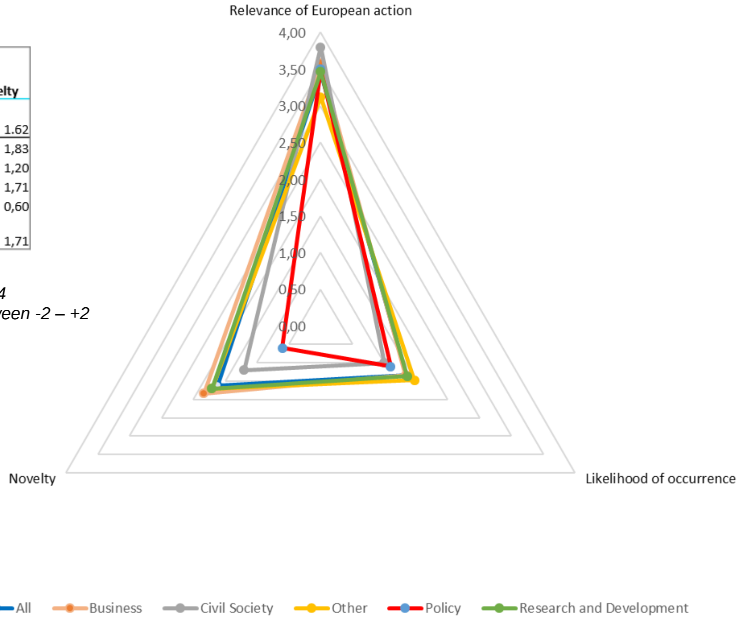
In the Arctic, the ice pack had reduced from 7,8 million to 4,2 million square kilometres from 1978 to 2016, which gives an indication of the ongoing global warming process. Ten years ago, the contribution of the melting of the ice of the polar caps to climate change (and related risk of slowing the great conveyor belt) was considered as low. Recent research showed that this contribution is crucial. The speed of the evolution of these two caps is one of the major indicator of the sustainability of our common environment. Moreover, the icepack reduction in summer allows the world maritime trade to use more and more the Artic route with increasing risks of pollution and warming. More scientific evidence is needed to establish relevant and anticipatory international rules and concrete measures.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (136)	3.45	1.34	0.89	1.57	1.62
Business (12)	3,58	1,33	0,75	1,50	1,83
Civil Society (5)	3,80	1,00	1,20	1,80	1,20
Other (17)	3,12	1,47	0,71	1,24	1,71
Policy (10)	3,50	1,10	1,00	1,70	0,60
Research and Development (92)	3,47	1,36	0,91	1,61	1,71

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



Preventing the melting of ice on polar caps is rated as the second- highest topic Relevance of European action, in total. The Civil Society is the sector with the highest rating of seeing it as extremely important. Yet, all participants see the likelihood of occurrence as somewhat unlikely. Concurrently, the Policy and Business sectors have a high discrepancy in evaluating Novelty.

Comments of RTD Participants

1 This is a really **optimistic timeframe**, and while it would be amazing, I think it's **unlikely to occur** - it requires **too much concerted effort and discipline from all parties** involved **-** all countries, and also all the citizens and stakeholders in each country.

2 I feel this is a **very optimistic trend** as this would require a **really concentrated and immediate action** in ALL the relevant countries and citizens.

3 **Too optimistic**, more achievable objectives should be proposed.

4 **I believe that EU can do it. I don't believe that USA, China, India, Russia, Brazil**, will do it. **EU MUST start putting carbon taxes** on the imported goods, money is the key and EU must start charging those that sell here their products without following EU standards.

5 Mission action for this trend should **focus on solutions. not research into regulations**. Solutions are at hand**, need to implement and work closely with industry and markets**. support innovators and first movers, the only way forward is to have a coalition of willing standing up and acting... and govt supporting through market and fiscal measures.

6 3.2 Certainly, it would be a great action, but **difficult for an EU action to attract the partners needed.**

7 Not sure if this trend would be effective in reducing the melting of ice as **other non-EU countries could increase carbon emissions.**

8 Unfortunately**, it seems unlikely** that a substantial goal can be achieved in ten years. The economic **interests for shipping to use the northern routes will be strongest in the coming years**. I fear that the countries concerned (USA, Russia, Canada, Scandinavia, etc.) will become aware of this later on.

