Identification of new and cross-cutting technologies and solutions to boost blue growth

WP4 – Deliverable 4.2

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1 – INTRODUCTION

The Europe 2020 strategy clearly signalled the importance of industrial competitiveness for growth and jobs as well as for Europe's ability to address societal challenges. In this context, mastering and deploying "enabling and cross cutting technologies" will be critical in developing new products and services needed to deliver a smart and sustainable knowledge-based maritime economy. Advanced technologies will become essential for a sustainable management of our seas, for the development of the blue growth agenda and for a better understanding of the marine environment in a context of increasing pressure of human activities and the growing vulnerability of our coastal areas.

However, the broad range of topics and issues related to the development of marine and maritime technologies is extending from traditional maritime industries such as fisheries, maritime transport and dredging to fast pace & cutting edge emerging blue growth sectors such as ocean energy and blue biotech. The technology frontiers are constantly evolving thus demanding continuous monitoring and surveillance of technological developments. An example of such a rapidly evolving frontier is biotechnology and genomics for marine monitoring[1].

Substantial mapping work has been performed at EU level in marine and maritime research and technologies by various organizations such as SEAS-ERA[2], BONUS[3], the European Marine Board[4], and MARTEC ERA-net[5] to name but a few. However, these mapping activities despite their relevance and quality, are too often focusing on specific disciplines, sectors or geographical areas, and fail to look to the intersections between sectors and disciplines. This is exactly where JPI Oceans adds value. JPI Oceans aims to address broad priority areas which lie at the intersections of the marine environment, climate change and human activities (see figure 1).

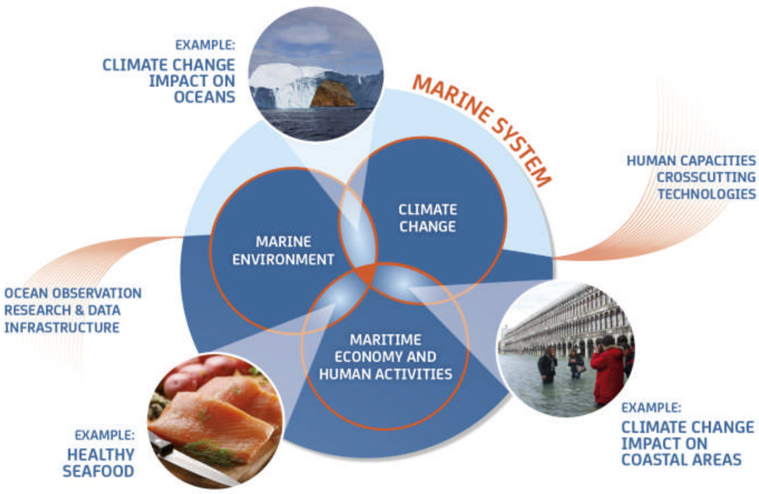


Figure 1: Cross-thematic areas of JPI Oceans (from JPI Oceans vision document, 2011)

[1] The potential marine applications of the latest genomic tools and techniques were recently compiled and presented in a policy brief and a white paper by the CSA project "Marine Genomics 4 Users".
[2] http://www.seas-era.eu/
[3] http://www.bonusportal.org/
[4] www.marineboard.eu/
[5] http://www.martec-era.net/

New and advanced technologies are enablers to reach any of the three goals of JPI Oceans, with sensor technologies as an example of essential developments for better observation and understanding of the marine environment.

This deliverable provides information primarily in a European context for "enabling and cross-cutting technologies", presenting examples of some key technologies, applications and mapping tools currently under development.

The content of the deliverable is based on the analysis of the outcomes of broad stakeholder consultations which took place in 2013 and complements deliverable 4.1 *"Mapping of maritime research and innovation strategies and funding".* The structure of this report builds on the document "State of play - analysis of stakeholders' consultation" presented to the JPI Oceans Strategic Advisory Board (StAB) and Management Board (MB) at the Oslo meeting in March 2014. In this structure each sub-chapter corresponds to a category of needs identified by stakeholders (see also 2.2 analysis of the stakeholders' consultation).

Gaps with relevance for JPI Oceans' joint activities are listed for each of these issues. As such this deliverable follows the structure adopted for the deliverable 3.2, 5.2 and 6.2. The outcomes of the present deliverable will be used to feed the draft Strategic Research and Innovation Agenda (SRIA) of JPI Oceans.

The report highlights needs and gaps to reach Strategic Goal 1 -'Enable the advent of a knowledge based maritime economy, maximising its value in a sustainable way' (**Chapter 3**), it identifies enabling and cross-cutting technologies (**Chapter 4**) and relevant procedures and sources for future scoping and analysis to enable JPI Oceans to identify new emerging technologies and to boost blue growth (**Chapter 5**).

The numerous gaps and needs call for improved joint programming and coordination of research and innovation strategies in Europe and for strengthening of the interface between industry and research. Finally, a set of recommendations is included in the last section (**Chapter 6**).

As a next step, Work Package 1 of the CSA Oceans project will integrate outputs of this gap analysis into a coherent Strategic Research and Innovation Agenda (SRIA) and recommend joint actions based on an assessment of the suggested proposals.

2 – METHODOLOGY

2.1 MAPPING OF MARITIME RESEARCH AND INNOVATION STRATEGIES AND FUNDING

In the first phase of the CSA Oceans project, Work Package 4 (WP 4) integrated mapping efforts conducted over years and gathered in the framework of completed or ongoing initiatives such as networks, platforms and projects. This included ERA-Nets (e.g. MARTEC and MARFISH), industry associations (e.g. European Dredging Association, European Ocean Energy Association), coordination and support actions (e.g. MARCOM+[6], EMARRES), technology platforms (e.g. WATERBORNE[7], EATIP[8]) and available databases as well as targeted information from European benchmarking and cluster studies. It compiled per Member State the research and innovation strategies to spur technological development in marine and maritime areas.

Thus report D4.1 "The mapping and preliminary analysis of the maritime research and innovation funding landscape in Europe" provided an overview of existing marine and maritime research and innovation strategies, as well as a preliminary analysis of EU efforts on national and international maritime R&D strategies. The report also looked at and common denominators between countries.
To complement this mapping, a broad consultation towards relevant stakeholders as well as the public was conducted in cooperation with Work Package 3 (Scientific needs, gaps and overlaps), Work Package 5 (Identification of options for a science to policy mechanism) and Work Package 6 (Needs and gaps in infrastructure and capacity building) aiming at collecting input on potential needs/actions/tools to achieve the JPI Oceans goals.

The consultation methodology and approach is fully detailed in deliverables 3.1, 4.1, 5.1 and 6.1.

2.2 ANALYSIS OF THE STAKEHOLDERS' CONSULTATION AND MAPPING OUTPUT

To fulfil the objectives of this deliverable, "**Identification of new and cross-cutting technologies and solutions to boost blue growth**", WP4 conducted an in-depth analysis of the stakeholders' consultation, supplemented with relevant desktop analyses. Analysis of the inputs of stakeholders and research funding agencies was carried out following the approach agreed by CSA Oceans partners involved in the development of the SRIA, in a combination of top-down and bottom-up.

As a first step, the needs and gaps related to maritime technologies and innovation highlighted by stakeholders were grouped into two broad categories addressing specific key issues:

- **JPI OCeans Goal 1 – "Enable the knowledge based maritime economy, maximising its value in a sustainable way.** This includes the needs and gaps to create a real ocean economy in Europe, to facilitate access to funding and financing for innovation players, and to accelerate an integrated approach to maritime spatial planning and coastal zone management

[6] http://marcom.eucc-d.de/
[7] http://www.waterborne-tp.org/
[8] www.eatip.eu/

- **Key enabling and cross-cutting technologies** which corresponds to one of the 10 operational objectives "*Foster enabling cross-cutting marine technologies across the maritime sectors*". This includes needs and gaps related to technologies to advance into *the deep, the far, the big, the harsh and the cold*, technologies to support an integrated European ocean observing system, as well as green and emerging technologies such as bionics.

The needs and gaps related to human capacity building and infrastructure are also covered as critical enablers. Growth in the blue economy will not be possible without an appropriately skilled workforce able to apply the latest technologies in engineering and other disciplines[9].

Secondly desk-based research was conducted in order to complement and confront the findings of the consultation. An indicative list of reference documents is available in Annex 1. Since the potential source of information is vast, only recent publications addressing cross cutting aspects of technological development and with a European geographical context were selected.

The desk-based research has been particularly useful to investigate how the topics that emerged from the stakeholder inputs are in line with the priorities of other organisations and their strategic documents.

As a third step, the most relevant needs and gaps were screened and selected, taking into consideration: a) The **principles of joint programming**:[10] to contribute to overcoming fragmentation and wasteful duplication of publicly funded research, and contribute to more efficient and effective use of public resources, and involve the key public initiatives within the area; and b) The **three strategic goals** and **ten specific objectives** of JPI Oceans[11], where those directly relevant for this deliverable are marked in red below.

- **Goal 1: Enable the advent of a knowledge based maritime economy, maximising its value in a sustainable way.**
- **Goal 2:** Ensure good environmental status of the seas and optimise planning of activities in the marine space.
- **Goal 3:** Optimise the response to climate change and mitigate human impacts on the marine environment.

[9] According to the Leadership2020 report from the stakeholders in the EU's shipbuilding industry the increased complexity of the products has created additional demand for highly skilled staff. Therefore a large part of the industry is suffering from a pronounced scarcity of skilled personnel and this is affecting growth.

[10] Communication from the Commission "Towards joint programming in research: Working together to tackle common challenges more effectively" http://ec.europa.eu/research/press/2008/pdf/com_2008_468_en.pdf

[11] JPI Oceans Vision document (approved by the Management Board, September 2011) http://www.jpi-oceans.eu/prognett-jpi-oceans/Documents/1253960389364

10 Specific objectives of JPI Oceans:

- **Foster enabling cross-cutting marine technologies across the maritime sectors**
- **Foster the marine bio economy in relation to new products, services and jobs**
- **Create the best enabling environment to maximise the development of marine renewable energies**
- **Develop the necessary knowledge and technologies to conquer the new deep-sea frontier**
- Understand and mitigate impact of climate change and pressure from human activities on the marine environment, to reach GES (Good Environmental Status) of our seas by 2020
- Improve understanding of marine ecosystems and their processes, in particular delivery of ecosystem services and the impacts of human activities
- Understand climate change impact on coastal areas and the design of marine and maritime structures and activities, to optimise mitigation and significantly reduce costly damages
- Develop and sustain infrastructure to support an integrated data and information base enabling industrial development and supporting maritime governance
- Develop a research to policy mechanism, in particular to support of the marine strategy framework directive and marine spatial planning and management
- Foster the inter-disciplinary human capacities that are necessary to the JPI goals

2.3 INDUSTRY EXPERTS IN JPI OCEANS STRATEGIC ADVISORY BOARD

The Strategic Advisory Board (StAB) was established by the Management Board of JPI Oceans following a nomination of a total of 17 outstanding experts from different stakeholder groups including industry. The StAB represents a recognised leadership in fields relevant to JPI Oceans, with the ability to bridge scientific, societal, innovation and policy issues. It has a substantial understanding of the organisational and operational setting of transnational cooperation with programmatic procedures and implementation of strategic research and innovation agendas, and finally the capacity to cover all major cross-cutting issues identified in the JPI Oceans Vision Document.

The StAB is mandated to provide support and advice to the JPI Oceans Management Board in the preparation of the Strategic Research and Innovation Agenda.

The 17 members are grouped in the three different stakeholder groups as follows:

- **Science -** 7 members coming from research centres, universities, technological centres, etc;
- **Industry -** 5 members coming from industry large-scale industry, SMEs, technological platforms, industry organizations, etc);
- **Civil society** - 4 members coming from public authorities and 1 Non-government organisations;

Furthermore it was agreed that the nominees not elected would be kept in a reserve list of independent experts in order to request their advice to the StAB and the Management Board when these boards need further inputs of experts to complement the expertise, skills and knowledge of the StAB. Detailed selection criteria of the StAB members can be found the JPI Oceans Terms of reference.

The list of StAB members is included in Annex 2a.

2.4 IDENTIFICATION OF JPI/CSA OCEANS STAKEHOLDERS AT A PAN-EUROPEAN AND INTERNATIONAL LEVEL

Identification of industry stakeholder networks at pan-European and international level was carried out as an integrated part of the overall identification of JPI Oceans stakeholders (WP 8 deliverable 8.2.). In this process JPI Oceans Management Board and the Strategic Advisory Board were consulted. The list of stakeholders was presented to the boards during their joint meeting in Dublin in February 2013. The list of stakeholders, including the selection criteria, was endorsed by the Management Board.

The following two main criteria were used to identify the most relevant stakeholders for JPI Oceans: **Geographical coverage** - only stakeholders that are involved in at least three or more European countries and **Relevance** - the goals and objectives of the stakeholder should be directly linked to at least one of the goals of JPI Oceans.

The industry reference list that emerged from this exercise was mainly categorised under Industry Associations and Technology Platforms (Annex 2c). Around 20 Industry Associations and Technology Platforms were identified as relevant to give input to the development of the SRIA. This identification of stakeholders was used when the CSA Oceans partners carried out their consultation during May-June 2013. A workshop conducted on 30.5.2013 was dedicated to the stakeholders from industry see list in annex 2c. The identified list of industry experts at a pan-European and international level includes both individual names and the Industry Association or Technology Platform they represent.

3 – JPI OCEANS GOAL 1 - ENABLE THE KNOWLEDGE BASED MARITIME ECONOMY

Analysis of the stakeholders' material from workshops, research funding agencies and the open web consultation concentrated on identifying needs and gaps of common nature in relation to the strategic goal of JPI Oceans, in particular Goal 1 – "Enable the advent of a knowledge based maritime economy, maximising its value in a sustainable way".

The outcome of this work provides a foundation for each topic where research and innovation needs gaps and barriers are described. Furthermore, the document provides information on research areas where more cooperation is needed and areas with the potential to create synergies and strengthen cooperation at EU level through regional or pan-European approaches and alignment of priorities of among JPI Oceans member countries. Each section identifies where stakeholders see the JPI Oceans added value.

The needs and gaps related to Goal 1 proposed by stakeholders were grouped into four categories:

- Promotion of a knowledge based ocean economy;
- Maximising the knowledge outcome and economic impact from research and innovation;
- Facilitating access to funding and financing streams and mechanisms;
- Accelerating an integrated approach to maritime spatial planning (MSP).

