COLUMBUS
KNOWLEDGE TRANSFER FOR BLUE GROWTH

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Knowledge Gaps per Focus Area

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1. EXECUTIVE SUMMARY

One of the specific objectives of Work Package 4 (WP4) as described in the Description of Action is to "identify research gaps in each Focus Area". Following the mid-term review, one deliverable from WP3, which had the aim of identifying challenges and knowledge needs per focus area, and one from WP4 were combined, resulting in Deliverable 4.5. This Deliverable aims to provide an overview of if (and how) identified needs – as documented in Deliverable 3.2 – in science, policy, industry and society have been met by the Knowledge Outputs (KOs) selected by each Node. Furthermore, it provides recommendations for the future research and priority needs of the sector, based on the experience of each sector expert - named Fellows - gathered over the lifetime of the COLUMBUS project.

In 2015, in order to guide the project collection phase carried out in WP4, the COLUMBUS Competence Nodes (CNs) were asked to identify relevant keywords within each of their sectors of competence (WP3). This allowed EurOcean to search for keywords within the abstracts of projects under the seventh (FP7) European Commission (EC) Framework Programme from the Marine Knowledge Gate database. Other projects from FP6, HORIZON2020, National and other EC funding programmes were successively added by fellows themselves. From the projects thus identified, the CNs selected those they considered most relevant to their focus area. The process of project selection and prioritisation was carried out by all CNs under the umbrella of the COLUMBUS framework, but different selection and prioritisation criteria were applied by the CNs. Each CN applied what they believed to be the most appropriate strategic approach for identifying relevant projects that may have KOs to fill the identified knowledge needs, bottlenecks and challenges.

For the development of Deliverable 4.5, needs and challenges identified by each CN - and presented in the Deliverable 3.2 - were reviewed. The collected KOs were then aligned with these needs for each Competence Node. Among the selected projects, only the KOs collected and previously validated by coordinators from FP7 projects were taken into consideration for the analysis. The number of projects and related KOs included in this study was therefore a small window of the overall landscape of European funded projects. It should be noted that there was not a strict alignment between the needs identified and all the KOs, as each CN had flexibility to choose the KOs they considered most promising to achieve impact. These issues therefore precluded a quantitative analysis of how many of the needs and challenges were met by the collected KOs as any such results would be meaningless. Once the needs and KOs had been linked by association, structured interviews were carried out with the CNs in order to get a more in-depth picture of how well the needs were addressed and to determine the CN s' perspectives on remaining sectoral gaps.

All the CNs successfully managed to collect KOs that addressed a number of the needs identified and that might potentially help to tackle the challenges within each CN sector. In most cases, KOs had a very strong science or industry focus, responding therefore to scientific or industrial challenges. Other CNs prioritised more policy-related KOs, where the timelines in terms of adoption and implementation can be longer. Society was the End User that was addressed the least.

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Deliverable 4.5 analysis demonstrates also how a particular need can be tackled by many sectors through different tools and approaches. Furthermore, it demonstrates that the COLUMBUS methodology is suitably flexible to be successfully applied across many sectors, with different stakeholders, End Users and tools. Marine litter is an example of a cross-cutting topic that has been identified and addressed by four of the CNs (Biological Resources, Marine Environment & Futures, Monitoring and Observation, Governance and Management). Specific recommendations in relation to filling outstanding gaps have been made. As mentioned above, this analysis is based on FP7 projects only. Since the conclusion of that programme, the marine litter issue has continued to grow as a very "hot topic", and it is important to note that some of the needs and gaps may have been addressed through subsequent projects funded under other programmes, such as Horizon 2020.

The **main barriers** to effectively addressing needs and sectoral challenges were highlighted by CNs; however, some **opportunities** for overcoming these barriers were identified and suggested by the Fellows:

1. From a **policy**-perspective, a lack of up-to-date policy frameworks for regulating the use and the commercialisation of brand new technologies was identified by a number of CNs (Transport, Physical Resources, Biological Resources, Fisheries, and Monitoring). For example, when new prototypes or technologies in ocean observing are ready to be commercialised, there is a **lack of a regulatory framework** which could allow the use of these innovations in the field. In the fisheries sector new technologies have to pass through many regulatory and patenting processes before being utilised, which makes exploiting the results arduous and sometimes impossible. **Streamlining of processes and more reactive policy development** could help mitigate these issues.

2. The **low maturity Level** of many KOs was for COLUMBUS a barrier to their transfer (Physical Resources, Biological Resources, Transport, and Monitoring). The main reason of not achieving higher maturity was often due to financial and time constrains necessitated by time-bound project contracts. This results in numerous early-stage non-commercially viable prototypes that require further developments. A valuable approach would therefore be a **comprehensive expert analysis of the wide range of European project results** in order to allocate resources prioritising the highest potential ones. A **compilation of the results developed by all the various projects** could be created, containing ancillary information such as maturity level, IP conditions, so that interested parties can more easily take it forward.

3. **Limited data and outputs access** due to poor Research Data Management & FAIR[1] Sharing by past projects was highlighted by three nodes (Monitoring, Biological and Physical Resources). Although data sharing is dealt with by other EC initiatives, our findings demonstrate the strong

[1] **FAIR** - a set of guiding principles to make data **Findable, Accessible, Interoperable, and Re-usable**

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complementarity and interdependence between EC Priorities on Open Science and Knowledge Transfer.