9 Curbing climate change is **not possible if economic growth remains a target.**

10 Curbing climate change wi**ll not happen with government driven by business.**

11 It has been tried for years to **negotiate with main polluters** and to combat CO2 production. And **the result is electromobility with heavy ecological impact, solar and wind power with energetically very consumptive decommissioning** and, primarily for water, bioenergy with production of crops leading to **degradation of ecosystems from tropical rainforests down to European arable soils.** Form the later, a lot of carbon has been released. **Restoration of inland and coastal wetlands and, primarily, ordinary soils in Europe, would have much higher positive impact** considering the limited resources and time. Energy for that may be gained from pollution-free nuclear energy with fuel recycling.

12 As per previous comments, what is the **RD&I aspect of this objective**?

Expert team reflections on findings

A majority of respondents consider that curbing the climate change with a significant impact on the slowing of the ice caps is very relevant but very unlikely, not because it could not happen but because the time scale is too short (10 years!). Moreover, they think that the efforts in that aim for the EU do not really make sense if big polluting countries do not really share this effort (Russia, China, USA…). In addition, a strong European policy in climate mitigation will have probably significant negative impacts in the socio-economy of this region and will reduce the short-term competitiveness for Europe. Last, nothing is said about the huge efforts to be done in R&D&I for decades if a rapid influence on ice cap melting is expected.

All this will require a complete revolution in our systems of production and consumption. The New Green Deal is going in this direction. The EU is the most advanced political entity in terms of sustainable policies (at least in terms of legislation, not necessarily in terms of enforcement).

The melting of polar caps is the most impacting effect of global warming, with dramatic negative influence on the atmospheric and oceanic climate, through the impairment of the Great Ocean Conveyor. Hence, the change in our systems of production and consumption requires lots of research, development and innovation.

3.3 By 2030, Europe shows global leadership in managing transboundary inland waters to safeguard climate resilient water ecosystems.

Background

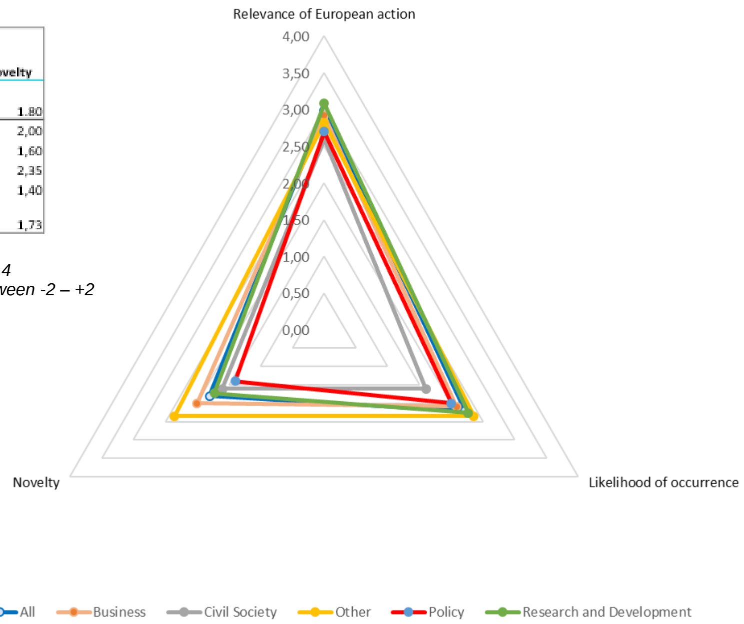
Good inland water management is a major driver for the climate resilient ecosystems and a way to reduce the carbon print of human activities. Forests and wetlands play an important role in the capacity of ecosystems to face rapid changes, to buffer excess of rain or dryness and to sustain biodiversity. They are also very efficient carbon sinks notably when multispecies forests can develop. But mega-fires are now frequent in several countries and the consequences are more and more costly with irreversible impacts such as the loss of soil after the destruction of the rain forest or chronic droughts even in rainy regions. The mismanagement of inland water has huge socio-economic impacts: ecosystems sustainability reduction, food security decrease, water stress, threats on human health, risks of mass migrations ("eco-refugees"). Water management can help maximize the services to human. Europe has resources, technology and skills to be a model for several countries under increasing water stress.