3.1 PROMOTING THE KNOWLEDGE BASED OCEAN ECONOMY

According to Eurostat, 3-5 % of EU’s gross domestic product (GDP) comes from the maritime sector. Some 90 % of foreign trade and 43 % of intra-EU trade take place via maritime routes. According to recent figures European shipbuilding accounts for 10 % of global production — and it is number one in the world for value of production. As regards boating, almost 100 000 boats are in operation around Europe in either fisheries or aquaculture. Next to these traditional industries, other more recently developed activities, such as mineral extraction, marine biotech and offshore renewable energy, are evolving fast. The maritime economy is a reality. Its contribution to the overall economy has been the subject of studies and initiatives in Europe (Blue Growth Agenda) and internationally such as the National Ocean Economics Program (NOEP) in the United States[12]. However, according to recent reports the maritime economic activities of Europe are limited compared to the enormous untapped potential[13] [14]. The awareness of the value created by the maritime economy is relatively low, a perception widely expressed across the stakeholder workshops.

More could be done to strenghten the visibility of the ocean economy and JPI Oceans could and should play a role. Stakeholders expressed the need of a single strong voice, also representing the industry, to raise awareness of the vast potential in the seas and oceans.

> ***Stakeholder Workshops:***
>
> *How we communicate is quite essential; we have to educate our surroundings and engage in the dialogue with the society, science and technology. If we fail there is no one to blame but ourselves.*

[12] http://www.oceaneconomics.org/
[13] http://ec.europa.eu/maritimeaffairs/documentation/studies/documents/blue_growth_third_interim_report_en.pdf
[14] "The Future of Blue Economy: Lessons for European Union", Wlodzimierz Kaczynski, School of Marine and Environmental Affairs, College of the Environment, University of Washington, Seattle, WA

Some stakeholders compared the situation with space research: "**We are at the level of space 50 years ago, we should be ambitious and strive towards a "European Ocean Agency, something similar to the space agency**".

Significant efforts have, however, taken place recently. Some member countries have developed national strategies for maritime technologies and innovation as illustrated in deliverable 4.1. Furthermore, Blue Growth as one of 12 focus areas for Horizon 2020 increases awareness and opportunities for blue growth in Europe. Hopefully the Blue Growth Focus Area will pursue the efforts of the Oceans of Tomorrow calls to capture the cross-cutting nature of marine research and the potential for discoveries in one area to have applications in others. However, in many countries maritime issues are still not on the top of the agenda despite the potential benefits that could result from a better understanding and knowledge of the value of the maritime economy.

> ***Challenge for Sustainable Blue Growth:***
>
> *"The state of the seas and oceans is not yet a concern shared by all countries and governments …!"*

To promote the ocean economy it is necessary to document the value of the maritime economy, including the ecosystem services and goods. Over the last decade, much progress has been made to better understand how the natural environment is contributing to our economic performance, although much of the efforts have focused on non-marine ecosystems. Knowledge of marine ecosystems services and the economic value of such goods and services remain scarce.

Another important common message across the stakeholder groups was **"the need for knowledge transfer and dialogue to bridge the gap between industry and science".** Stronger links between science and industry are needed, and "JPI Oceans can really give a fresh look", as voiced strongly in the ERA activities workshop and echoed in the workshop with UN and international organizations. Cross-sectorial and multidisciplinary cooperation between science and industry was a need broadly expressed, but which is not yet institutionalized. This need for stronger relationship between industry and science echoed very well one of the actions planned in the recently adopted communication from the Commission[15] "Innovation in the Blue Economy: realizing the potential of our seas and oceans for jobs and growth". The Commission plans to establish a Blue Economy Business and Science Forum which should provide opportunities for cross-fertilization of ideas and research results between industrial sectors, NGOs and other stakeholders with a common interest in the blue economy.

JPI OCEANS ADDED VALUE

- **JPI Oceans** can play an important role in educating society on the value created by the maritime economy and thus increase "ocean literacy". In a long-term perspective, we should be ambitious and strive towards a "European Ocean Agency", aiming to give oceans economy a national and European status, and make it a priority;
- **JPI Oceans** could promote and help defining the marine and maritime as an economic sector. It should highlight at the highest level the gap between investment and impact on the oceans and ensure support for more work and employment opportunities in this field;

[15] COM(2014) 254 final/2

- **JPI Oceans** could manage fora and platforms to facilitate concrete economic and societal outputs;

IDENTIFIED NEEDS AND SPECIFIC OBJECTIVES

Focus	Identified needs	Specific objectives
Coordination	There is a need for a dedicated, strong voice in Europe to raise the awareness of the potential of our seas and oceans.	• Develop a more coherent strategy of ocean literacy, including dedicated policy briefs
Research / Coordination	Better understanding of the value of the maritime economy to address the blue growth agenda. Development of criteria and goals for evaluating long term economic sustainability of maritime services	• Valuation of ecosystem products and services will advance our knowledge on socio-economic effects of different management options. • Standardize methods and terminology for socio-economic assessments.
Training / awareness raising	Lack of attractiveness of jobs in the maritime sector is a barrier to recruitment	• A more coherent strategy of ocean literacy and training programmes will increase the awareness of the engineers & technicians of tomorrow about marine and maritime opportunities.

3.2 MAXIMISING THE KNOWLEDGE OUTCOME AND ECONOMIC IMPACT

Generating new knowledge and turning it into new products and services is crucial to maintaining and enhancing the EU's competitiveness at large and the marine sectors in particular. Transforming the results of scientific research into new commercial products is, however, a complex process involving a broad range of actors. The Commission's Annual Growth Survey for 2014[16] reported that there is not yet enough collaboration between the public and private sectors on innovation and that the inability to transfer research results into goods and services as well as a growing skills gap are affecting knowledge intensive sectors. There is an important need to ensure that researchers and industry work closely together and maximise the social and economic benefits of new ideas.

Companies are essential for translating good ideas into jobs and wealth. Having science and industry work together will require a mind-set shift on both sides. However, efficient knowledge transfer is hindered by a range of factors, including: cultural differences between the business and science communities; lack of incentives; different goals such as publication versus innovation and

> ***Stakeholder Workshops:***
> *"Knowledge from science and technology will only create economic impact and jobs if we foster and develop a European industry capable of implementing this innovation in a competitive way. "*

[16] http://ec.europa.eu/europe2020/pdf/2014/ags2014_en.pdf

patenting; legal barriers; and fragmented markets for knowledge and technology. One stakeholder argued that in maritime conferences there are too many scientists present relative to representatives from the maritime industry sectors, often ten to one.

Compared to other sectors, the marine and maritime scientific communities in Europe are small and fragmented, thus weakening the innovation and knowledge transfer. Mature industries, often prefer to conduct the research themselves, rather than prepare and conduct publicly funded research projects with the science community. More tailor-made systems are needed, where JPI could play a role.

Intellectual property rights (IPR) constitute a challenge that limits open discussions between science and the economic sector. Many scientists are not ready to cope with the associated legal aspects and restrictions. Some say that we need to look at new schemes to stimulate cooperation on research, development and innovation between the science community and the industry. More efforts need to be put into knowledge management and knowledge transfer from projects to optimise cost-benefit. We should put in place new ways to enhance the quality and usefulness of knowledge outputs from projects as there is no point in establishing excellent knowledge transfer mechanisms if it cannot be applied and put to use.

JPI OCEANS ADDED VALUE

- **JPI Oceans** could design and implement a coherent plan for design, management of innovative research projects to improve cost-benefit for projects addressing issues with a commercial potential. Knowledge on commercialization from academy to industry and understanding of industrial needs are essential elements;
- **JPI Oceans** can play a role in identifying the opportunities by bringing industry and science closer together in research projects. JPI Oceans should strive to identify best practices for pushing academia to better incorporate industry needs in project designing;
- **JPI Oceans** could provide opportunities for "*out of the box*" thinking and planning. It could be a community-based match-making process which would entail significant synergy effects, and attract interested parties. It could create a protected zone for exchange of ideas freely, such as think tank meetings designed to increase openness of discussion, under rules similar to Chatham House Rule[17].

IDENTIFIED NEEDS AND SPECIFIC OBJECTIVES

Focus	Identified needs	Specific objectives
Managem ent /coordinat ion	Need for more knowledge and for cross-cutting areas of research and innovation between economic activities, incipient transfer of knowledge and good practice	• Examine and overcome barriers in the RTD system currently preventing maximum innovation and impact.

[17] http://www.chathamhouse.org/about/chatham-house-rule

	between companies. Improve knowledge transfer and integration of maritime sectors. Improve cooperation and enhance knowledge transfer between knowledge-producers and the knowledge-users.	• Involve industry and public administration in knowledge-building activities • Map vocabularies to simplify the dialogue between scientists and other actors.
Coordination	More international coordination efforts and change in national procedures are needed to facilitate cross-border (regional, EU or global) alignment of efforts.	• Create a coherent plan for design and management of innovative research projects to optimise cost-benefit

3.3 FACILITATING ACCESS TO FUNDING AND FINANCING MECHANISMS

Challenges in accessing finance to bring ideas to the market place are not new. The so-called *valley of death* is a recognised European weakness compared to other parts of the world. The recent financial crisis has further complicated the situation. Furthermore, marine and maritime emerging sectors are not attracting the attention of venture capitalists and other private financing institutions. New and innovative firms are particularly important, as they often exploit technological or commercial opportunities that have been neglected by more established companies. Well-functioning venture capital markets and the securitisation of innovation-related assets and intellectual property are key elements for financing of innovative start-ups, often combined with sources of public funds.

> ***Stakeholder Workshops:***
>
> *"Putting aquaculture at sea is big business, but nobody can afford it"*
>
> *"If an ocean industrial activity is a European priority, they should put the money for it and not ask industry too much to fund; we can't."*

In the fast emerging sector of Blue Growth, ocean energy, the approach developed in the United Kingdom illustrates the need to pool different sources of funding and financing to help a sector to deploy[18]. The marine renewable energy industry is still in its early stages, and further research is needed to determine how best to exploit the resources in an economical manner. However, the UK is already seen as a world leader and focal point for the development of wave and tidal stream technologies. In addition of an excellent marine resource, and, the UK could leverage its expertise in oil and gas exploration to develop related wave and tidal stream services. Such approaches are worth exploring in an European context.

Research is paramount for innovations and there is a gap between RTD investments and impact on the Oceans that is well recognized. There are some parallels between the early space industry and the current development of the ocean industry such as transfer of applications/technologies from one sector to another one. Another compelling argument is that many of the customers and suppliers are the same across different maritime sectors. In this context, and If ocean is the new space, the ratio of public investment versus turnover in the development of maritime activities should match that of the space industry (in its early phases establishment of NASA/Apollo programmes). It is beyond the self-funding capability of today's maritime industry to advance like the space industry. Even big maritime companies are small compared to the space industry. Public investments and incentives are needed - and are paramount in the precompetitive stage.

Stakeholders suggested support for practical testing of technological innovations and support for large scale industry driven research- and technology projects. It was proposed to establish a fund for testing and piloting of new innovative solutions and technologies, and to establish a marine and maritime non-sector specific technology fund to fuel cooperation and clustering across ocean sectors and marine science to support green technologies.

[18] https://www.gov.uk/government/groups/117

Funding mechanisms for joint projects are well developed from experience with ERA-nets and Art.185 projects. These projects and true bi- and multilateral projects meet challenges from differences in funding mechanisms and rules for funding between the partner countries. These challenges are shared by all JPIs and should be discussed at a higher level such as the GPC.

JPI OCEANS ADDED VALUE

- **JPI Oceans** could be a marine hub for European research funders in international programmes and a forum for Member States on ocean related international aspects.
- **JPI Oceans** could initiate public-private partnerships for funding of research with industry.
- **JPI Oceans** could impact the finance market by communicating the opportunities of the seas and oceans to the community.
- **JPI Oceans** could advocate the blue growth instrument in European business enterprise to relevant industry partners.
- **JPI Oceans** could initiate and prepare an application for a Marine KIC.

A repository of public funding opportunities for marine research is accessible in the deliverable 4.1.

IDENTIFIED NEEDS AND SPECIFIC OBJECTIVES

Focus	Identified needs	Specific objectives
Management	Attract more innovative SMEs into marine and maritime research and innovation	• Financial support, tax deduction schemes or other mechanisms should be explored
Coordination	Increase access to competent capital willing to take technology risks in the maritime industry.	• Market stimulation and mechanisms to attract investors from traditional marine and maritime sectors

3.4 ACCELERATING AN INTEGRATED APPROACH TO MARITIME SPATIAL PLANNING

> ***EU Commissioners Maria Damanaki and Janez Potočnik :***
>
> *"Only if we coordinate the various activities taking place in our seas can we make access to maritime space more predictable for investors and at the same time reduce the impact of maritime activities on the environment."*

With rapidly increasing demand for maritime space for new activities, from renewable energy to aquaculture installations, better and coherent planning of maritime activities at sea is indeed needed. In coastal and maritime areas, many activities compete for the same space and resources. The EU recently adopted a framework directive for Maritime Spatial Planning (MSP). This will help Member States develop plans to better coordinate the various activities that take place at sea, and ensure efficiency and sustainability.

Furthermore it will help reduce or avoid potential conflicts between the diverse uses and create a stable environment attractive to investors, thereby contributing to sustainable growth. These are some of the benefits put forward by the EU Commission for the proposing a framework Directive for maritime spatial planning and integrated coastal management.

The CSA Oceans stakeholder consultation confirmed that maritime spatial planning is a key to create new growth opportunities across all maritime sectors. Human activities on European coasts and seas are increasing and have significant growth potential, however, limitations due to competition for space or environmental threats occur more frequently.

Stakeholders also highlighted the needs for large scale observatory networks, monitoring at local scale, access to data, cooperation, training for science-policy-dialogues, and more efficient marine spatial planning and governance of the EU maritime domain. Efficient governance is essential at national, regional and EU level as well as internationally.

International major challenge:

"To maintain healthy and productive oceans and seas in a context of increased international competition to access marine resources, short term based policy making, and lack of efficient global governance and accountability" (IHO)

The MSP Directive sets minimum requirements for the drawing up of national maritime spatial plans. These plans will identify all existing human activities, taking into account land-sea interactions, and the most effective way of managing them. Spatial management in the marine environment has developed rapidly, and some European countries have already put in place MSP. In the EU MSP is defined as a process for public authorities of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives. *Properly implemented it will, at the same time, support the industry, the protection and good environmental status of the seas and oceans and the society.*

MSP is expected to provide the industry with a long-term perspective on where, when and how they will be allowed to operate in the oceans. In the future, marine and maritime industrial activities and resource exploitation could be licenced based on advanced knowledge and fundamental understanding of the systems they operate in and the impact of cumulative pressures. The space allocation policy should emphasize where it is most suitable for the various activities to operate, letting them take advantage of natural local conditions, and should also assess the safety perspective, future impact of climate change and risks from hazards in the area. Research to support new management systems can contribute to a better integration of marine environmental concerns with industrial activities in coastal and marine spaces.