4. Awareness of "**low readiness levels/potential high-payoff**" KO's among industry is low (Biological Resources, Physical Resources) yet research outputs hold potential for added-value pharmaceutical products and ocean energy developments, for example. In addition **sharing of non-patentable results** (and negative research results) can increases chances of awareness (and investment) and reduce duplication of effort.

5. Incentivising more systemic reliance on **co-creation and project co-design with end-users** can in the immediate-term optimise science-to-society transfer and science-based policy formulation (Marine Environment & Futures); in the long-term making **Ocean Literacy** part of standard education can lay the ground for better ocean stewardship.

Despite the limited number of projects considered (in total 84, with 924 KOs) and the COLUMBUS project's constraints in terms of financial and time resources, this analysis demonstrated how the identification of challenges and needs, followed by a strategic selection of project KOs that can tackle them, can provide concrete information on what has and hasn't been addressed by EU funded projects. It also highlights what out to be prioritised for future research.

If such an approach as that implemented by COLUMBUS were carried out systematically following the completion of research projects or programmes, it could lead to being able to meet needs and challenges in a more timely and targeted manner. This could also result in the reduction of duplication of research effort where often the same need is addressed by a number of projects at different times, but without awareness of the work already carried out.

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2. INTRODUCTION

As part of the Work Package 3 (WP3) analysis, in 2015, the COLUMBUS Competence Nodes (CNs) developed a profile of their CN. The second part of these profiles identified key challenges, bottlenecks and knowledge gaps in the various sectors through a literature review of sector relevant documents and reports. Deliverable 3.2 provided a short introduction to each CN, followed by a description of its specific knowledge needs.

In 2015, in order to guide the project collection phase carried out in WP4, the COLUMBUS Competence Nodes (CNs) were asked to identify relevant keywords within each of their sectors of competence (WP3). This allowed EurOcean to search for keywords within the abstracts of projects under the seventh (FP7) European Commission (EC) Framework Programme from the Marine Knowledge Gate database. Other projects from FP6, HORIZON2020, National and other EC funding programmes were successively added by fellows themselves.

Deliverable 4.5 is part of WP4, which has the aim of identifying, collecting and monitoring past and current research activities with a view to collecting KOs focused on priority areas defined in WP3. Within the WP4 scope, one of the specific objectives of the work package is to identify research gaps in each CN's focus areas. While the Description of the Action (DoA) points towards focus areas, the assessment of needs and challenges carried out in WP3 was based on End Users for each of the CNs (D3.2-CNs Profiles). Deliverable 4.5 also followed the End Users approach for each CN, as agreed by the project consortium at the "legacy meeting". Deliverable 4.5, therefore, aims to provide an overview of if and to what extent the identified needs - as documented in Deliverable 3.2, in science, policy, industry and society - have been met by the KOs collected by each CN. Furthermore, it provides recommendations for the future research and priority needs of each sector, based on the Fellows´ experience gained over the lifetime of the COLUMBUS project.

It should be noted that there is not a strict alignment between the needs identified and all the KOs collected. Whilst the projects that were identified should be aligned with the knowledge needs per sector, as they were selected based on the keywords within their project abstracts, each CN had flexibility to choose which projects they collected KOs from.

In some cases KOs have a very strong industry focus. Other CNs prioritised policy-related KOs, where the timelines in terms of adoption and implementation can be longer. The CNs were tasked with collecting KOs from projects that they felt had potential for impact, and could respond to the needs identified in the profiles (Deliverable 3.2). Each CN carried out the project selection process following different approaches; selecting projects in their area of expertise, those with high maturity level, or projects that clearly target the needs previously identified. Moreover, **only FP7-funded projects were considered for the development of Deliverable 4.5**, and among these only validated KOs (those confirmed as correct by the project coordinators). Identifying gaps in priority areas was considered more coherent when looking within only one framework programme, i.e. FP7, instead of considering all programmes. In accordance with the COLUMBUS methodology, non-validated KOs were not taken forward or utilised for any additional COLUMBUS activities, as they can be biased, partial or incorrectly

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representative of the work and its results. As a result, this study is not fully comprehensive in covering all the needs and gaps identified and only deals with a subset of projects (i.e. validated FP7) within each CN.

3. METHODOLOGY AND APPROACH

The development of Deliverable 4.5 was carried out in three phases.

Information collection phase: Information on CN sector status, needs and challenges identified within each CN were collected by reviewing Deliverable 3.2 and the CN profile mentioned above.

Matrix development: only Seventh Framework Program funded projects were considered, and among these only KOs validated by project coordinators. Each KO was analysed against the specific needs identified per CN and subsequently associated to those needs it was considered to address. This exercise was captured in a matrix which showed how each KO was associated with one or more need (Annex 1). The matrix formed the basis from which to extract the following information:

- most addressed needs
- needs not tackled by any KOs
- maturity of the KOs (high or low)
- main thematic topic addressed
- most targeted End User

Given the different approaches taken by the CNs to selecting the projects and KOs they decided to take forward, the matrix analysis only served to provide a general overview. As the nodes did not systematically collect projects aligned with the needs identified, it proved impossible to carry out any meaningful quantitative analysis of the above metrics. Hence, this approach was supported by carrying out interviews with each CN Fellow.