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (132)	2.98	2.21	0.80	1.15	1.80
Business (12)	2,92	2,08	0,67	1,17	2,00
Civil Society (5)	2,60	1,60	0,60	1,20	1,60
Other (17)	2,82	2,35	0,53	1,00	2,35
Policy (10)	2,70	2,00	0,90	1,30	1,40
Research and Development (88)	3,08	2,26	0,86	1,16	1,73

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The participants see a need for global leadership in managing transboundary inland waters, with high relevance in European action. Regarding the likelihood of occurrence, all sectors, with the exception of Civil Society, evaluate it as likely that global leadership will occur. Furthermore, the Policy sector is quite aware of this topic, while the Business is less aware.

Comments of RTD Participants

1 This should be required by the EC: after 20 years of the WFD, which requires this, in **many countries have not still a real implementation of these trans-boundaries issues** (the same can be said for MSFD and MSPD).

2 At last one points that really takes into account inland waters. **In spite of the title, which clearly mentions inland waters, most points focus on marine aspects**. It is nonetheless paramount to **maintain free-flowing** (preserve connectivity!), **healthy fresh waters**. They just sustain most terrestrial and inland aquatic biodiversity and associated so-called **"ecosystem services".**

3 With poor success of the WFD over the last two decades, one **can question whether Europe is really in a position to lead in this area.**

Expert team reflections on findings

The management of transboundary waters to better face the climate change is considered by a broad majority of respondents as a very important and likely evolution with high positive impacts. All stakeholders recognize the usefulness of safeguarding a resilient water ecosystem at the scale of Europe. Mega-fires and heat waves will become more and more frequent all over the world, including

Europe. The respondents are aware of these threats. The ecological role of wetlands and resilient rivers and irrigation systems is better known and measured. But how can EU become a leader in this field?

3.4 By 2030, offshore wind energy reaches to 10 percent of global electricity production.

Background

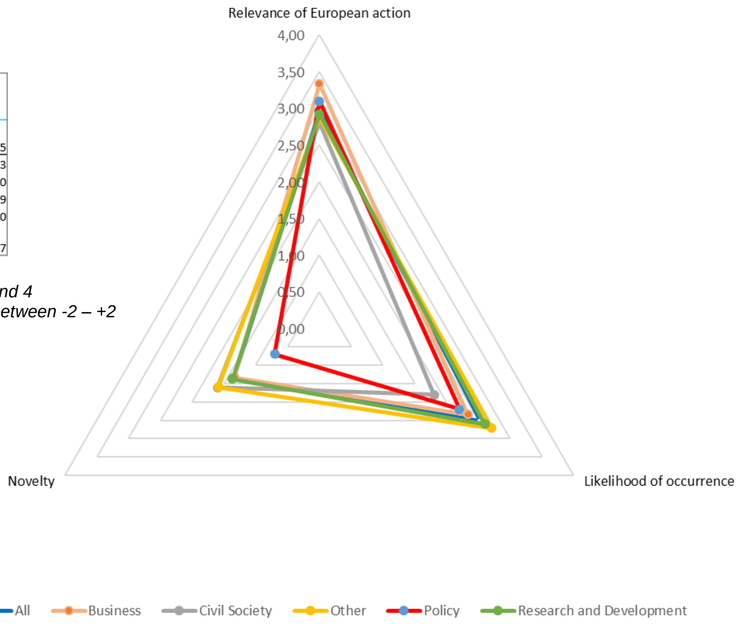
Wind energy is rapidly becoming the new norm for power generation and may deliver even 30% of all global electricity production by 2050, according to some estimates half of it from offshore wind. At the end of 2017, nearly 84% (15,780MW) of all offshore installations were located in Europe. The remaining 16% is located largely in China, followed by Asia and the United States. The number of countries planning full-scale development is rapidly growing. When looking at the future of offshore wind energy, two mega-trends are very clear. Firstly, the relentless drive to reduce the levelized cost of energy. Secondly, as a result of the *first trend, turbines and wind farms will become even larger.*

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (136)	2.96	2.53	0.93	0.58	1.35
Business (12)	3,33	2,33	1,25	1,00	1,33
Civil Society (5)	2,80	1,80	0,60	1,00	1,60
Other (17)	2,88	2,71	1,00	0,29	1,59
Policy (10)	3,10	2,20	1,40	0,80	0,70
Research and Development (92)	2,92	2,60	0,85	0,53	1,37

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



Regarding the offshore wind energy reaching 10 percent of global electricity production, there is a large consensus amongst the participants on its relevance. The topic seems to be relatively new to the participants except to the Policy. In general, the topic is seen as likely in occurrence, only Civil Society rates the likelihood clearly lower than the rest of the experts.