The planning should be based on agreed standards for assessment of the various human activities and industries, and their interactions affecting society, economy and environment. It should be predictable, allowing some flexibility, address market aspects and competitive conditions and ensure that management of the activities are in accordance with the principles of sustainable development. For fisheries and aquaculture MSP is a way of implementing ecosystems based management. To ensure sustainability, regional differences in ecosystems and socio-economic conditions need to be a driver for the planning. It should take into account comparative mapping of human interests and identify current and future marine ecosystem opportunities and vulnerabilities. It should aim to be flexible in response to local conditions through the year.

For example, if dredging is required in an area that is an important spawning ground, rather than prohibiting the activity a management plan could allow for dredging outside of the spawning season.

Comprehensive scientific knowledge of the state of the ecosystems, the impacts of human activity and of the vulnerabilities of ecosystems is an essential prerequisite for successful spatial planning (Navigating the Future). In particular there is a need for long-term research and monitoring programs that address changes in conditions for seafood production. This will provide a knowledge base for conducting sustainable aquaculture production in decades from now.

This kind of research and planning calls for a multidisciplinary approach, and one example is to improve integration of fisheries and aquaculture research and expertise in societal and business related plans.

It is a challenge to make scientific data for the planning process accessible and integrate it with existing knowledge. We need tools to bridge the gap between science and policy making, a language that can be understood by scientist, politicians and users. Information about nature and ecological relationship may be of little value if not understood and accepted by end users. New management framework that incorporate new principles in the utilisation of resources such as e.g. result-based management to maximise output of product and services and ensure internalisation of costs in production to measure and mitigate ecosystem effects.

JPI OCEANS ADDED VALUE

- **JPI Oceans** could be a portal or a coordination platform home for modelling and big data such as atmosphere, oceans, biotech and genomics. We need big data, new modelling and support for the development of new services based on user requirements. New modelling approaches would address inter-disciplinary prediction and complex environments e.g. coastal marine hazard tracking which integrates ecosystems, climate and economics through better access to existing high performing computing facilities. Any activity would have to be carry out in accordance with existing frameworks such as EMODnet;
- **JPI Oceans** could develop and advance indicators to evaluate and assess the impact of various human activities on marine ecosystems. Understanding of the key ecological and biological processes can be used to establish indicators for sustainable economic activities. This work should integrate and build upon the current activity taken place in the JPI Ocean Pilot Action *"Joint funding of the scientific intercalibration exercise for the Water Framework Directive (WFD) coastal and transitional waters in the North-East Atlantic"*;
- **JPI Oceans** could promote good practices of maritime spatial planning.

IDENTIFIED NEEDS AND SPECIFIC OBJECTIVES

Focus	Identified needs	Specific objectives
	Common, public and legally accepted standards for assessing the environmental impact of industry, before and during the operational phase. Understanding the activities' impact on economy, jobs and nearby coastal societies. Valuation of ecosystem goods and services and the vulnerability of the ecosystems.	• Establish a common understanding and agreement of economic, social and ecological sustainability. • Understand the ecological risks and consequences of industrial and economic development in a long term perspective.
Management	Understand the expected environmental impacts of the different and multiple activities. Baselines need to be established to coordinate existing information on different features of marine space, including sea waters, sea bottoms and living resources.	• Interdisciplinary and multidisciplinary research to establish methodology for understanding the interactions between the various sectors and the environment.
	Need for tools for actors that are involved in coastal development so they can digest, accumulate and use "state-of-art" knowledge from political, social, economic and natural science in their daily work and bridge the gap between advanced science and local marine and coastal zone management.	• New models which combine marine ecosystems and economic dynamics; based on multi-disciplinary approach. • Assess the impact of normal operational activities, and the risk and consequences of any accidents
Management	Need planning strategies based on the application of ecosystem planning, climate change mitigation, reaction against natural disasters, or sustainable use of resources, among others	• Networking - Interdisciplinary and cross-sectorial dialog requires a "common language" through a semi-formal mechanism /communication platform,

4: KEY ENABLING AND CROSS-CUTTING TECHNOLOGIES

4.1 A NEW JOINT INDUSTRIAL APPROACH FOR SCIENCE, INNOVATION, AND ENGINEERING

"Foster enabling cross-cutting marine technologies across the maritime sectors" is one of JPI Oceans' ten operational objectives.

A new "technology push" is strongly needed in order to spur the maritime industries towards increased job and value creation while at the same time taking responsibility for mitigating the effects of climate change, pollution, deterioration of nature and unacceptable use of natural resources. To succeed it is necessary to take decisive steps in bringing the maritime sectors, together with regulatory bodies/ decision makers and academia. Technology will be a prerequisite for success.

Stakeholders have confirmed that there is insufficient cooperation and networking activities between maritime sectors, despite the fact that they share many common interests. The technology and engineering community is very scattered and specialised. A common message was: **"Long term research, observation and monitoring programs are needed for creating a sustained and enabling environment for the development and integration of new technologies**".

The spectrum of technologies with a potential as enabler for oceans related activities is extremely broad. All the basic cross-cutting technologies such as nanotechnology, materials, sensors, genomics, robotics, cyber technology and energy technologies are relevant for ocean applications.

> ***Stakeholder Workshops:***
> *"Marine biotechnology and –omics as well as joint modelling efforts are important technologies, and actions at a European level are needed."*

To boost blue growth, industry need to win new areas for production and activity, and to push "the deep, the far, the big, the cold and the harsh" boundaries. These challenges will require scientific and technological competence to allow industry to operate safely and sustainably, often in extreme environments, such as in the Arctic.

Maritime industries have substantial experiences in their respective sectors. Despite their differences they also face common challenges. Crossing sectorial barriers and bringing the sectors together can contribute to radical advances. Shipbuilding and other maritime technologies have to contribute with significant changes.

In the coming decade innovation will be essential to drive a thriving maritime economy, and technology innovations will be needed to support smarter, greener and more efficient activities, whilst maintaining responsibility towards nature[19] Innovation rarely occurs in isolation; it is highly interactive, multidisciplinary and increasingly involves collaboration by a growing and diverse network of stakeholders, institutions and users. Development of fully functioning knowledge networks and markets could have a significant impact on the efficiency and effectiveness of the innovation effort[20].

[19] European Marine Board, Position paper 20 Navigating the Future IV, June 2013
[20] OECD Innovation strategy http://www.oecd.org/site/innovationstrategy/

There is need for a joint approach between marine scientists and engineers to take further steps to realize the opportunities that lie ahead in the maritime sectors. This calls for an integrated and interdisciplinary involvement of researchers from different scientific disciplines and engineering, and a closer cooperation and integration between science, engineering and industry. Europe needs to improve in translating knowledge into new marketable products and services. It is of vital importance to connect users and producers of science and technology. Lack of knowledge transfer between knowledge-producing sector (institutes, universities etc.) and knowledge users (business and society), can be counteracted through clustering industry and research.

> ***Stakeholder Workshops:***
>
> *"Marine science can benefit from working closer with technology providers and different industries to enable more efficient ways of conducting science, brokerage and targeted workshops "*

Businesses are essential to transform science and technology development into jobs, products and services. For shipbuilding and other marine technologies, funding opportunities for advanced technologies, technology transfer and commercialization will be necessary. To make it worthwhile to invest in in maritime activities, the industry stressed the need for stable and long-term framework conditions[21] to capitalise on investments; a framework that should be harmonized across sectors and regions. Some regulatory needs were noted, such as the need for a space allocation policy for seaborne structures and clear rules to secure access and regulate ownership. Environmental responsibility is required for commercialisation of deep-sea resources. An agreed standard and protocol for assessment and approval of the impact of industrial activities on the environment would contribute to a predicable framework for the industry and it would benefit the protection of the environment.

Instruments are needed along the whole chain from science and technology to innovation. Stakeholders addressed the need to build infrastructure with industrial potential, benefitting many sectors operating in the ocean space. Pilot and large scale demonstrators are particularly important for commercialisation of ideas to get them over "the valley of death".

Enhanced collaboration on development and application of technologies for the maritime sectors is an obvious solution to boost blue growth. Stakeholders strongly seek venues for production and dissemination of knowledge and ideas. The arenas should be multi-national, multi-sectorial, multi-disciplinary and involve multiple groups of stakeholders, including academia and industry (including supply-industry), who are the main users of knowledge and innovation for the blue industry. Policy-makers, other stakeholders from society, including consumers, as well as venture capitalists, should be considered as players in these venues.

Human capital[22] is the essence of innovation. The competence of the employees is the key to improve economy and safety in the marine/maritime industry. The industry needs competence to commercialize innovation. Some sectors are less mature than others; and are in particular need for highly educated people.

[21] Policy-issues are in general addressed and covered by CSA Oceans WP 5, Deliverable 5.2.

[22] Needs for skills and human capital in the maritime sectors are in general addressed and covered by CSA Oceans WP 6. Deliverable 6.2

There is a need for specialist training of engineers, technicians, etc. to introduce new operational practices and new technologies, also using simulators and demonstrators (e.g. for adapting offshore technology to aquaculture). Hence, universities, colleges and vocational training centres are essential nodes in the innovation system. There is need for multidisciplinary education of scientists and scientists in industry. PhD students and post-docs in industry-related projects will bring academia and industry closer together at an early stage in a research career.

JPI OCEANS ADDED VALUE

- **JPI Oceans** could be the preferred platform to engage and maintain a discussion forum and facilitate networking between business, science and technology, engineering and economy and regulatory bodies across disciplines, sectors and national borders.
- **JPI Oceans** could increase the engagement of industry and promote synergy and transfer of technology between sectors, identifying needs for technology and devising new solutions in the short and long term.
- **JPI Oceans** could foster inclusion of smaller entrepreneurial businesses in broad-scale projects.
- **JPI Oceans** could stimulate industry-university cluster with strong relation to the research community for a knowledge based maritime industry.

4.2 TECHNOLOGIES FOR AN INTEGRATED, EUROPEAN OCEAN OBSERVING SYSTEM

RATIONALE

In the context of large scale oceans observatory networks, promotion of mechanisms that standardize measurements, indicators and data formats are needed. An improved understanding of the functioning of marine ecosystems is required for a broad range of scientific and innovative developments. Added to this is the need for geological data to better understand the seabed and sediments, hazards and risks.

An integrated, European ocean observation system will serve a wide range of marine environmental, climate change and blue growth issues. It would support EU marine and maritime related policies and provide science and industry with the information needed for their activities. Policy makers need information/instruments for monitoring as basis for plan. EOOS provides such an instrument. In general EOOS provides data for environmental analyses, assessments and forecasts for marine and maritime polices, including hazards, defence and security.

From an industry perspective an important achievement with EOOS would be the deliverable of data needed for implementation of maritime spatial planning, which is the basis for a knowledge-based and sustainable distribution of sites and licenses for industrial activity.

It may identify areas that are particularly vulnerable or particularly interesting for industry purposes. Furthermore it may provide data for assessment of environmental impact from the activity during the operational phase, systems for reporting hazards etc.

Towards a European Network of Marine Observatories for Monitoring and Research (16 Sept. 2010, Brussels)

The Forum culminated in a unanimous call from its participants for the prioritization at national and EU level of actions to deliver a long-term, stable and integrated network of strategic marine observatories, installed and operated through multi-national cooperation and support, providing consistent in situ data from the seas and oceans in support of the EU Integrated Maritime Policy and as a driver for smart, sustainable and inclusive growth in Europe (Europe 2020)".

Today observation is based on multi-platform and integrated systems (using buoys, satellites, ships, autonomous underwater vehicles, HF radar, oceanic profilers, gliders etc.), also assuring quasi real time, and quality controlled data availability for both researchers and society[23].

Technology developments (e.g. ICT, electronics, robotics, sensors, nanomaterials, biotechnologies, -omics, etc.), are key to improve more efficiently and smartly the knowledge of the marine environment and its resources. New observation technologies will be needed to improve underwater vehicles capacities for hot-spot observation and sampling, for sub-sea instrumentation deployment and maintenance, to foster interoperability of underwater vehicles and payloads on the wider range of research vessels and in connexion with deep-sea observatories, and to deliver a digital map of the entire seabed of European waters by 2020 (ref. CSA Oceans Deliverable 6.2).

JPI OCEANS ADDED VALUE

- **JPI Oceans** could coordinate an International board of experts from industry, regulatory bodies/ policy makers and academia to address cross-cutting challenges and provide recommendations on organisation, technology, components, system design, operational and financial responsibilities to facilitate a holistic approach. The work should take place within the framework of EOOS.

Focus	Identified needs	Specific objectives
Coordination	Organise general support to an integrated and fully operational EOOS from the maritime sectors and academia.	• Bring stakeholders from maritime sectors together with academia to discuss opportunities, needs and solutions • Provide advise on how to best implement EOOS to relevant decision makers • Identify specific bottlenecks in technology, components, systems organisation and responsibilities

[23] The need for infrastructure to support a fully operational EOOS is covered by CSA Oceans WP 6 in deliverable 6.2.

4.3 TECHNOLOGIES FOR SAFE, GREEN AND SMART ACTIVITIES AT SEA (INSTALLATIONS, OPERATIONS AND SHIPPING)

RATIONALE

Expanding industrial activities and going offshore needs technology and infrastructure and a legal framework to ensure reliable activities in exposed sea areas. New multi-use concepts will emerge to support business development at sea, based on making combined use of technologies, and even amalgamation of technologies. To meet these needs and opportunities, it is required to enable tech transfer and cooperation across maritime sectors, rather than each sector developing their own solutions.

Activities moving further offshore are expected to include fish and algae farming, marine energy production and extraction of minerals. Examples of multi-activity platforms may be offshore installations combining aquaculture and windmill energy production. Such concepts require a new set of management, logistics, monitoring, energy production, materials, IT-systems, biological solutions, maintenance and so on. The competences of various maritime sectors must be put to use, and new cross-cutting competence must be developed. Environmental issues must be included in every aspect.

Multi-activity platforms and their internal logistics, installations, assembling and deployment of these ocean multiuse platforms or their components require new concepts, and architectures, new materials and construction engineering: There is a need for energy supply, control systems, systems for operational analysis and simulations to increase the efficiency of every element in the complex maritime operations and transmission of data from far offshore to shore

The total impacts of the expansion of maritime transport, fishing, exploitation of energy and mineral resources, is not well understood. Further knowledge on how to exploit resources without jeopardizing the environment will be necessary. Monitoring will be an essential part of the development, also with respect to pollution.

There is much experience to build on. The shipping industry has over time developed advanced and specialised service vessels for the offshore industry. The fish farming industry has developed novel service vessels and advanced production cages capable of withstanding rough conditions. Parts of today's fishing fleet are highly technologically advanced. Past accidents in maritime operations (marine, maritime, offshore) may provide lessons for the future.