Interviews and analysis: Skype interviews were carried out with the eight CN Fellows[2]. Before each interview, a questionnaire was sent to all the Fellows (Annex 2). The interview was a valuable tool to provide context and a better understanding of the information extracted from the matrix. The interview also allowed the identification of reflections and future research recommendations based on the experience of the Fellows. Combining matrix evaluation and interviews with the Fellows, one chapter for each CN was developed and, composed of three sections:

- an overview of the sector description and needs identified

[2] A ninth Competence Node, Marine Tourism, collected KOs but was closed prior to this study being performed and, hence, is not included.

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- a description of the general situation of the projects and KOs collected within the CN and their success in addressing needs
- an overall reflection of needs met with recommendations for the future

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4. COMPETENCE NODE ANALYSIS

4.1 Maritime Transport and Logistic Competence Node

Description of Competence Node Sector

The last decade has brought significant improvements of production technologies to the European transport sector. In addition to the more standard ship types and designs, new business fields are growing in specialised markets, which are challenging the sector with the needs for new technologies and innovations. The most promising fields include the fast-rising offshore renewables sector, the exploration of new shipping routes (e.g. polar) and deep-sea resource prospecting (e.g. oil, gas, minerals). As stated in D3.2, completed in 2015, by 2050, the European transport sector will not only encompass transportation, manufacturing and trade but will be an essential part of offshore food production, energy generation and mineral exploitation. Key goals for future developments are therefore to achieve well organised, safe, sustainable, competitive and resource efficient systems throughout the whole industrial, societal and environmental value chain, whilst addressing the market pressure from outside the EU.

In 2015, the Maritime Transport and Logistics CN experts identified specific challenges and needs necessary for an innovative and sustainable development, meeting the principles of the Blue Growth (Deliverable 3.2). These identified needs were grouped under bigger challenges regarding **addressing climate change**, **serving rapidly growing societal needs, competing with international markets,** and a development of a supportive **up-to-date European framework for the maritime transport and logistic sector.**

Projects and Knowledge Output Collected: meeting the needs identified

With a time constraint and a large range of topics and projects, Maritime Transport and Logistic CN experts identified 22 European funded projects, with 235 KOs, based on the relevance of the topic, which could address the challenges mentioned above. This selection was based on the most innovative and those considered as having the best market potential. All validated FP7 projects (twelve projects with 126 KOs) were considered for the matrix analysis, as specified in the methodology.

Since market demand is currently mainly focussed on the need for more sustainable solutions and efficiency, in line with the challenge of **addressing climate change while serving societal needs,** most of the projects were dealt with new sustainable technologies**.** The majority of KOs identified among the projects were specifically addressing the needs of **"finding innovative technological and environment-friendly solutions in the maritime sector and reduction of emissions** (including noise) towards an eco-efficient vessel". The projects AQUO (Achieve QUieter Oceans by shipping noise footprint reduction), and SONIC (Suppression Of underwater Noise Induced by Cavitation), generated KOs specifically addressing the underwater noise issue, developing tools to investigate and mitigate the effects of underwater noise caused by shipping. ADAM4EVE, (Adaptive and smart materials and structures for

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more efficient vessels) and RETROFIT (RETROFITting ships with new technologies for improved overall environmental footprint), had a specific focus on improving efficiency in terms of ships energy and emission performance. Generally, while the projects identified had interesting innovative outcomes, only a few of them had TRLs[3] mature enough to be transferred to End Users.

The projects THROUGHLIFE (Development and proof of new approaches for through-life asset management based on next generation of materials and production technology) and HILDA (High Integrity Low Distortion Assembly) were considered to be the best examples producing KOs that were relevant, innovative and cost-effective, whilst having a high TRL and a strong potential to be commercially valuable. Specifically, the needs addressed by THROUGHLIFE were "**finding innovative technological and environment-friendly solutions in the maritime sector**", "**new design methodologies aiming for life cycle designs"** and **"resource efficient transport systems (raw material and consumables)"**. The HILDA KOs addressed the "**implementation of practicable standards of maritime safety and security, efficiency of navigation and prevention and control of pollution leading to 80% reduction in casualties**". This need was also tackled by the KOs of projects ADAM4EVE and INCASS (Inspection Capabilities for Enhanced Ship Safety).

Due to the project selection criteria and the type of results that were produced (mainly prototypes, designs, and technologies), the End Users addressed the most were those from the industry and science sectors. However, two KOs did target policy and the need for a "**good European framework for the maritime transport and logistics sector**". Project RETROFIT and the KOs from AQUO addressed the **"Methodology for defining a regulation regarding the control of underwater noise** due to shipping in a given maritime area for protection of marine life" and "**Standard for the accurate measurement of ship underwater radiated noise** (source level) of ships in deep and shallow waters".

Outcomes and Recommendations:

As previously mentioned, projects collected and analysed were a small number of the entire FP7 landscape related to the maritime transport and logistics sector; however, it was possible to identify the following outcomes and recommendation for the future of the sector.