Comments of RTD Participants

1 I believe **integrated use of space is/should be the future** to positively impact ecology. Building of the **windmill parks can at first have a negative impact** on ecosystems, but once built, the parks **can offer a shelter for many ecosystem species** and create a space for restoration/ integrated use of space (e.g. with bivalve farming). **Monitoring of species (animal) health and diseases** should be integrated in the latter idea.

2 I believe this is doable as in many countries **renewable energies account for as much as 30-50%** of their annual consumption **so this can indeed be spread to EU**. On the other hand, current technologies (like floating) are being developed to reduce the ecological impact of their implementation.

3 I have a **very mixed feeling** about this topic, as I believe many of the potentially **negative impacts that off-shore windfarms are still unknown**. For this solution to be interesting we would have to be able to store this type of energy with minimal loss, really know **the effect of these farms on marine life** (seabirds, marine mammals) just to name a few, be really careful where we put them (bird migration routes, fishing grounds...) and really **develop floating farms** to avoid having to put concrete on and in the sediments like we are doing on land.

4 **More EIA, SEA and monitoring** should be applied before extending this, we risk thinking that the whole ocean can be covered by any device we invent.

5 Technology and procedures are in place. **EU, Canada, etc. have competitive advance** and experience in optimizing models, generators, operations... **should play a stronger role as part of equitable and sustainable development.** target of 10% seems not ambitious enough.

6 3.4 10% of the global electricity production **by offshore wind arrays is too large.**

7 **Ten years is the time it takes to set up and deploy 5 GW power in Europe**. The trend is good, the results should come.

8 A territory is like a sailing boat that tries to use the energies around her, not only wind power. For example, **an island should use wind on land and offshore power, solar panels, waterpower, marine heat energy** (in tropical areas), waves energy...

9 Indeed, a strong need to **further enhance research**, innovation and deployment activities in this field.

Expert team reflections on findings

The strong development of wind energy is not a novelty as Europe is already a world leader in this technology (85% of the world offshore renewable energy production). However, respondents have contrasted ideas about this relatively new energy sector: some of them think that the ecological impact could be higher than predicted, and some others think the opposite, notably on the long term. This justifies a specific effort in R&D&I for decades, not only in offshore wind energy but also in all the other marine technologies for renewable energies, notably for islands as they are surrounded by numerous forms of marine energy: waves, currents, thermic (in tropical areas), biomass… The EU should develop all these technologies and not only classical marine wind parks.

3.5 By 2030, major hurricanes inspire increased interest in improving coastal resilience, in particular by tripling global investment in wetland restoration.

Background

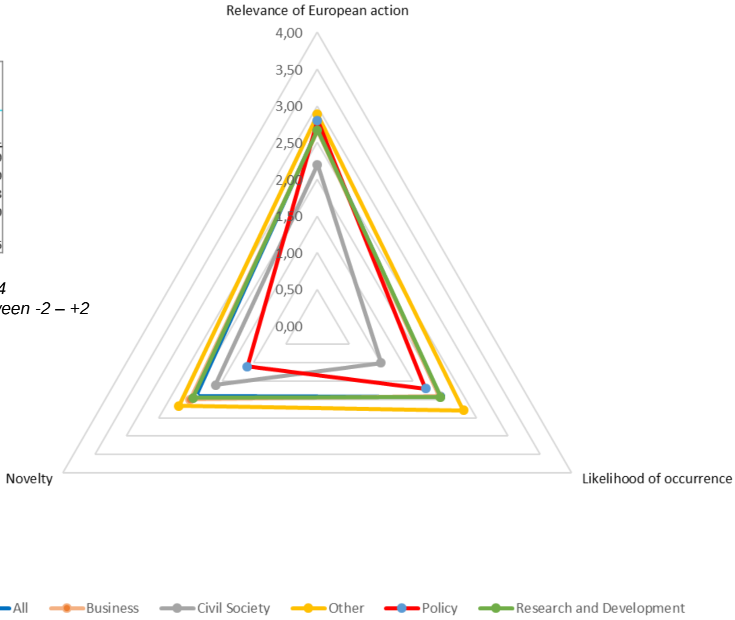
Research shows natural, “green,” solutions achieve a consistently greater cost–benefit ratio compared to most grey infrastructure solutions and can provide a significant reduction in total economic risk and offer efficient means for capturing greenhouse gases. For instance, the Indian Ocean Tsunami of 2004 provided evidence of the protective role of mangroves against extreme events impacting on coastal areas leading *to major restoration efforts in the region.*