JPI OCEANS ADDED VALUE

- **JPI Oceans** could initiate a cross-cutting maritime technology and engineering community able to support the development of new industrial activities at sea;
- **JPI Oceans** could stimulate blue growth in diversified selected and specific areas within marine and maritime engineering;
- **JPI Oceans** could establish a better cooperation between industry, academia and regulatory bodies to facilitate efficient use of competence, financial and human resources;
- **JPI Oceans** could identify complementary partners to work towards common goals;

Focus	Identified needs	Specific objectives
Management / coordination	Identify cross-cutting common goals between partners from different maritime sectors. Identify cross-cutting demands for new materials, construction engineering and automation and energy solutions.	• Bring stakeholders from maritime sectors (marine, maritime, offshore),together with academia to discuss opportunities, needs and solutions • Establish task groups to follow defined projects • Develop systems to analyse combined uses, construction and operational aspects

4.4 TECHNOLOGICAL CHALLENGES FACING THE EXPLOITATION OF DEEP SEA RESOURCES

It has been said that we know less about the deep sea than the outer space. The deep seas represent both challenges and opportunities. Foremost it is necessary to understand its nature much better before making use of it in an extensive, commercial manner. Previously, we thought it was invulnerable, today we find footprints of human activity in the deepest troughs of the world's oceans. It is dark, cold and not easily accessible.

Any activity connected with the deep oceans is very costly and requires robust competence and large budgets. Interest for seabed mineral mining is sharply increasing due to the scarcity of a number of minerals and metals required by various industries, including maritime industries. Oil and gas exploitation at sea is gradually moving into deeper and more hostile waters requiring new technologies to enable remote operation without traditional platforms. Technologies for seabed mineral extraction may build on technologies for offshore oil and gas exploitation. Environmental issues must be included in every aspect.

Focus	Identified needs	Specific objectives
Coordination	Extended use of ocean space in terms of industrial activity will require unprecedented clustering of industries, competence, technologies and processes.	• Bring stakeholders from maritime sectors together with academia to discuss opportunities, needs and solutions • Deep sea technologies research- cross-cutting technologies for deep-sea exploration and management of vulnerable marine ecosystems. • Autonomous and remotely operated vehicles and systems

4.5 EMERGING TECHNOLOGIES

The terms "maritime technologies" or "oceans technologies" are wide. Some technologies are developed specifically for use in the marine environment, such as the shipbuilding industry and easy to identify. Many technologies have originally been developed for use on land such as feed production, now being used by aquaculture, or wind turbines, now being adapted to offshore renewable energy production. Some technologies are of generic character and are being developed without oceans applications in mind. Ocean technologies may originate from all these and the other way around; specific maritime needs may spur the development of new and specialized technologies.

> **Key enabling technologies (KET)**
>
> *Key Enabling Technologies comprise micro-and nanoelectronics, advanced materials, industrial biotechnology, photonics, nanotechnology and advanced manufacturing systems. Most innovative products nowadays, whether it is the smart phone or electric car, incorporate several KETs simultaneously, as single or integrated parts.*
>
> http://europa.eu/rapid/press-release_MEMO-14-359_en.htm
>
> *From KET Summit in Grenoble 19 May 2014*

It is essential for the maritime industries that new technologies and methods are developed to ensure progress in the sector. Key enabling technologies (KET) provide the technology bricks that enable a wide range of innovative product applications, including those required to address societal challenges. KETs are being of crucial importance for industrial competitiveness. KETs are generic technologies, which can be widely applied to various industries. The maritime industry should take an active part in defining needs and incorporate them in their own development.

This section presents a list of emerging technologies with a particular potential to boost blue growth. It highlights technologies that were advocated by the stakeholders in the CSA Oceans' consultation, also reflecting the list of technologies addressed in the publication "Navigating the Future IV" from the Marine board.

4.5.1 SENSORS

Sensors of all kinds are in everyday use in the maritime sector. Sensors are instruments which detect events or changes in quantities and provide a corresponding output, generally as an electrical or optical signal. Biosensors represent a new technology, which use a biological component with a physicochemical detector. These are highly advanced components and tailor made to specific needs. Other sensors are for example optical sensors to measure biological substances and monitoring biological processes. Rapid technological progress allows more and more sensors to be manufactured on a microscopic scale as micro-sensors with accuracy. Miniaturization of sensors and sampling equipment will allow for an increased use of unmanned research platforms. The maritime sector benefits largely from the general development of sensors in all areas. However, sensors adapted to the marine environment and special purposes are needed.

> **Harnessing Our Ocean Wealth - An Integrated Marine Plan for Ireland**
>
> *"Improved sensor and surveillance technologies, including satellite and unmanned surveillance systems, along with situational and analytical technology, skills and capacity, will enhance delivery of maritime safety, security and surveillance services across all systems"*

Every step forward in sensor technology is a new puzzle in amalgamating various technologies. Development of fully autonomous systems that can operate independently for longer periods of time, with full data-recovery in realtime is important. Technical advances to develop sustained long term and high-resolution observing systems for biological processes are needed, as well as technology to develop automated sensors for the detection of harmful organisms and their toxins and physico-chemical parameters (T, pH, O2).

4.5.2 ROBOTICS AND AUTONOMOUS SYSTEMS

As for unmanned space exploration, ocean robotics and autonomous systems offer much cheaper and smarter, and often safer for personnel, marine and maritime activities. Such systems often combine the needs of industry, management and research and expand the knowledge frontiers rapidly. Maritime Industries find these devices essential in opening new business opportunities. They are technically and operationally very complex, combining various basic technologies. ROVs (Remotely Operated Vehicles), Autonomous Underwater Vehicles (AUV) and gliders are all already in extensive use and will be increasingly used. Due to their efficiency, considerable expansion is expected. To make them even more useful concerted actions among the main stakeholders is necessary to ensure maximum usefulness and technological and economic efficiency.

4.5.3 ACOUSTICS TO ENHANCE MARINE ECOSYSTEM MANAGEMENT

Acoustics has been in use for a long time and is being rapidly developed to become ever more useful for various purposes; mapping of seabeds, guidance of underwater vehicles, study of phenomena in the ecosystem, underwater communication and tracking of fish schools and marine mammals are examples. Technological development has allowed species-specific monitoring and analysis of biophysical parameters and closer study of spatial phenomena. New advances in acoustics technology will make acoustics more valuable, also in conjunction with other technologies and as part of other equipment.

4.5.4 TELEMETRY AND ROMOTE SENSING

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on site observation. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation). It may be split into active remote sensing, when a signal is first emitted from aircraft or satellites) or passive (e.g. sunlight) when information is merely recorded.

Telemetry is the highly automated communications process by which measurements are made and other data collected at remote or inaccessible points and transmitted to receiving equipment for monitoring. Remote sensing and telemetry are essential to the development of the maritime sector. The marine environment presents specific challenges and opportunities for industry, management and academia.

4.5.5 BLUE BIOTECHNOLOGY

Biotechnology has a wide range of applications in maritime economy and science. Marine biotechnology contributed to a multibillion industry with large projections for growth both as an industry on its own, but also as an enabler to other land- and oceans based industry sectors and human health. This reflects an increasing need for development of tools and knowledge for sustainable development of marine based products, including food, neutraceuticals, biomedical and other commodities. To advance in this field we need a better understanding of innovative use of marine extracts and bioactive compounds, for example as chemotherapeutic agents, drugs, food additives, cosmetic ingredients, biosensors, etc. In addition the utilization of marine biomass in well-developed biorefinery processes will need new biotechnological tools and methods and a multidisciplinary approach. Biotechnology must be balanced with the need to preserve biodiversity, and can also be used as a tool to this end.

Genomics has become indispensable in aquaculture. The sequencing of the salmon genome has provided a new and powerful tool in natural breeding (not GMO) to enhance growth, disease resistance, etc. In fisheries it is used to determine ownership and migration of fish stocks.

Bioinformatics is used to identify specific properties of marine organisms such as bioactive substances and molecules which can be used in medicine, cosmetics and research. Bioinformatics has a clear commercial potential.

4.5.6 BIONICS (NATURE-INSPIRED DESIGN)

Bionics, the mimicking of nature's techniques and technologies for marine and maritime applications, is an emerging and active field. Bionics / biomimetics are a young science of adapting designs from nature to solve modern problems. The fact, that marine species and maritime activities share the same environment suggests a particular high potential of knowledge transfer between marine sciences and maritime technologies by mimicking nature and bionics. Bionics provide a specifically interesting cross-cutting path to find nature-based ways of replacing harmful man made substances in the ocean with nature based materials with properties that have the same properties but are not harmful. The aim of this research is to systematically investigate in an interdisciplinary manner the potentials of marine bionics and explore potential technical applications with the aim to increase efficiency, safety and reduce negative impacts to the marine environment. Learning from nature as well as the latest developments in material sciences and production technologies (e.g. rapid prototyping) will pave the way for a more efficient and sustainable adaptation of natural solutions in technical products.

4.5.7 NEW MATERIALS AND NANOTECHNOLOGY

Installations and devices are exposed to corrosion, algae growth and winds, waves and currents. In addition to steel, more use of other inorganic and organic materials are continuously being introduced, ranging from concrete, "new" metals, and composites and alloys for use both in construction as well as in machinery, instruments and sensors. New demands will be put on coatings and paints and on materials themselves to meet higher standards of functionality and economy. New exotic materials often contain harmful substances to the environment and must be considered at all stages in development and use.

4.5.8 INFORMATION & COMMUNICATION TECHNOLOGIES

Today ICT is an integrated, basic technology and prerequisite for most industries and operations at sea. Cloud computing and hybrid data structure are some of the novel keywords. Connected to these technologies are general data handling, storage and dissemination. It is also important to develop the role of ICT as an arena for distributing and sharing knowledge and as an arena for collaboration.

4.5.9 CLIMATE-FRIENDLY, GREEN TECHNOLOGIES

The world is facing serious climate challenges due to the use of fossil fuels. The maritime sectors must take its part in alleviating future damage, and at the same time create business opportunities, principally in three ways;

- generate new, clean energy from wind, waves, currents and algae;
- minimize energy consumption related to all maritime activities;
- use depleted petroleum reservoirs as storage for CO2;

The maritime sector can and must be mobilised to play an important role in the global need for reducing emissions. This role depends to a large degree on maritime sector's ability to join forces across the board to develop technology and processes, and put them to use. One example shows the potential of the shipping industry to reduce its environmental impact through new and modified propulsion technologies. Recent analyses from DNV GL demonstrate that replacement of fossil fuels with batteries in ships could save ten times as much CO_2 as placing the batteries in a car.

Other areas are new technology for offshore wind turbines, energy transfer system to shore, energy saving technologies in fishing vessels and ships, and energy management across the board in the maritime industries.

Areas where the oceans must contribute in the global process of switching from fossil fuels to green energy is to make use of wind, waves, currents and its biological production potential. Systems harnessing energy from wind, waves and currents require a whole set of technologies, systems and logistics. So-called energy converters show promise. Although in use, offshore generation is in its infancy and is in need for coordination at all stages of further development.

Marine plants, from seaweed to micro-algae, can be used to produce biofuels. Fast growth rates render some marine plants viable for converting to fuels. Pilot activities are being performed today, but to become commercial, a whole set of technologies and operational systems must be developed and put use, in order to become a large scale industry and an important factor in the world's renewable energy supply.

Climate friendly alternatives are often more expensive to apply for the industry and it is a challenge and it may be difficult to mobilise relevant industries to participate in joint ventures outside their primary business areas. Still, climate friendly technologies are an emerging field, and a recent report from the World Bank and ClimateWorks Foundation[1] present macro-economic analyses that demonstrate overall economic benefits from climate-smart developments.

[1] http://documents.worldbank.org/curated/en/2014/06/19703432/climate-smart-development-adding-up-benefits-actions-help-build-prosperity-end-poverty-combat-climate-change-vol-1-2-main-report

5 – PROCEDURES FOR MAPPING AND ANALYSIS OF MARINE AND MARITIME RESEARCH FRAMEWORK TO FOLLOW BEYOND THE CSA OCEANS LIFETIME

Application and use of new technologies are critical to boost the blue growth agenda. The development of some blue growth sectors is fast paced and cutting edge. Constant monitoring of technological development and trends might be needed, it is certainly time consuming and not helpful if not targeted.

The description of work planned to draft procedures for mapping and analysis of marine and maritime research framework to follow beyond the CSA Oceans lifetime. The procedures proposed in the section are divided into two parts, the tools and the main resources generators of information on blue growth.

Firstly, this section provides examples of tested methods and procedures which may be useful to identify new and cross cutting technologies and research areas of importance in the future on a constant manner and above all, beyond the lifetime of CSA Oceans.

Following a desktop research study, tools and procedures to identify emerging technologies were grouped in the following four categories:

- Foresight and other forward looking stakeholder involvement;
- Technology fora, research conferences and trade shows;
- Bibliometry: data mining of science publication repositories;
- Patent database searches and consultations with patent offices;

Secondly, we focused our analysis on the main stakeholders generating information on blue growth and technologies. As a result, actors, resources and policies to boost blue growth were grouped in the following two categories:

- European actors and policies
- International organizations and actors

Examples, practices and links under these headings contribute to an evolving canvas of tools to search for emerging and cross cutting technologies and solutions to boost blue growth.

5.1 FORESIGHT AND OTHER FORWARD LOOKING STAKEHOLDER INVOLVEMENT

CSA Oceans has delivered a review of current foresight methods "Foresight for JPI Oceans - Definition and Review of Relevant Processes (Deliverable 7.1)[24]. This review defined as "*a systematic, participatory, future intelligence gathering and medium to long-term vision-building process aimed at present-day decisions and mobilising joint actions*". Furthermore "Foresight involves bringing together key agents of change and sources of knowledge, in order to develop strategic visions and anticipatory intelligence. Of equal importance, Foresight is often explicitly intended to establish networks of knowledgeable agents, who can respond better to policy and other challenges. (FOREN 2001: 3).

[24] http://www.jpi-oceans.eu/prognett-jpi-oceans/Deliverables/1253989109651

The first foresight report from CSA Oceans describes different methodological approaches and gives a review of how such methods have been applied in the European marine and maritime landscape. The second report "A Programmatic Foresight Process for JPI Oceans" (Deliverable 7.2[25]) proposes a concrete approach for JPI Oceans; the run of a test foresight exercise. It also proposes *a framework for identifying the key future themes and challenges* related to the healthy and productive development of our seas and oceans. In essence a two-pronged foresight process is recommended and described in order to cater to the needs of JPI Oceans: a *strategic approach* to serve as a forum for critical debate about the future strategic orientation and a *programmatic approach* that seeks to develop solutions and proposals for actions for specific topic areas. The latter has already been tested and applied to the JPI Oceans' pilot action on the Environmental Impacts of Microplastics.

Focus groups constitute another methodology of summoning relevant stakeholders to forward looking activities and exercises. Since JPI Oceans will primarily apply the described two-pronged foresight methodologies, we will not address other participatory forward looking activities in the present context. Last but not least, *social media and blogs* are emerging as important arenas to connect and share knowledge, technologies and policies. Three examples of LinkedIn groups; "Maritime Network", "Science Technology and Innovation Policy", "European Innovation Policy Group" represent only a very small fraction of such fora of relevance.