European research and funds are currently going in the correct direction regarding innovative solutions towards a more environmentally-friendly sector. Many new tools, materials, technologies and designs are being developed to increase efficiency and to reduce environmental impact of ships and vessels. Progress is being made in new technologies and innovation addressing offshore energy and a unique production methodology. However, there is still significant opportunity for improvement, as most new shipping technologies are still very costly and therefore beyond the reach of many potential End Users.

[3] Technology Readiness Levels (TRLs) are indicators of the maturity level of particular technologies. This measurement system provides a common understanding of technology status and addresses the entire innovation chain. There are nine technology readiness levels; TRL 1 being the lowest and TRL 9 the highest

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Much more research is still needed to **combat underwater noise**, **reduce emissions** and **increase the use of renewable energies**. **Ballast water treatment** is still an issue as well as **safety at sea**, which has to be addressed through new design solutions and implementation of policy regulations. A high potential direction for further research is towards the concept of **flexible vessels** and new technologies for the **discovery of new potential shipping routes.**

The overall Fellow's perception regarding current allocation of European funds is that many of the **project outcomes cannot reach a mature TRL due to time and money limitations**. The result is then a wide landscape of early-stage non-commercially viable prototypes that require further developments. A valuable approach would therefore be a **meticulous expert analysis of the wide range of European project results** in order to allocate funds prioritising the highest potential ones. This would enable them to progress further along the value chain. Moreover, the **establishment of research and innovation solution networks** to foster the fast use of innovation in applications, an **improved communication** within the entire sector as well as a committed **involvement of End Users in the project development** would increase the potential of generating transferrable and commercially ready-to-use outputs.

4.2 Marine Monitoring and Observation Competence Node

Description of Competence Node Sector

The Marine Monitoring and Observation Competence CN had a broad reach. It included all aspects that support the generation of marine knowledge in the form of data, data-products, services and information through marine monitoring and observations for End Users in policy, science, industry and civil society. Europe's ocean observation infrastructure capability is technologically quite advanced. It ranges from research vessels, observing and monitoring infrastructures, (which include networks of satellite-based, airborne and *in situ* platforms and sensors), remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), marine stations and data management facilities. However, the collection, storage and accessibility of marine observations data have proceeded so far in an uncoordinated way. Infrastructures are not properly coordinated among owners and governments, **generating a large degree of variability in spatial and temporal data coverage**. The long-term sustainability of data collection through monitoring programmes is extremely challenging due to time and resource limitations. A **fully integrated European Ocean Observation System** capable of supporting the coordination of data and information among different infrastructures, bodies, countries and sectors is not in place. Such an integrated system is the target of the European Ocean Observing System framework currently under development. Another one of the current biggest challenges is the **lack of publicly available data**: a large amount of valuable data and information is still difficult for users to find or is not available in a usable form. These current challenges are contributing to inefficiencies in European marine observation, and marine data collection, collation and sharing.

Europe's current marine observing capacity, designed mainly for monitoring and understanding the marine environment, must be further developed to address these issues while also considering the increasingly diverse needs of users from policy, industry and civil society. In 2015 the Monitoring &

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Observation Node experts identified specific needs that should be addressed to result in more efficient monitoring of Europe's marine environment and in a greater access to harmonized marine data for a variety of users (Deliverable 3.2).

Projects and Knowledge Outputs Collected: meeting the needs identified

CN experts focused their project selection primarily on results addressing the problem of data sharing and availability, which was the one most aligned with their area of expertise and networks. Twenty-six projects were collected with 228 related KOs; of these, 7 validated FP7 projects with 64 KOs were considered for the matrix analysis.

Most of the projects considered were focussed on **sensor technologies**. The projects COMMON SENSE (Cost-effective sensors, interoperable with international existing ocean observing systems, to meet EU policies requirements) and SEA-ON-A-CHIP (Real time monitoring of SEA contaminants by an autonomous Lab-on-a-chip biosensor) were directly working with **biosensor technology**, addressing the need for the **development of biogeochemical and biological sensors for automated observational platforms**. Some of the projects had very low TRLs, while others had successfully reached much higher TRLs. For instance, outputs from the project SMS (Spectrophotometric method for the detection of sulfonamides) were considered of high relevance for the development of a novel sensor for the detection of harmful algal blooms and also for its potential application for the detection of other species. SENSEOCEAN (Marine sensors for the 21st Century) also successfully developed new sensors with market-readiness. Within the MYOCEAN project (Development and pre-operational validation of the "Ocean Monitoring and Forecasting" component of the future GMES Marine Core Service) the "Service and access to products web portal" was identified as being relevant to the need for the **establishment of European Marine Environment Monitoring Service.** SeaDataNet (Pan-European infrastructure for Ocean & Marine Data Management) developed global vocabularies and standards for data management which are necessary tools **for improving data harmonisation and management**. While most of the KOs were addressing industry and science, the Wildsea Europe project was considered relevant for its aim of **enhancing citizen involvement in data collection**, targeting society directly. The project has the aim of promoting observation data collection through tourism activities such as citizen science initiatives. None of the KOs considered addressed policy directly, although all would have application to contribute to improved marine monitoring and management to support implementation of the Marine Strategy Framework Directive.