Ratings of RTD Participants

Stakeholders	Relevance of European action	Likelihood of occurrence	Socio-economic impact	Ecological impact	Novelty
All (135)	2.69	1.93	0.84	0.98	1.91
Business (12)	2,67	1,92	1,08	0,92	2,00
Civil Society (5)	2,20	1,00	0,80	1,00	1,60
Other (17)	2,88	2,29	0,88	1,00	2,18
Policy (10)	2,80	1,70	1,10	1,10	1,10
Research and Development (91)	2,67	1,93	0,77	0,97	1,96

Number of participants per stakeholder group in brackets

Relevance, Likelihood and Novelty: Scores between 0 and 4
Socio-economic impact and Ecological impact: Scores between -2 – +2



The interest in coastal resilience is rated as quite important by the majority of experts and only the Civil Society rating this lower. The most divergent opinions come from Policy for rating Novelty and Civil Society for rating Likelihood of occurrence.

Comments of RTD Participants

1. This triple investment would be great; it is needed and would **have major economic impacts in coastal regions and businesses** but also allowing maintenance of coastal ecosystems.

2. Hurricanes in Europe? Despite this, rather than wetlands restoration, **I find more important to restore coastal seagrasses, dunes, seaweed fields, etc**.

3. **Building with nature, nature-based solutions, restoration economy provides opportunities also socio-economic** (jobs, risk mitigation, new investments, ...). EU can support first mover, build **competitive advantage** in EU, support equitable sustainable development. This is part of Green deal concept.

4. Relevance to Europe: yes, **particularly if we take into account overseas territories.**

5. **The awareness of coastal resilience will grow** undoubtedly, but the question is **too much focused on wetland restoration**, and this can be only one of the possible solutions, depending of the coast characteristics, **other measures would be needed.**

Expert team reflections on findings

The issue of more powerful hurricanes and the related investment for more resilient coastal wetlands is not really “new” for most of the respondents. They know that this issue is very important and very likely and that it is logical to expect considerable impacts of “perfect storms” in a near future. Actually, they emphasize the fact that several other ecosystems play a useful role in the reduction of the impacts of extreme coastal events: seaweeds fields, dunes, coastal seagrasses… Globally speaking this issue is a part of a more holistic approach described as “Nature based solutions” which relevance and usefulness is clearly observed in tropical areas (e.g., Mangrove reforestation to stabilise the sandy ground, to provide shelters to biodiversity protection and to reduce the direct impact of waves and currents. A majority of respondents consider that a mix of protection measures is also an opportunity for socio-economic local development.

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The EU introduced missions as a new instrument in Horizon Europe. Mission Boards were appointed to elaborate visions for the future in five Areas: Adaptation to Climate Change, Including Societal Transformation; Cancer; Healthy Oceans, Seas, and Coastal and Inland Waters; Climate-Neutral and Smart Cities; Soil Health and Food. Starting in autumn 2019, five Foresight on Demand projects supported them with foresight expertise and methodology.

This report provides the work in support of the Mission Board on Healthy Oceans, Seas, and Coastal and Inland Waters. It encompasses a comprehensive horizon scanning to identify trends and drivers, weak signals and wild cards. On this basis, five focal areas were proposed. A real-time delphi survey on further uncertainties incorporated a wider community of experts.

Studies and reports

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