A significant ongoing international foresight project is the one conducted by OECD's International Futures unit *"The Future of the Ocean Economy: Exploring the prospect for emerging ocean industries to 2030"*. The objective is to conduct a global forward-looking assessment of the ocean economy to 2030, with special emphasis on the development potential of emerging ocean-based activities[26]. The project will explore the growth prospects and the potential for employment creation. JPI Oceans is involved in the project and has offered to contribute to a workshop on "Science – policy – industry interface" by involving JPI Oceans' Management Board and Strategic Advisory Board. The project builds on OECD's established foresight methodology and builds on OECD's vast resources of international statistics and status reports. Engagement in this project expands JPI Oceans' global perspective.

Knowledge is an important and inherent basis of strategic and forward looking activities. In Europe the European Marine Board (EMB)[27], is a provider of compiled marine knowledge as well as performing forward looking activities. It develops common positions on research priorities and strategies for European marine science, thus facilitating enhanced cooperation between stakeholders involved in supporting, delivering and using marine research and technology. The EMB represents an important and broad knowledge base for the marine and maritime community.

5.2 TECHNOLOGY FORA, RESEARCH CONFERENCES AND TRADE SHOWS

The number of relevant fora and conferences are almost unlimited and they span over broad array of themes and topics. Lists are quickly out-dated; therefore relevant fora for marine and maritime goals are simply illustrated by three examples. The first one, the "**World Ocean Council"**, represents a broad array of industry stakeholders and the second one, "**Oceanology international"**, is a

[25] http://www.jpi-oceans.eu/prognett-jpi-oceans/Deliverables/1253989109651
[26] http://www.oecd.org/futures/oceaneconomy.htm
[27] http://www.marineboard.eu

comprehensive ocean technology arena with an interesting satellite event. This third example **"Catch the Next Wave"** conference addresses essential technology areas for ocean industries. The need for venture capital is essential to innovation and job creation, and venture capital, business angels and match-making between innovators and funding are often part of conferences and trade shows. Both public and private funding is essential, and is mentioned more specifically below in the context of European innovation actors and frameworks.

The World Ocean Council (WOC)[28] is an international, cross-sectorial industry leadership alliance on "Corporate Ocean Responsibility". It brings together the diverse ocean *business community* to collaborate on stewardship of the seas. WOC is engaging a wide range of ocean industries, including: shipping, oil and gas, fisheries, aquaculture, tourism, renewable energy (wind, wave, tidal), ports, dredging, cables and pipelines, carbon capture and storage, as well as the maritime legal, financial and insurance communities, and others. A growing number of companies and associations share the WOC vision of a healthy and productive ocean and its sustainable use and stewardship, and they call on others to join them.

Oceanology International (OI)[29] is among the very largest technology conferences. It addresses technologies in the broadest sense, and in 2014 it had approximately ***8,400 attendees*** and ***528 exhibiting*** **companies** from ***35 countries***. It hosted the world's largest display of state-of-the-art marine technologies, and the conference and discussions connected delegates with the latest developments and technology transfer opportunities in offshore, marine and subsea sectors. It occurs every second year.

The "Catch the Next Wave" conference[30] was organised back-to-back with Oceanology International in 2014. It has taken a longer-term view on *the capabilities that will shape our future ability to explore, understand, use and protect our oceans*. It looks ahead to see *what new technologies are emerging*, with leading experts describing developments that are set to change the way things are done in application areas as diverse as Formula One racing cars and the aerospace industry. Forward thinkers from the marine technology community explored *how these technologies are finding application in the oceans*. The objective was to stimulate creative thinking in areas such as materials science, sensor technology and complex systems (see illustration with water drops), and to charge delegates with new ideas that will lead to new research and business opportunities. The next event is in March 2016 in London.

[28] www.oceancouncil.org
[29] www.oceanologyinternational.com
[30] http://www.ctnwconference.com/

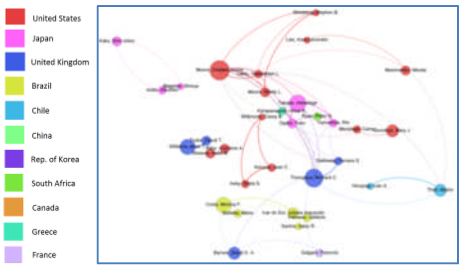
5.3 BIBLIOMETRY: DATAMINING OF SCIENCE PUBLICATION REPOSITORIES

Bibliometrics is a set of methods to quantitatively analyse academic literature, based on content and impact. It is used in many fields to explore the impact of the field, researchers, or a particular paper. It is also used to search for scientific activity and actors in defined fields and topics, including technologies. Thus *it is a tool to search for emerging fields and technologies*. The two global databases used are Elsevier's *Scopus* and Thomson Reuters' *Web-of-Science.* Some 17 million scientific papers were registered in the Scopus database in the period 2003 – 2012. In these databases scientific papers are stored with its content, journal data, author and institutional data etc. in a reference list format. Regular literature searches for full papers will provide additional detailed information.

In the CSA Oceans DOW (Part B page 19) it is stated that "The JPI Oceans being broad and addressing cross-cutting issues will require the support of *specific tools for mapping and gap analysis* in defined areas: Baseline setting, continuous monitoring and mapping of researchers, institutions and collaborative networks." JPI Oceans has explored such *bibliometric methods* in connection with the Pilot Action "Environmental aspects of microplastics in the marine environment".

Table and Figure: a. leading countries in Microplastics and marine pollution research, and b. Institutional collaborative networks in Microplastics and marine pollution research

Country	Papers	Trend	ARC	ARIF	SI
United States	191		1.13	1.12	1.15
United Kingdom	77		1.33	1.19	1.75
Japan	47		1.04	0.89	1.07
China	40		0.59	0.74	0.51
Australia	36		*1.04*	*1.19*	*2.25*
Brazil	35		1.32	0.89	3.15
Canada	29		*1.16*	*1.16*	*1.24*
Germany	24		*1.85*	*1.14*	*0.58*
France	22		*1.47*	*1.06*	*0.73*
World	**578**		**1.00**	**1.00**	**1.00**



The two examples (Table and figure) are from this report. The first one presents the *leading countries* in this research, and also visualizes their trend in publications since the start of this topic in 1996. The second example from the report shows visualization of *collaborative networks* between key institutions and countries in this field. For details and method description see the full report in Annex 3 "Bibliometric assessment of research activities related to microplastics marine pollution"

5.4 PATENT DATABASES: MINING FOR TECHNOLOGIES AND INNOVATION ACTORS

Patents and patent information are stored in databases that are searchable in a manner comparable to the bibliometric information described for scientific publications. The European Patent Office (EPO)[31] web pages include simple or advanced search options for patent information, and it also provides lists of other patent databases. See example next page for "marine biosensor".

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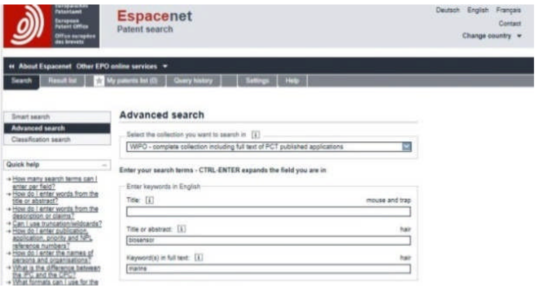
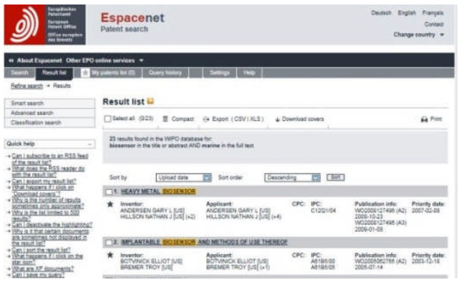
[31] www.epo.org





Espacenet search results on 13-05-2014 13:52

23 results found in the WIPO database for:
biosensor in the title or abstract AND marine in the full text
Displaying selected publications

Publication	Title	Page
WO2008127496 (A2)	HEAVY METAL BIOSENSOR	2
WO2005062765 (A2)	IMPLANTABLE BIOSENSOR AND METHODS OF ...	3
WO0132911 (A2)	IMMOBILISED BACTERIA	4
WO2012066321 (A1)	BIOSENSOR AND USES THEREOF	5
WO2012037543 (A1)	HOST SUPPORTED GENETIC BIOSENSORS	6
WO2011110825 (A1)	BIOSENSOR APPARATUS AND USE THEREOF	7
WO2011064595 (A1)	AQUATIC POLUTION MONITORING	8
WO2010142532 (A1)	MODIFIED BACTERIOPHAGE, BIOSENSOR CON...	9
WO2010092539 (A1)	POLYMERIC IMMOBILIZATION MATRIX FOR L...	10
WO2006105801 (A1)	GENETICALLY ENGINEERED BIOSENSOR TO M...	11
WO2009126841 (A1)	ENZYMATIC BIOSENSORS WITH ENHANCED AC...	12
WO2009016366 (A1)	BIOSENSOR	13
WO2004076685 (A2)	FUNGAL BIOSENSOR AND ASSAY	14
WO2004001067 (A2)	DETECTION OF TOXIC ALGAE	15
WO03027680 (A2)	BIOSENSOR FOR DETECTION OF TOXIC SUBS...	16
WO03025627 (A2)	OPTICAL BIOSENSOR WITH ENHANCED ACTIV...	17
WO02093145 (A1)	THIN-FILM BIO-SENSOR, AND METHOD OF O...	18
WO0111080 (A1)	A PRINTED CIRCUIT BOARD, BIOSENSOR AN...	19
WO0100783 (A2)	MONITORABLE THREE-DIMENSIONAL SCAFFOL...	20
WO0014267 (A1)	BIOSENSOR	21
WO9932636 (A1)	BIODEGRADATION OF EXPLOSIVES	22
WO9855870 (A1)	DETECTION OF BIOLOGICALLY ACTIVE MOLE...	23
WO9807839 (A1)	BIODEGRADATION OF EXPLOSIVES	24

Country	Institution	Pri year
CN/GB	Industry	2011
US	Univ	2010
GB	Univ	2010
NO	Industry	2009
BE	Univ	2009
IT	Univ	2009
US	Univ	2009
US	Univ	2007
GB	Univ	2007
EG	TTO	2005
GB	Industry	2004
US	Industry	2003
US/DE	Univ	2002
US	Private	2001
US	Univ	2001
US	Univ	2001
US/PL	Industry	2001
GB	Univ	1999
US	Industry	1999
GB	Univ	1998
GB	Gov/defence	1997
SE	Industry	1997
GB	Gov/defence	1996

Country and region distribution	
Belgium	1
China*	1
Egypt	1
Great Britain	8
Italy	1
Norway	1
Sweden	1
United States	10
Germany*	1
Poland*	1
Europe	14
Other (US, CN, EG)	12

*shared with other country

Applicant type	
Industry	7
University	12
Person	1
TTO	1
Gov.	2

As an example of a patent search, a test case for "marine biosensors" was performed. In the EPO search page the key word "biosensor" was entered, and yielded 1 479 results from the World Patent Office (WPO) database. To refine the yield the advanced search was used, searching for: "biosensor" in title or abstract AND "marine" in the full text. This key word combination reduced the yield to 23 patents of significantly higher relevance. Essential information was returned by the web-tool as a web-based table, and a report was exported, which included the front page of each of the patents and a cover page listing the patents (illustrated below). Information on country, applicant institution type, priority date, as presented in the tables below, as well as more detailed description of the patented technologies was obtained.

If more in-depth searches for technologies, competitors or potential partners are needed, it is recommended to use professional patent lawyers and the services of patent offices. Well planned strategic approaches to intellectual property rights is essential for commercial success of innovative technology based companies and businesses.

5.5 EUROPEAN ACTORS AND INITIATIVES

The European Commission unveiled on May 13, 2014, an important communication: Innovation in the Blue Economy: realising the potential of our seas and oceans for jobs and growth[32]. It suggests an "action plan to tackle barriers to innovation to unleash the blue growth potential", and also points to important match making activities. Dialogues between JPI Oceans with its 22 member countries and the Commission services are essential at the policy level as well as the work sharing level. Cooperation between the commission and nationally funded initiatives are numerous.

One important example of initiatives to facilitate research and growth in the blue sectors is the DG MARE initiative European Marine Observation and Data Network (EMODnet)[33]. It is a consortium of organisations within Europe, with the main purpose to unlock fragmented marine data resources and to make these available to individuals and organisations (public and private), and thus to facilitate investment in sustainable coastal and offshore activities. It is part of the Marine Knowledge 2020 strategy[34].

Marine Genomics 4 Users[35] is another quite different example. It is a 1.5 year limited CSA FP7 project with 7 partners from 6 countries and it has resulted in two focused and informative documents describing *frontier technologies and their potential for marine applications*: a) A workshop report "The potential of genomics for marine monitoring and biodiversity mapping: from concept to realization." and b) A policy brief "*The use of genomics for marine monitoring: an introduction to the latest tools and techniques*". This FP7 action is a good example of collecting forward looking knowledge about technologies for the future.

Another important tool for blue growth is the *SME instrument* of Horizon 2020 which under the Europe 2020 initiative provides easy access to € 2.8 Billion to SMEs for funding research and innovation[36]. SMEs can form collaborations according to their needs, including for subcontracting research and development work to apply for funding and support. Direct and indirect financial support can be provided as it aims at creating a bridge between the core of the framework programme - support to research, development and innovation projects - and the creation of a favourable ecosystem for SME innovation and growth".

5.6 INTERNATIONAL POLICIES, ORGANIZATIONS AND ACTORS

To promote blue growth in an era of globalization an international perspective should be mandatory and self-evident in technology- as well as policy matters. OECD as an international organisation with a mission to promote economic growth and development is central in this context. It provides the knowledge base as well as policy views. OECD's forward looking activities have been mentioned above. However, equally important is the vast work being performed relating to science and technology policy, economic indicators and studies on new technologies and emerging cross cutting research topics. This includes country statistics, and the topics pages are highly informative on for

[32] COM(2014) 254
[33] www.emodnet.eu
[34] http://ec.europa.eu/maritimeaffairs/policy/marine_knowledge_2020/
[35] www.mg4u.eu
[36] http://ec.europa.eu/digital-agenda/en/sme-instrument-

example: Science and Technology Policy[37], Innovation [38] and Green growth and sustainable development[39]. Comprehensive thematic reports are compiled and published.

The vast resources on innovation include a subsection dedicated to "Innovation in science, technology and industry"[40] and "The Innovation Policy Platform (IPP), a web-based interactive space, developed jointly by the **OECD and the World Bank**, providing an *online repository of resources to support better innovation policy making and analysis*. Furthermore, the Science and Technology Policy section offers relevant resources. Public innovation is discussed in a recent publication "Commercialising Public Research"[41]. Policy-makers have high hopes for public research as a new source of growth, as it has been the source of significant scientific and technological breakthroughs that have become major innovations.