Outcomes and Recommendations:

Over recent years, a significant number of technological advances in ocean observing have been made, however not all of this progress has been fully capitalised on. Within the overall European project landscape, many EU financed projects deliver **outcomes that are not mature enough** to be transferred along the value chain via existing mechanisms or markets. This results in a high number of similar project outcomes, which in some cases are encountering the same barriers and issues at the same development phases, without the possibility to be utilised by any of the target users. Sometimes

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competition for funding generates the tendency to inflate expectations for project results that due to time and resource limitations are not ultimately met. Conversely, when projects do manage to successfully develop full new prototypes or technologies ready to be commercialised, there is a **lack of a regulatory framework** which could allow the use of these innovations.

Managing, curating, archiving and making project outputs visible with the support of governmental regulations and frameworks open to new technologies are required for the successful development of the sector. A **compilation of the results developed by all the various projects** could be created, containing ancillary information such as TRL level, IP conditions, so that interested parties can easily take it forward. In addition, another major barrier is the **lack of availability of data**; much of the research data from projects is still not made openly available, and this limits its potential to support policy implementation such as the Marine Strategy Framework Directive (MSFD) and the Blue Growth. Making data publicly available is still not rewarded within many research institutions. However, the requirement now under Horizon 2020 to implement the open data policy (and the more recent ability to cite datasets) within all funded projects will help to address this.

Together with **more transparency and cooperation** among data owners and between sectors, the **involvement of society in the data collection** through tourism or general citizenship activities (e.g. WildSea Europe project) could help in the compilation of public and easy-to-use data. In relation to data availability COLUMBUS is delivering recommendations to industry through a "best practice guide for data sharing"[4].

Future research still needs to focus on **biological sensor and biological observations**, for species abundance and distributions and seabed habitats. Additional investments are required for **marine litter and microplastic solutions**, and **sensor technology for climate change.**

4.3 Marine Biological Resources Competence Node

Description of Competence Node Sector

Marine biotechnology is an emerging and promising field with great economic potential: the global market for marine biotechnology products and processes is believed to offer significant growth. By 2020, it is forecast that the European marine biotechnology sector will be able to sustainably address key societal challenges in food and energy security, treatment drugs for human and animal health, industrial materials and processes. As a result, there is an increasing need for developing **tools and knowledge for the sustainable development of marine based products** (food, feed, nutraceuticals, cosmeceuticals, biomedical, biopolymers, enzymes with industrial applications and a range of other commodities), combined with **awareness programmes** for policy makers, the private sector and the general public about the potential of marine aquatic products.

[4] ttp://www.columbusproject.eu/Columbus_engage_industry_best_practice.pdf

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In 2015, the Marine Biological Resources CN identified needs required to achieve sustainable development of the sector. At the policy level a **common strategy on marine biotechnology** and **legal certainty in blue biotechnology** are needed for harmonising activities and requirements relating to the traceability and sustainability of marine resource. On a scientific and industrial level, there is the need to **map the blue biotechnology landscape in Europe** and **facilitate knowledge sharing and communication**, with coherent and coordinated efforts along the value chain from marine biomass to markets. There is the need for new **organism models and knowledge from genomics and taxonomy** on marine biodiversity and ecosystems. On the society level, the **implementation of a communication strategy** on marine biotechnology could increase public and stakeholder awareness with regards to the issues and benefits of the sector.

Projects and Knowledge Outputs Collected: meeting the needs identified

The process of project selection was not straightforward due to the nature of biotechnology related projects: many project results were in the form of publications, therefore difficult to allocate to the needs identified. Twenty-two projects were selected, with 154 KOs. Of these, 12 projects with 77 related KOs were validated and considered for this exercise.

Results of most of the projects were scientifically specific and with an early stage TRL. This made it difficult to evaluate their potential and innovation. However, a number of projects had interesting outputs addressing the needs included in the challenges mentioned above. "**Overcoming disconnection between research and commercialisation and application of marine biotechnology products and services**" was the most addressed need: a lot of results were not necessarily ready for market, but there are potentially good technologies or methodologies that could be employed by monitoring agencies, cultivators, etc. The need **for coherent and coordinated efforts along the value chain from marine biomass to markets** and that **of enhancing knowledge from genomics and taxonomy on marine biodiversity** were generally met by several KOs identified. Specifically, **genome bioinformatics and computational biology, sequence and structure analysis, and molecular evolution and genomic technologies** were the most investigated fields among the collected projects. Most of the projects were built with a science to science interface; however some projects had relevant outcomes directly targeting industry, addressing specific needs of the End User. Namely, SYMBIOCORE (SYnergies through Merging BIOlogical and biogeochemical expertise in COral Research) had interesting results targeting the coral cultivation and aquarium industry while BIOCLEAN (New BIOtechnologiCaL approaches for biodegrading and promoting the environmEntal biotrAnsformation of syNthetic polymeric materials) targeted plastics production and waste treatment facilities for the removal and treatment of micro-plastics.

A valuable proof of good collaboration and implementation of results was the combination of the three projects: MaCuMBA (Marine Microorganisms: Cultivation Methods for Improving their Biotechnological Applications), MICRO B3 (Marine Microbial Biodiversity, Bioinformatics and Biotechnology) and PHARMASEA ("Increasing Value and Flow in the Marine Biodiscovery Pipeline"; although PHARMASEA was a part of the MaCuMBA/MICRO B3 cluster, as an on-going project the KOs were not able to be collected within the COLUMBUS project). These projects together formed an excellent example of using

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multiple projects to more realistically tackle knowledge gaps that exist along multiple parts of the value chain and that would be beyond the capacity of any single project.

Outcomes and Recommendations:

As a relatively young and fast-growing field, there is still plenty of scope for improvements and for new innovations in marine biotechnology. However, several barriers are hampering the advancement and success of the sector in the European economy. **Availability of data and results is still very low**, especially in the pharmaceutical biotechnology field; there are **barriers in data sharing** and scientists tend to patent their results and innovation (primarily for career reasons) rather than provide them openly for others to take-up. **Industry therefore does not always have access to science innovation** and cannot invest in it. Frequently new outcomes and discoveries obtained from research cannot be brought into the market because of lack of investment. The biotech field is an extremely complex one, with a very low rate of success of new discoveries. To tackle this, **successes *and* failures need to be disseminated** in order to avoid investing time and resources in something already successfully (or unsuccessfully) investigated. Scientists also need to be supported: funding **agencies must incentivise industries to collaborate with science**, or at least to create bridge companies that are better equipped and have the time and resources to bridge the research-to-application gap. The entire sector needs to move towards a more integrated research. **Collaboration and communication** must improve, not only among scientists but also within the science to policy and science to industry interfaces; the needs of End Users must play a greater role in driving the direction of research.

Currently Marine biotechnology research is moving towards **new bio-discovery directions,** trying to find solutions for the biggest environmental challenges we are now facing; new compounds, microorganisms and microbes are being investigated as **potential tools for polymer degradation (plastic waste treatment)** and biofuels.

Future investments should focus on developing the **pharmaceutical field** and in mitigating **environmental micro-plastics pollutions.** New technologies for more effective evaluation of new compounds are needed along with enhanced marketing of the ones with the highest potential.

4.4 Fisheries Competence Node

Description of Competence Node Sector

Fisheries in the EU are regulated by the Common Fisheries Policy (CFP). Since the 2002 reform of the CFP, there has been increasing focus in Europe towards implementing multi-annual or long-term management plans. Besides providing more stable investment possibilities for the fishermen, long-term management plans have also been introduced to avoid political disputes on Total Acceptable Catch (TAC) limits (that are set for commercial fish stocks). Additionally, there has been a general trend over

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the last decade to move away from the Precautionary Approach[5] and towards Maximum Sustainable Yield (MSY) as the overarching management objective. Besides that, the landings obligation (discard ban) introduced in the recent CFP reform is a major change that takes steps towards optimising the overall yield of the ocean. This reform came after many years of battling discards in fisheries, a battle that was hard to win due to the economic incentives to discard. A major current challenge of the CFP is to make objectives and regulations that lie within the larger Europe 2020 Strategy for smart, sustainable and inclusive growth.

In 2015, the Fisheries CN considered the overall European fisheries sector and identified needs and challenges for the sustainable development of this sector. **Food security** was one of the major global societal challenges. Fisheries is still the largest sea food provider, although aquaculture as a source of seafood is increasing. Research is currently investing in optimising fishing activities but still much more remain to be done in order to achieve real sustainability within the sector. These needs include developing **efficient and more selective gears**, **reducing fuel consumption** by fisheries vessels, reducing **discard and bycatch**, improving **traceability and labelling** and **stakeholders' involvement**. In order to reach a **healthy, productive and safeguarded European marine environment,** improving **marine spatial planning, marine restricted areas**, and applying the **ecosystem-based approach** in management must be also prioritised in the near future. Furthermore, the effect of **climate change** on the environment has lead to behaviour changes in some species, such as changes in migration and competition patterns of both commercial and invasive species, which are worsening spatial resource disputes and subsequently amplifying challenges to fisheries and their management.

Projects and Knowledge Outputs Collected: meeting the needs identified

Project selection by the Fisheries CN was based on the major expertise area of the group, namely **gears technology and development** and specific tools for fisheries management. Fourteen projects were selected, with 141 KOs, of which 4 validated FP7 projects with 36 KOs were considered in the exercise.

Since many projects were dealing with gears technology, the need of **development of more energy efficient fishing gears** was found to be the most addressed one. However, this was by no means the only sector need. **Improving sea habitat modelling and sea habitat mapping,** generally with tools for environmental monitoring (sound data, sensors etc.), was a need addressed by the NEXOS project (Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management). MYFISH "Influencing the decision making of multiannual plans through participatory work" sought to **enhance stakeholder involvement in the decision making of fisheries regulation** as well as develop **long term management plans in order to reach/keep MSY.** Finally, the project BENTHIS (Benthic ecosystem fisheries Impact Study) aimed to **improve methods and specific case studies of environmental impact assessment**.

[5] http://www.fao.org/docrep/003/w3592e/w3592e07.htm#TopOfPage

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Most of the KOs were at a mature state and the most addressed End User was industry. The FP6 funded Project **NECESSITY** (Nephrops and cetacean species selection information and technology), while not considered in the analysis, is a good example of transferred results of a new development of gears to industry.