International frameworks are important for the marine and maritime economies. The United Nations Convention on the Law of the Sea is central to coastal and oceans communities. Bodies under the convention are: Commission on the Limits of the Continental Shelf; International Seabed Authority, International Tribunal for the Law of the Sea[42]. In 2012 Ban Ki-moon launched the "Oceans Compact", stating; "The world's oceans are key to sustaining life on the planet. The ocean constitutes a conduit for ninety per cent of the world trade, and for connecting people, markets and livelihoods. In light of the ocean's interconnectedness, all nations of the world should strive to make the oceans places of safety and sustainability of maritime activities for all humankind".

The Intergovernmental Oceanographic Commission (IOC) of UNESCO is the United Nations body for ocean science, ocean observatories, ocean data and information exchange, and ocean services such as Tsunami warning systems. Its mission is to promote international cooperation and to coordinate programmes in research, services and capacity building to learn more about the nature and resources of the oceans and coastal areas, and to apply this knowledge to improved management, sustainable development and protection of the marine environment and the decision making processes of States. Collaborating with the United Nations Environment Programme (UNEP) is the GRID-Arendal[43], a centre established in 1989 with a mission to communicate environmental information to policy-makers and facilitate environmental decision-making for change. Through capacity development, assessment initiatives and innovative communication and facilitation tools and processes, their Marine Division promotes responsible and sustainable management of our oceans and coasts by addressing issues of sovereignty, natural resource management, coastal habitat conservation and a transition to a green economy.

The lists of international reports and publications concerning aspects of the blue economy are exhaustive and include resources to identify cross cutting technologies. Scientific output and policy- and review publications constitute a vast knowledge base. Four examples are mentioned below.

The *Canadian Consortium of Ocean Research Universities (CCORU)* recognized the importance of ocean science, and asked the *Council of Canadian Academies* to undertake an expert assessment of

[37] http://www.oecd.org/science/sci-tech/
[38] http://www.oecd.org/innovation/
[39] http://www.oecd.org/greengrowth/
[40] http://www.oecd.org/innovation/inno/
[41] http://www.oecd.org/sti/sci-tech/commercialising-public-research.htm
[42] http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm
[43] http://www.grida.no/

the state of ocean science in Canada, focusing on future opportunities and challenges for Canada and its coasts. This evidence-based assessment follows on the Council's priority setting exercise and expert workshop report, 40 Priority Research Questions for Ocean Science in Canada. A comprehensive report was released: "Ocean Science in Canada: Meeting the Challenge, Seizing the Opportunity"[44] which addresses global challenges and the need for international collaboration.

The *US National Academies* (of Sciences, of Engineering, Institute of Medicine, and National Research Council) are private, non-profit institutions that provide expert advice on some of the most pressing challenges facing the nation and the world. *"Ocean Acidification. A National Strategy to meet the Challenges of a Changing Ocean*" is relevant also in a European context. Moreover the National Academy of Sciences issued a report on "*Sustainable Development of Algal Biofuels in the United States*". Finally, as only one example from the vast "*ocean"* of published knowledge, this one is mentioned, which sets the oceans in perspective: Davor Vidas and Peter Johan Schei (Eds), *The World Ocean in Globalisation* (Leiden/Boston: Martinus Nijhoff Publishers/Brill, 2011), pp. 3–15.

[44] http://www.scienceadvice.ca/en/assessments/completed/oceans.aspx

6. RECOMMENDATIONS

The large and increasing international attention and interest in ocean resources and the opportunities of the blue economy demands consolidated action and activities to boost blue growth in Europe.

Blue growth occurs in companies, in young or mature industries. Some of the challenges are unique to each of the industry or even a company. JPI Oceans is in nature cutting across all maritime sectors, all seas and oceans in Europe and addresses several societal challenges. Innovation and industrial growth can be promoted in a number of ways. Many of them would take extraordinary efforts to organize. JPI Oceans should seek to identify a limited number of significant cross-cutting projects between two or three sectors (marine, maritime, offshore) that engage and involve dedicated partners with common goals and defined roles. Such projects will probably be constituted by partners from industry, academia and authorities, draw benefit from the partners' competence and also define joint knowledge needs in terms of research and development. They should be in areas where organisation of many partners must be involved to succeed and/or in novel areas where new knowledge and technology must be developed across the sectors.

With its cross-cutting nature, JPI Oceans has a particular potential as facilitator to increase the engagement of the industry and promote synergy and transfer of technology between sectors, playing a role in identifying needs for technology and devising new solutions. A key message from the consultation to how JPI Oceans can contribute to blue growth is the production and application of knowledge, particularly from science and technology, and the transfer of knowledge to make use of it. We should identify the industry technology needs in the long term or short term; and make them into a "Marine Economic Strategy implementation plan".

SUGGESTED ACTIONS

1. **JPI Oceans should lead an initiative to facilitate a maritime engineering and technology community.**
   A public-private innovation partnership on technology development for the blue industries could create substantial synergy across sectors and regions. A KIC would be one way of organizing such a partnership. A KIC, built around relevant industries, institutes, universities and centres of excellence should therefore be considered as a tool in the further implementation of Blue Growth in Europe. The initiative should be concentrated around a few selected areas. Suggested areas are maritime technology, materials and nanotechnology, cross-cutting, bionics, technology for deep-sea resources and sensors.

2. **JPI Oceans should facilitate research on prioritised, crosscutting issues of common interest to the blue industry.**
   It should aim to maximise the knowledge outcome with a commercial potential, and a plan for identifying such outcome and transfer of such knowledge to those who can make use of it. Some selected research area of particular interest to promote blue growth across industry sectors are knowledge that can contribute to the development of standardized and mutually accepted protocols for measurement and assessment of environmental impact of industry activities, research to underpin knowledge based MSP and ICZM, seabed mapping, and research on biological and technological challenges related to large installations at sea. Calls or actions should

reflect a high level of funding commitment and funding should come from different sectors to promote blue growth in a cross sectorial manner.

3. **JPI Oceans should facilitate research for more sector-specific knowledge needs**, thus supporting the development of the bio-economies, marine renewable energies and deep-sea exploitations. Furthermore, calls or actions should be initiated and conducted in collaboration with the relevant sectors, ongoing activities, ERA-nets, technology platforms and interested member countries. For example, in relation to maritime technologies, collaboration with MARTEC would be a relevant opportunity. Calls and actions should preferably be ERA collaborations, and thus reduce fragmentation and duplication.

4. **JPI Oceans should establish networking venues**
With its long-term and cross cutting perspectives JPI Oceans could be a home and facilitator of knowledge transfer is and collaboration between science and industry, between industrial sectors, and between science and technology disciplines. In addition to JPI Oceans networking venues it is also recommended that the industry stakeholders identified by CSA Oceans should participate in the Blue Economy Business and Science Forum that the Commission foresees to establish, aiming to meet for the first time during the 2015 Maritime Day. Networking arenas should aim at converging into an Oceans Agency, as suggested by numerous stakeholders. Such a process holds the potential to achieve effects similar to the development of a space agency and programmes.

Annex 1 - Reference documents

2nd Marine Board Forum Proceedings, published April 2012, Towards a European Network of Marine Observatories for Monitoring and Research (16 September 2010, Brussels)

3rd Marine Board Forum Proceedings, published March 2014, 3rd Marine Board Forum Proceedings New Technologies for a Blue Future (18 April 2012, Brussels)

Andrusaitis, A., K. Kononen, M. Sirola, et al. (2014), BONUS strategic research agenda 2011–2017, update 2014. BONUS Publication No. 14.

Boyen C., Heip C., Cury P., Baisnée P.-F., Brownlee C., Tessmar-Raible K., et al. (2012) EuroMarine Research Strategy Report - Deliverable 3.2. Seventh Framework Programme Project EuroMarine - Integration of European Marine Research Networks of Excellence. FP7-ENV-2010.2.2.1-3. Contract Number 265099.

European Commission, "Blue Growth opportunities for marine and maritime sustainable growth", COM(2012)0494 final, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, European Commission, Brussels

European Commission, "Innovation in the Blue Economy "(COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS), Communication COM(2014) 254 European Commission, Brussels

European Commission, "Towards Joint programming in Research: Working together to tackle common challenges more effectively", COM(2008) 468 final, (COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS), European Commission, Brussels

European Marine Board, Position Paper 15, Marine Biotechnology: A New Vision and Strategy for Europe. September 2010, Oostende, Belgium

European Marine Board, Position paper 16, Monitoring Chemical Pollution in Europe's Seas Programmes, Practices and Priorities for Research, November 2011, Oostende, Belgium

European Marine Board, Position paper 20 Navigating the Future IV, June 2013, Oostende, Belgium

European Marine Board, Vision document 2, Marine Renewable Energy Research Challenges and Opportunities for a new Energy Era in Europe, October 2010, Oostende, Belgium,

Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, 23 July 2014, Brussels

OECD (2010) The OECD Innovation Strategy. Getting a Head Start on Tomorrow; ISBN 978-92-64-08470-4, Paris: OECD

SEAS-ERA, Deliverable 7.1.1, Strategic Research Agenda for the Mediterranean Sea-Basin, February 2012, 62pp.

SEAS-ERA, Deliverable D.6.1.1, Towards a Strategic Research Agenda/ Marine Research Plan for the European Atlantic Sea Basin, November 2013, 44pp.

SEAS-ERA, Deliverable D.8.1.1, Black Sea Strategic Research Agenda, April 2012, 69pp

Annex 2.A - JPI Oceans Strategic Advisory Board – List of Members

NAME		ORGANISATION	STAKEHOLDER GROUP
BARANGE	Manuel	Plymouth Marine Laboratory & Chair of the ICES Science Committee	SCIENCE
BOYEN	Catherine	CNRS	SCIENCE
GIULIANO	Laura	CIESM	SCIENCE
GONZÁLEZ ROMERO	Arturo	INNOVAMAR	INDUSTRY
HERZIG (Chair)	Peter	GEOMAR Helmholtz Centre for Ocean Research Kiel	SCIENCE
KROG [45]	Jørn	County Governor of Sør-Trøndelag	CIVIL SOCIETY & PUBLIC AUTHORITY
LOCHTE	Karin	Alfred Wegener Institute	SCIENCE
LOCK [46]	John	Department for Environment, Food and Rural Affairs (Defra)	CIVIL SOCIETY & PUBLIC AUTHORITY
MCDONOUGH	Niall	Marine Board-ESF	SCIENCE
MINSTER	Jean-Francois	TOTAL	INDUSTRY
ORDRUM	Sigve	Aker Biomarine Antartic	INDUSTRY
POLAT BEKEN	Sevcan Çolpan	Tubitak MRC	SCIENCE
POUTANEN	Eeva-Liisa	Ministry of the Environment	CIVIL SOCIETY & PUBLIC AUTHORITY
ROLAND	Frank	Center of Maritime Technologies e.V. (CMT)	INDUSTRY
SHIELDS	Yvonne	Commissioners of Irish Lights	INDUSTRY
STENSETH	Nils Christian	Centre for Ecological and Evolutionary Synthesis (CEES) - University of Oslo	SCIENCE
VERREET	Gert	OSPAR Secretariat	CIVIL SOCIETY & PUBLIC AUTHORITY
WATSON-WRIGHT	Wendy	UNESCO Intergovernmental Oceanographic Commission (IOC)	CIVIL SOCIETY ORGANISATIONS

[45] Appointed August 2013
[46] Resigned July 2013

Annex 2.B - List of participants in the CSA Oceans stakeholders consultative workshops organized by CSA Oceans in 2013.

WORKSHOP	Participant Name	Organisation/Initative/Project
Technology platforms - Industry, Innovation & Economic Associations **30 May 2013** **Chair: Kathrine Angell-Hansen (RCN, NO)** **Co-Chair: Berit Johne (RCN, NO)**	Maribel Rodriguez Olmo	ARIEMA – EFTP (European Fisheries Technology Platform)
	Francois Marie Duthoit	DCNS - WATERBORNE
	Courtney Hough	European Aquaculture Technology and Innovation Platform (EATiP)
	Paris Sansoglou	European Dredging Association (EuDA) - WATERBORNE
	Vilma Radvilaite	European Wind Energy Association (EWEA)
	Ralf Fiedler	Maritime Technologies (MARTEC)
	Leif Magne Sunde	SINTEF - EATiP
	Hanne Digre	SINTEF - EFTP
	Patrick Sorgeloos	UGent - EATiP
International Scientific Organizations and Associations **13 June** **Chair: Kathrine Angell-Hansen (RCN, NO)** **Co-Chair: Jacky Wood (NERC, UK)**	Adi Kellermann	International Council for the Exploration of the Sea (ICES)
	Alessandro Crise	European Marine Board
	Jo Foden	EMECO
	Robin Cook	European Fisheries and Aquaculture Research Organisation (EFARO)
	Josien Steenbergen	European Fisheries and Aquaculture Research Organisation (EFARO)
	Catherine Boyen	EuroMarine
	Mike Thorndyke	EuroMarine/MARS
	Michael Weeb	ECORD
ERA activities (ERA-NETs, Art 185) **12 June** **Chair: Kathrine Angell-Hansen (RCN, NO)**	Andris Kaisa	BONUS
	Andrusaitis Kononen	BONUS
	Dennis Steffen	Cooperation in Fisheries, Aquaculture and Seafood Processing (COFASP)

Co-Chair: Jacky Wood (NERC, UK)	Lisbjerg Syberg Hansen	Cooperation in Fisheries, Aquaculture and Seafood Processing (COFASP)
	Steinar Bergseth	Marine Biotech
	Ralf Fiedler	Maritime Technolocgies MARTEC II
	Kostas Nittis	Towards Integrated Marine Research Strategy and Programmes (SEAS-ERA)

WORKSHOP	Participant Name	Organisation/Initative/Project
United Nations Organisations and Groups /International Organizations - Policy and Regional Conventions/Advisory bodies **1 June 2013** **Chair: Kathrine Angell-Hansen (RCN, NO)** **Co-Chair: Jacky Wood (NERC, UK)**	Elisa Berdalet	GEOHAB - International programme of Harmful Algae
	Albert Fischer	International Oceanographic Committee (IOC)-UNESCO/GOOS
	Katherine Hill	Global Climate Observing System (GCOS)
	Gyorgyi Gurban	UNEP/MAP/ Barcelona Convention
	Irena Makarenko	Black Sea Commission
	Gert Verreet	Secretariat of the OSPAR Convention
	Andrew Brown	Standing Committee on research for fisheries (SCARFISH)
	Trevor Platt	Partnership for Observation of the Global Oceans (POGO)
	Yves-Henri Renhas	SHOM - Service hydrographique et océanographique de la marine
Infrastructure Initiatives, projects and Organizations **5-6 June 2013** **Chair: Kathrine Angell-Hansen (RCN, NO)** **Co-Chair: Rudy Herman (VLIZ, BE)**	Olivier Lefort	OFEG
	Kostas Nittis	EuroGOOS
	Helen Glaves	ODIP
	Paolo Favali	EMSO
	Wouter Los	Lifewatch
	Simone van Schijndel	HYDRALAB IV
	Peter Wellens	HYDRALAB IV
	Jacques Binot	EUROFLEETS II
	Herman Hummel	EuroMarine
	Henning Wehde	NOOS
	Patrick Farcy	JERICO I3
	Adelino Canario	EMBRC
	Donatella Castelli	I-MARINE
	Marc Vandeputte	AQUAEXCEL
	MARIEKE REUVER	AQUAEXCEL

FP7 projects - Collaborative projects **20 June 2013** **Chair: Kathrine Angell-Hansen (RCN, NO)** **Co-Chair: Jacky Wood (NERC, UK)**	Ferdinando Boero	CoCoNet and VECTORS
	Øivind Bergh	COEXIST and STAGES
	Anthony Grehan	CoralFISH
	Tim O'Higgins	KnowSeas
	Wojciech Wawrzynski	MARCOM+
	Paula Kiuru	MAREX
	David Murphy	MarineTT
	Detlef Quadfasel	NACLIM
	Nikoleta Bellou	PERSEUS

Annex 2.C

List of organisations who contributed with written responses to the CSA Oceans stakeholder consultation organized by CSA Oceans in 2013.