Outcomes and Recommendations:

Despite significant research on gears technologies and selectivity, **implementation of new technologies and solutions** is still a challenge in the fisheries sector. Fishermen themselves are developing new gears technologies and solutions to industry problems but the whole process of implementing these new innovative solutions is slow and inefficient. New technologies have to pass through many regulations and patenting processes before being utilised, which makes exploiting the results arduous and sometimes impossible. Landing Obligation (LO) legislation approval takes usually two years (or more) to approve TRL mature solutions.The Danish national funded project FastTrack, however, is a good example on how this process could be shorter and bring into the market effective solutions in line with End User needs.

Future research must invest more in **currently under or non-utilised species** (e.g. deep-sea species) with high potential for biomedical purposes or fish feed. European funds are not prioritising research in this area, due to the high cost (stock assessment is the first step) and uncertainty of the financial benefits. Regarding regulations, as **landing obligation** is a relatively new concept and more must be done in order to efficiently implement it.

4.5 Aquaculture Competence Node

Description of Competence Node Sector

European aquaculture is a diverse activity that covers the production of finfish, shellfish and other aquatic species, including algae, in both freshwater and marine conditions. Over the last decade, EU aquaculture has seen little or no volume growth (estimated at 0.5% Annual Percentage Rate), compared to estimated global aquaculture growth of 7% Annual Percentage Rate over the same period (Deliverable 3.2). Despite this, aquaculture is still a distinct component of many recent European strategies, including those covering Blue Growth and the bioeconomy[6]. The European aquaculture sector is currently driven by three priorities: assuring a sustainable aquaculture sector, establishing a stronger relationship between the aquaculture industry and the consumer, and consolidating the role and importance of aquaculture in society.

In 2015, the aquaculture CN identified major challenges and consequent needs that the sector is currently facing for achieving sustainable and substantial growth. These challenges and needs were:

[6] http://ec.europa.eu/programmes/horizon2020/en/h2020-section/bioeconomy

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- application of **new knowledge and technology innovations for environmentally sustainable industry**
- **competition in the marketplace** principally from imports
- **productivity increase** to meet consumption demand
- **diversification of species and products**
- **better evaluation of the ecological impact** of biogenic wastes
- **feed quality and sustainability**
- **Minimise the threat of existing exotic diseases** and of the persistent agents used in aquaculture
- **improve aquaculture public perception**
- **better communication** of the role the European aquaculture sector plays in society.

Projects and Knowledge Outputs Collected: meeting the needs identified

Some aquaculture CN projects were prioritised based on the maturity of their KOs', focusing on the ones with the highest level. There were three maturity levels developed by the CN:

- Maturity Level 1: Projects not relevant to aquaculture (basic research projects).
- Maturity Level 2: Projects with no applied results, or results that are difficult or immature to commercialise publicly but which might be commercialised privately.
- Maturity Level 3: Tangible KOs that address industry problems, with high potential interest to be utilised by the Aquaculture industry.

Most of the projects selected were within maturity level 2 and 3. Twenty projects were selected with 80 KOs. As only FP7 projects are considered in this analysis, a total of 5 validated FP7 projects with 32 KOs are considered.

Certain needs identified were found to be directly addressed by a number of KOs. More specifically, these needs were **"adapt existing and develop new management tools and measures used for environmental monitoring, production optimisation and minimising aquaculture impact"** and "**understand mechanisms and risks for harmful ecosystem interactions of alternative products for disease control, chemical antifoulants, new feed diets and new feed ingredients"**. These needs were explicitly met by KOs of the project EnviGuard (Development of a biosensor technology for environmental monitoring and disease prevention in aquaculture ensuring food safety). Other needs were: **"improve environmental monitoring (including predictive tools) and information towards professionals, including a better responsiveness of monitoring networks"** and **"adapt and utilise advanced methods to understand and model nutritional responses"**. Both were met by the KOs of the FISHINUTRIGEN project (Fish intestinal nutrigenomics in response to fish oil replacement in Atlantic salmon diets).

Outcomes and Recommendations:

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The COLUMBUS Aquaculture CN believes that **the future of the industry relies on fish nutrition, health and robustness**. All innovative technologies that contribute to the **reduction** of the annual 10 billion USD global **fish disease impact** and **address the sustainability issues in fish nutrition and alternative nutrient sources** especially in terms of fish meal and fish oil substitution are essential for the future sustainability of the sector. **Integration of disruptive technologies** (artificial intelligence, big data, sensors, smart technologies etc.) from other sectors would help to address many aquaculture sector needs. The COLUMBUS Knowledge Transfer Methodology, by identifying tangible solutions for the industry, should be coupled with some financial supports such as small seed funding schemes to the IP holders that would allow the technology and Knowledge Transfer strategies to be implemented, and the pilot validation of their technologies in the field. The importance of **knowledge and technology transfer should be emphasised** and these specialised "knowledge brokerage/innovation amplifier companies or groups" should be encouraged to actively search, identify and implement a continuous loop of innovation. This would enable the translation of research results to tangible products and services to industry, not only in the aquaculture sector but among all sectors contributing to Blue Growth.