Stakeholder group/Workshop	Organisation/Initiative/Project
Tech Platforms and Industry, Innovation & Economic associations	European Aquaculture Technology and Innovation Platform (EATiP)
	European Fisheries Technology Platform (EFTP)
	Maritime Technologies (MARTEC)
	WATERBORNE
International Scientific Organisations and Associations	European Aquaculture Society (EAS)
	European Consortium for Ocean Research Drilling (ECORD)
	European Fisheries and Aquaculture Research Organisation (EFARO)
	European Marine Ecosystem Observatory (EMECO)
	EuroMarine - FP7 coordination and support action designed to bring together the three FP6 marine Networks of Excellence (NoE) communities; EUR-OCEANS, MarBEF and Marine Genomics Europe
	European Marine Board
	International Council for the Exploration of the Sea (ICES)
ERA activities (ERA-NETs, Article 185)	BONUS EEIG - Baltic Organisations Network for Funding Science
	Cooperation in Fisheries, Aquaculture and Seafood Processing (COFASP)
	Maritime Technolocgies (MARTEC)
UN - International Organisations, Policy and Regional Conventions	Fishery Committee for the Eastern Central Atlantic (CECAF)
	Commission on the Protection of the Black Sea Against Pollution (Bucharest Convention)

	Group on Earth Observations Biodiversity Observation Network (GEO BON)
	International programme of Harmful Algae (GEOHAB)
	Helsinki Commission (HELCOM)
	International Hydrographic Organization (IHO)
	Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO)/ Global Ocean Observations Systems (IOC-GOOS)
	Secretariat of the OSPAR Convention
	Standing Committee on research for fisheries (SCARFISH)

Stakeholder group/Workshop	Organisation/Initiative/Project
Infrastructure Initiatives, projects and organisations	Aquaculture infrastructures for excellence in European fish research (AQUAEXCEL)
	COOPEUS
	European Marine Biological Resource Centre (EMBRC)
	European Multidisciplinary Seafloor Observatory (EMSO)
	Towards an Alliance of European Research Fleets, FP7 funded infrastructure project (EUROFLEETS II)
	European Global Ocean Observing System (EuroGOOS)
	Gliders for Research, Ocean Observation and Management (GROOM)
	TOWARDS A JOINT EUROPEAN RESEARCH INFRASTRUCTURE NETWORK FOR COASTAL OBSERVATORIES - FP7 funded project (JERICO I3)
	e-Science European Infrastructure for Biodiversity and Ecosystem Research (LIFEWATCH)
FP7 projects - Collaborative projects	European Marine Knowledge Transfer and Uptake of Results (MarineTT)
	Exploring Marine Resources for Bioactive Compounds: From Discovery to Sustainable Production and Industrial Applications (MAREX)
	Policy-orientated marine Environmental Research for the Southern European Seas (PERSEUS)
	Towards COast to COast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential (CoCoNet)
	Towards and Integrated Marine and Maritime. Science Community (MARCOM+)
	North Atlantic Climate, FP7 Collaborative Project (NACLIM)
	Changes in Carbon Uptake and Emissions by Oceans in a Changing Climate, FP7 Collaborative Project (CARBOCHANGE)

Annex 3 - Bibliometric Assessment of Research Related to Marine Microplastics

BIBLIOMETRIC ASSESSMENT OF RESEARCH ACTIVITIES RELATED TO MICROPLASTICS MARINE POLLUTION

Contribution to CSA Oceans by WP1;

The JPI Oceans being broad and addressing cross-cutting issues, will furthermore require the support of *specific tools for mapping and gap analysis* in defined areas: Baseline setting, continuous monitoring and mapping of researchers, institutions and collaborative networks. "*In partnership with the European Commission bibliometric studies will be tabled to support this process*." (DOW Part B page 19)

BIBLIOMETRIC MAPPING – WHY AND HOW: A MICROPLASTICS PILOT

In addition to the comprehensive mapping of the existing marine research and programs relevant to JPI Oceans by WP3 and the resource demanding analysis of CSA Oceans' consultation questionnaires by WP3,4,5,6), there is a need for more targeted, flexible, and less resource consuming mapping methods.

Bibliometry provides one such tool, and should be used in conjunction with other mapping methods.

Thus, a limited bibliometric study with relevance to the Microplastics Pilot Action was performed. It gives a good illustration of the usefulness of this tool for CSA Oceans and JPI Oceans when exploring new fields and evaluating potential new activities. It is also a tool for monitoring and evaluation of research fields, activities and actors.

BACKGROUND

According to the Description of Work (DOW page 6) for CSA Oceans, "the overall aim of work package 1 (WP1) is to deliver a coherent draft Strategic Research and Innovation Agenda, Implementation Plan, Joint Activities ..". Among the specific objectives of [WP1] are to: "Provide guidance to the mapping and gap analysis activities (WP3, 4, 5, 6) to ensure CSA Oceans collects information through an *appropriate process that is relevant for the JPI Oceans SRIA and Implementation Plan*" and "Develop *procedures for continuous mapping* after the end of the CSA Oceans project, based on the experience and best practices gathered in the mapping and gap analyses (WP3, 4, 5, 6). The overall strategy of CSA Oceans is to complete a number of strategic actions and come up with concrete deliverables, which will strengthen the foundation and provide significant momentum for the successful development of the JPI Oceans (DOW Part B page 17).

Likewise *mapping and gap analysis will be conducted rationally*, thus where questionnaires will be developed this will be done in cooperation amongst the WPs to cover all needs. Moreover, "the JPI Oceans being broad and addressing cross-cutting issues will *require support of specific tools to quality and provide baselines for gaps where it is expected that JPI Oceans can add value*. In partnership [and dialogue] with the European Commission bibliometric studies will be tabled to support this process." (DOW Part B page 19).

WP3 will conduct a comprehensive mapping and analysis of the existing marine research investments, strategies and programs relevant to JPI Oceans' needs and objectives. Input from the broad consultations performed by WP3,4,5,6 will be analysed, constituting a comprehensive basis for the work toward the Strategic Research and Innovation Agenda (SRIA).

The bibliometric study described in this report is *an example* of one alternative *"more targeted, flexible, and less resource consuming mapping methods"*

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1. "Bibliometric assessment of Research Activities Related to Microplastics Marine Pollution" Power point slide report by Science-Metrix:
2. Data sheets

Science-Metrix

BIBLIOMETRIC ASSESSMENT OF RESEARCH ACTIVITIES RELATED TO MICROPLASTICS MARINE POLLUTION

Presentation to: **JPI Oceans** | **February 5th, 2014**

Introduction

- Science-Metrix was mandated by JPI Oceans to provide bibliometric data in the field of microplastics marine pollution for the 1996-2012 period.
- Given that preliminary search yielded very few publications on the topic in the database, this study constitute more of a "scoping exercise" than a full-fledge bibliometric study.
- Publishing trends at the world level and for leading countries are presented in this project. Leading institutions and researchers over the global period are also presented. Other indicators on specialization and scientific impact are included where needed, and a collaboration network between leading researchers completes this analysis.

Methods

- Bibliometric data have been produced using the metadata from 24 million scientific papers published between 1996 and 2012 and indexed in Scopus (Elsevier).

- **Identification of papers related to microplastics marine pollution:** A query that searches for specific combinations of keywords within titles, keywords and abstracts has been employed. A primary "plastic" term has been combined with a secondary term. Example of primary "plastic" terms are: *microplastic, microscopic plastic, plastic particle, plastic pellet, etc...* Secondary terms include *ocean, sea, pollution, marine environment, toxicity etc…* Those terms were selected through a validation process which consisted in taking a random sample of the selected articles and reading the abstract to see if the article was relevant to microplastics marine pollution. If a keyword or a combination of keywords yielded false results it was discarded. Optimal keywords were selected by repeating this process for every new keywords or combinations of keywords.

Methods (cont'd)

- **Specialization index (SI):** Measures the intensity of research of an entity (e.g., country, institution) in a given field relative to the intensity of the world in the same field. It is calculated as follow:

  SI = % of the entity papers in microplastic / % of world papers in microplastic

- **Average of relative citations (ARC):** Indicates the observed scientific impact of research conducted by an entity (e.g., country, institution) based on the average number of citations its papers received relative to the average number of citations received by world papers. Citation counts are normalized to account for different citation patterns across fields of science.

  ARC > 1 → The entity's research is more cited than the average world research
  ARC < 1 → The entity's research is less cited than the average world research

- **Average of relative impact factors (ARIF):** Similar to the ARC, but indicates the expected scientific impact of research conducted by an entity based on the impact factor of the journals in which its papers are published.

Methods (cont'd)

Important note on impact scores

- Given the small number of papers involved in the following analysis, impact scores are prone to fluctuation since extreme values can highly impact the averages in the computation of the ARC and ARIF.
- Usually, Science-Metrix does not compute impact scores for entities with less than 30 papers having valid relative citations scores (RC) or relative impact factor scores (RIF), but applying this limitation for this study would have resulted in most entities not having any impact scores presented at all.
- Consequently, ARC and ARIF scores are included in the analysis even for entities with less than 30 papers with relative impact scores (RCs or RIFs), but in these cases the ARCs and ARIFs are formatted using a light gray font. The readers should be careful in using/interpreting the following results as most scores would not have been computed normally.

Methods (cont'd)

Collaboration network of leading researchers

- The node size is proportional to the researcher's output (varies from 4 to 13 papers).
- Each link represent collaborations between two researchers.
- The width of links is proportional to the number of collaborations (varies from 1 to 5 collaborations).
- The color of the nodes represents the country in which all or the majority of a researcher's output has been produced.

Leading countries in microplastics marine pollution

Country	Papers	Trend	ARC	ARIF	SI
United States	191		1.13	1.12	1.15
United Kingdom	77		1.33	1.19	1.75
Japan	47		1.04	0.89	1.07
China	40		0.59	0.74	0.51
Australia	36		1.04	1.19	2.25
Brazil	35		1.32	0.89	3.15
Canada	29		1.16	1.16	1.24
Germany	24		1.85	1.14	0.58
France	22		1.47	1.06	0.73
World	**578**		**1.00**	**1.00**	**1.00**

- Small field: Less than 600 papers published between 1996 and 2012 at the world level.
- Nevertheless, the area is becoming more and more of interest, with an annual output reaching 92 publications in 2012, compared to only 9 in 1996.

Among countries with at least 20 publications:

- Most cited countries (ARC) : Germany (1.85), France (1.47) and UK (1.33)
- Highest impact factor (ARIF): UK (1.19), Australia (1.19) and Canada (1.16)
- Most specialized countries (SI) : Brazil (3.15), Australia (2.25) and UK (1.75)

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Leading institutions in microplastics marine pollution

Institution	Papers	ARC	ARIF
NOAA - National Oceanic and Atmospheric Administration	46	0.92	0.90
University of Hawaii at Manoa	26	0.96	0.99
Natural Environment Research Council - NERC	15	1.82	1.28
University of Plymouth	15	2.79	1.71
Algalita Marine Research Institute	13	3.19	1.40
Universidade Federal de Pernambuco	11	1.91	0.94
Tokyo University of Agriculture and Technology	10	2.63	1.32
University of California, San Diego	10	1.03	0.94
USGS - US Geological Survey	10	1.21	1.00

Among organisations with at least 10 publications:

- NOAA (46 papers) and the University of Hawaii at Manoa (26 papers) have the largest scientific productions in microplastics marine pollution research.
  - A large portion of NOAA research is carried in Hawaii, hence most publications come from this region. This probably strengthen the position of the University of Hawaii at the world level.
- University of Plymouth and the Algalita Marine Research Institute score the highest ARCs and ARIFs. However, these are based on less than 15 publications.

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Leading researchers in microplastics marine pollution

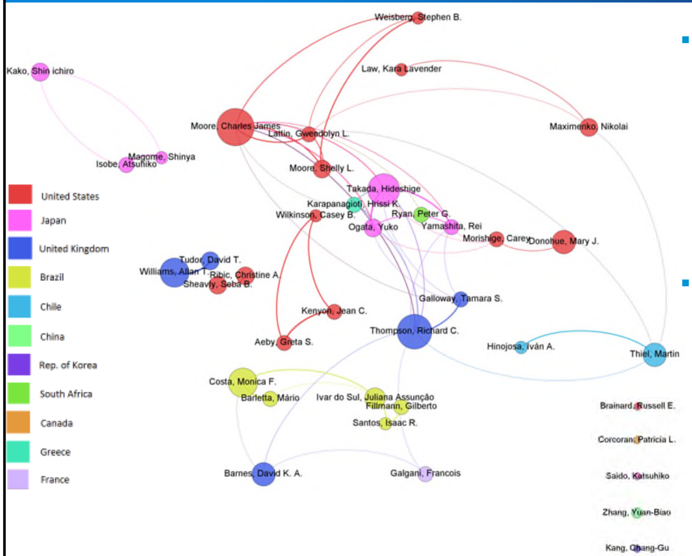
Researcher	Papers	ARC	ARIF
Moore, Charles James	13	3.19	1.40
Thompson, Richard C.	11	3.61	1.65
Takada, Hideshige	11	2.34	1.21
Williams, Allan T.	10	0.48	0.72
Costa, Monica F.	10	1.73	0.95
Donohue, Mary J.	8	0.69	1.11
Barnes, David K. A.	8	1.98	1.30
Thiel, Martin	7	2.56	1.30
Ivar do Sul, Juliana Assunção	7	2.14	1.20

- Only 5 researchers published at least 5 publications in the field over the period (1996-2012).

- Charles James Moore (Algalita Marine Research Institute) was the most active researcher in microplastics marine pollution at the world level with 13 publications between 1996 and 2012.
- Richard C. Thompson (Plymouth University) ranks 1st among researchers with at least 7 publications for both the ARC (3.61) and the ARIF (1.65), but based on 11 publications only.

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

Collaboration network of researchers



- Even if the field is small, collaborations are relatively frequent, with many national structures emerging in the international network (e.g., US, Brazil, Japan)
- National clusters are also connected together, which is surprising considering the few opportunities to collaborate. Leaders in the field form a closely integrated community according to these results.

Source: Computed by Science-Metrix using the Scopus database (Elsevier).

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Science-Metrix

Bibliometric Assessment of Research Activities Related to Microplastics Marine Po
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These statistics were produced by Science-Metrix from data derived from Scopus (Copyright Elsevier)

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Leading countries in microplastics marine pollution (1996–2012)

Country	Papers	Trend	ARC	ARIF	SI
United States	191		1,13	1,12	1,15
United Kingdom	77		1,33	1,19	1,75
Japan	47		1,04	0,89	1,07
China	40		0,59	0,74	0,51
Australia	36		*1,04*	*1,19*	*2,25*
Brazil	35		1,32	0,89	3,15
Canada	29		*1,16*	*1,16*	*1,24*
Germany	24		*1,85*	*1,14*	*0,58*
France	22		*1,47*	*1,06*	*0,73*
Rep. of Korea	17		*0,31*	*0,70*	*1,22*
South Africa	14		*1,47*	*1,05*	*4,79*
Italy	14		*0,94*	*0,94*	*0,62*
Spain	13		*0,86*	*0,73*	*0,73*
India	12		*0,65*	*0,54*	*0,70*
Netherlands	12		*1,28*	*1,17*	*0,94*
Greece	11		*1,09*	*1,10*	*2,62*
New Zealand	9		*1,80*	*1,22*	*2,98*
Switzerland	8		*0,71*	*1,18*	*0,87*
Chile	8		*2,22*	*1,24*	*4,88*
Sweden	8		*2,02*	*1,50*	*0,90*
Norway	6		*3,09*	*1,15*	*1,58*
Belgium	6		*2,42*	*1,38*	*0,85*
Turkey	6		*0,33*	*0,63*	*0,83*
World	**578**		**1,00**	**1,00**	**1,00**

Note: Scores in light gray are highly prone to fluctuations; please use/interpret with caution

Source: Compiled by Science-Metrix using Scopus database (Elsevier)

Annual number of scientific publication on microplastics pollution, 1996–2012

Country	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
United States	3	9	7	5	3	6	8	8	8	9	11	12	14	17	18	21	32
United Kingdom	2	5	1	2	0	2	3	6	4	4	2	4	3	10	6	14	9
Japan	0	0	0	1	1	2	2	1	4	6	0	0	4	7	5	8	6
China	0	0	0	0	0	1	0	0	2	0	1	2	4	3	11	9	7
Australia	0	2	2	2	1	0	2	2	2	1	0	1	2	2	2	7	8
Brazil	0	0	0	0	0	1	0	0	3	2	0	5	1	5	7	8	3
Canada	0	0	0	1	1	0	1	0	0	0	3	2	4	1	5	7	4
Germany	0	0	0	0	0	0	0	0	0	1	0	2	3	0	3	5	10
France	1	0	1	1	1	1	2	1	0	0	0	0	1	2	4	5	2
Rep. of Korea	0	0	0	1	0	0	0	0	0	3	1	1	2	3	2	3	1
South Africa	0	1	0	3	0	0	1	0	0	1	0	0	1	3	0	0	4
Italy	0	0	0	1	1	0	0	3	0	0	1	1	0	0	0	2	5
Spain	0	0	0	0	0	0	1	1	1	0	3	1	0	2	1	1	2
India	0	0	0	0	0	0	1	0	0	0	1	0	1	0	3	3	3
Netherlands	0	1	0	1	0	1	1	0	0	0	0	1	0	3	0	1	3
Greece	0	0	1	1	0	0	0	0	2	0	0	1	2	1	1	1	1
New Zealand	1	0	0	1	1	0	1	0	0	0	0	0	0	2	1	0	2
Switzerland	0	0	0	0	0	0	0	1	1	0	0	0	0	1	2	2	1
Chile	0	0	0	0	0	0	0	1	0	1	0	0	0	3	0	2	1
Sweden	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	2	1
Norway	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	3	1
Belgium	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	3	1
Turkey	0	0	0	0	0	0	0	0	1	1	1	0	0	0	2	1	0
World	9	19	12	19	10	15	25	22	29	29	24	30	39	48	71	85	92

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Leading institutions in microplastics marine pollution (1996–2012)

Institution	Country	Papers	ARC	ARIF
NOAA - National Oceanic and Atmospheric Administration	United States	46	0,92	0,90
University of Hawaii at Manoa	United States	26	0,96	0,99
Natural Environment Research Council - NERC	United Kingdom	15	1,82	1,28
University of Plymouth	United Kingdom	15	2,79	1,71
Algalita Marine Research Institute	United States	13	3,19	1,40
Universidade Federal de Pernambuco	Brazil	11	1,91	0,94
Tokyo University of Agriculture and Technology	Japan	10	2,63	1,32
University of California, San Diego	United States	10	1,03	0,94
USGS - US Geological Survey	United States	10	1,21	1,00
University of Exeter	United Kingdom	9	3,57	1,41
EPA - Environmental Protection Agency	United States	9	0,74	1,16
University of Cape Town	South Africa	8	2,05	1,14
FURG - Universidade Federal do Rio Grande	Brazil	8	1,30	1,07
Ehime University	Japan	8	2,66	1,40
University of Wisconsin-Madison	United States	8	0,60	0,94
CNRS - Centre national de la recherche scientifique	France	7	1,66	1,32
University of Patras	Greece	7	1,48	1,19
Jinan University (China)	China	7	0,35	0,20
IFREMER	France	7	1,87	1,70
CSIRO - Commonwealth Science and Industrial Research Organization	Australia	7	0,98	0,86
Universidad Catolica del Norte	Chile	7	2,56	1,30
Helmholtz-Gemeinschaft e.V.	Germany	6	2,81	1,37
University of Tasmania	Australia	6	0,64	1,05
Chinese Academy of Sciences	China	6	0,46	1,00
Environment Canada	Canada	6	1,52	1,29
Centro de Estudios Avanzados en Zonas Áridas (CEAZA)	Chile	6	2,82	1,33
University of Glamorgan	United Kingdom	6	0,40	0,81
Fisheries Research Agency (Japan)	Japan	6	0,96	1,30
University of Western Ontario	Canada	5	1,54	1,23
University of Queensland	Australia	5	1,36	1,33
Hokkaido University	Japan	5	1,73	1,22
Southern Cross University	Australia	5	0,89	1,15
University of Washington	United States	5	2,03	1,08
North Carolina State University	United States	5	4,67	1,74
Sea Education Association-SEA	United States	5	3,08	1,60
Sheavly Consultants	United States	5	2,11	1,27
University of Hawaii at Hilo	United States	4	0,91	0,78
University of Florida	United States	4	0,47	1,06
Kyushu University	Japan	4	1,00	0,84
Florida Fish and Wildlife Conservation Commission	United States	4	0,72	1,26
Woods Hole Oceanographic Institution	United States	4	3,78	1,86
University of Miami	United States	4	0,94	0,88
KORDI - Korea Ocean Research & Development Institute	Rep. of Korea	4	0,12	0,72
CSIC - Consejo Superior de Investigaciones Científicas	Spain	4	1,04	0,94
WUR - Wageningen University and Research Centre	Netherlands	4	5,17	1,52
Nihon University	Japan	4	0,23	0,13
National Research Foundation (NRF)	South Africa	4	3,44	1,27
CONICET	Argentina	4	0,66	1,46
University of Guelph	Canada	4	0,86	0,92
University of Auckland	New Zealand	4	1,87	1,66
University of Tokyo	Japan	4	0,96	0,54
Sanyo Techno Marine Inc.	Japan	4	2,02	1,30

Note: Scores in light gray are highly prone to fluctuations; please use/interpret with caution

Source: Compiled by Science-Metrix using Scopus database (Elsevier)

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Leading researchers in microplastics marine pollution (1996–2012)

Researcher	Papers	ARC	ARIF
Moore, Charles James	13	3,19	1,40
Thompson, Richard C.	11	3,61	1,65
Takada, Hideshige	11	2,34	1,21
Williams, Allan T.	10	0,48	0,72
Costa, Monica F.	10	1,73	0,95
Donohue, Mary J.	8	0,69	1,11
Barnes, David K. A.	8	1,98	1,30
Thiel, Martin	7	2,56	1,30
Ivar do Sul, Juliana Assunção	7	2,14	1,20
Sheavly, Seba B.	6	1,58	1,27
Tudor, David T.	6	0,53	0,65
Moore, Shelly L.	6	1,22	1,08
Ogata, Yuko	6	3,59	1,24
Ribic, Christine A.	6	0,75	1,29
Kako, Shin ichiro	6	2,02	1,32
Zhang, Yuan-Biao	5	0,44	0,22
Yamashita, Rei	5	3,30	1,39
Ryan, Peter G.	5	2,44	1,27
Morishige, Carey	5	1,04	1,24
Kenyon, Jean C.	5	0,70	0,41
Fillmann, Gilberto	5	1,31	1,08
Isobe, Atsuhiko	5	2,02	1,34
Galgani, Francois	5	1,87	1,98
Galloway, Tamara S.	5	4,04	1,70
Karapanagioti, Hrissi K.	5	1,81	1,17
Aeby, Greta S.	5	0,70	0,41
Barletta, Mário	5	2,89	1,01
Saido, Katsuhiko	4	0,23	0,13
Weisberg, Stephen B.	4	0,61	1,00
Santos, Isaac R.	4	1,33	1,13
Wilkinson, Casey B.	4	0,59	0,40
Magome, Shinya	4	2,02	1,30
Maximenko, Nikolai	4	1,09	1,57
Kang, Chang-Gu	4	0,00	0,38
Hinojosa, Iván A.	4	2,20	1,24
Law, Kara Lavender	4	2,20	1,68
Lattin, Gwendolyn L.	4	1,74	1,24
Corcoran, Patricia L.	4	1,53	1,17
Brainard, Russell E.	4	1,56	0,98

Note: Scores in light gray are highly prone to fluctuations; please use/interpret with caution

Source: Compiled by Science-Metrix using Scopus database (Elsevier)

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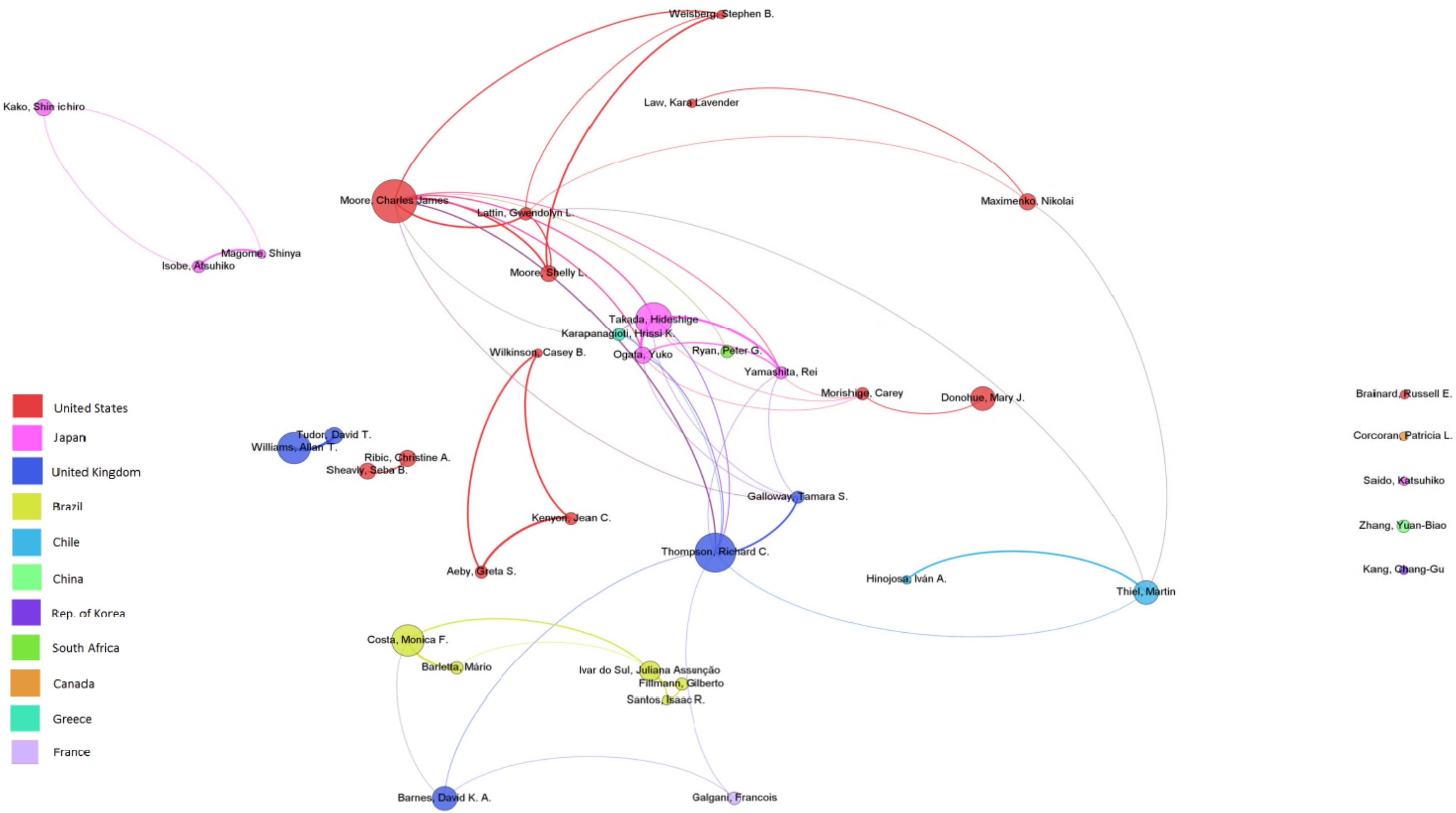
Collaboration network of leading researchers in microplastics marine pollution (1996–2012)



Note: The size of the bubbles is proportional to the number of publications and the width of the links is proportional to the number of co-publications. Nodes are colored based on country affiliation of researchers.
Source: Compiled by Science-Metrix using Scopus database (Elsevier)