4.6 Marine Physical Resource Competence Node

Description of Competence Node Sector

Ocean energy and seabed mining are two of the five high potential sectors listed under the Blue Growth Strategy. While marine physical resources include several sub-sectors, the COLUMBUS Marine Physical Resources CN focused on **Ocean Energy.**

Europe is currently at the forefront of **ocean energy** development. However, it is facing increasing competition from China, Japan, United States, Canada and other industrialised nations. Offshore wind is the most advanced technology in the ocean energy sector. The EC objective is to install 100GW of wave and tidal technologies by 2050. However, there are a number of barriers that need to overcome in order to achieve that aim. In 2015, the Marine Physical Resources CN identified several needs to be addressed in order to overcome barriers for its sustainable growth in this sector. These barriers include needs across policy, industry, and science areas. These needs are: **Lack of a policy and regulatory framework**, as specific national strategies and policies for the marine renewable energy (MRE) sector need to be developed and **lack of guidelines and standards for MRE technologies; Lack of clarity on the rules of intellectual property, collaboration and knowledge sharing**; and, while **environmental integrity must be maintained, a balance should be found between that and the progression of the industry**. Existing environmental legislation is extremely expensive and is stifling innovation and the progression of deployment**. Ocean Energy (OE) would benefit from a clear, stable and supportive policy framework in order to attract investment**, but there is **lack of long term clarity on profitability and commercialisation of (OE) in the sector**. **Development of a standardised method for ocean energy site characterisation and project planning** is also needed, as well as **constant training and**

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development of a technical and professional workforce and a reduction of the cost of all technical phases (D3.2).

Projects and Knowledge Outputs Collected: meeting the needs identified

Projects were selected based on CN expertise, trying to cover the needs identified in 2015 related with ocean energy. Twenty-eight projects were collected among FP7, national, H2020 and ERDF programmes, with 286 KOs. Twelve FP7 validated projects with 152 KOs were considered for the analysis.

The majority of the projects were focussed on **advancing technology in the Ocean Energy sector**. (e.g. H2OCEAN, Development of a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy). Many projects were also focussed on **multiuse platforms**, with KOs from projects such as TROPOS (Modular Multi-use Deep Water Offshore Platform Harnessing and Servicing Mediterranean, Subtropical and Tropical Marine and Maritime Resources) and MERMAID (Innovative Multi-purpose off-shore platforms: planning, Design and operation) tackling **risk assessments** and **environmental monitoring programmes**. Generally, KOs were found to be in an early stage of TRL, meaning many projects delivered very valuable results that were not fully ready to be transferred and utilised. Nevertheless, some projects had models and results that were mature enough and available to the End Users: DEEPWIND (Future Deep Sea Wind Turbine Technologies) and LEANWIND (Logistic Efficiencies and Naval architecture for Wind Installations with Novel Developments). These projects generated results that were considered valuable examples of ready-to-use outcomes. The **training and development of a technical and professional workforce** need was specifically addressed by the project WAVETRAIN 2 (Initial training network for wave energy research professionals). Projects with **coating-focused** KOs tended to have the most success in producing high-TRL KOs.

Project outcomes mostly addressed industry; however, a number of KOs were found to be tackling policy. Among these was like the TROPOS project with its KO: “Report summarising the potential positive or adverse environmental and social impacts on local community and local environment due to future offshore windfarm projects with mitigation techniques and recommendations for policy makers”. Other KOs focused on **environmental impact and risk assessments,** addressing the need of maintaining **environmental integrity and sustainable practices.**

Outcomes and Recommendations:

As mentioned above, the Physical Resources CN decided to focus on ocean energy, although many needs were also identified in Deep Sea Mining (DSM). This is a growing sector, but currently the European landscape of research and projects on **DSM is still small, and not easily reachable in terms of results sharing and collaboration.**

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The ocean energy sector is technologically with many new innovations developed from EU-funded projects. However, **many interesting outcomes are still in an early phase of development** and need incentives to be brought further. As described in the Marine Monitoring and Observation CN, this results in a high number of similar project outcomes, which in some cases are encountering the same barriers and issues at the same development phases. From the experience of the Marine Physical Resources CN fellow, End Users were able to give advice to knowledge owners on how to improve KOs, successfully refining the outcome to best suit their needs. This approach would help the process of bringing results to commercialisation more effectively. A policy-related barrier, however, is the **lack of national and international standards related to the management of the environmental impact of industries** (e.g. best practices for industries).

4.7 Marine Environment and Futures Competence Node

Description of Competence Node Sector

Media, non-governmental organisations and even social network groups are discussing anthropogenic impacts on our environment with increased intensity - especially regarding the seas and oceans. Based on the UN Rio declaration, climate change and related issues like coral bleaching and sea-level rise, as well as pollution by plastic littering or harmful substances and the over-exploitation of its resources (all of which eventually lead to the extinction of species), are the predominant marine issues currently discussed in the media. Tackling this comprehensive list of marine problems requires strong collaboration between scientists, politicians, industry and civil society. In recent years, because of ongoing global change, environmental awareness and precautionary action, have found their way into societal behavior and the cultural norm. However, more education and engagement are still required in order to achieve sustainable action and internationally harmonised regulations. Nevertheless, there are significant developments at the political level. During the course of the COLUMBUS project the G7 science ministers working group on the "Future of Seas & Oceans" defined **"strengthening existing ocean observing systems"** as well as **"development of innovative marine biogeochemical sensor technology"** as key issues and challenges to be tackled in the near future.

At the beginning of the COLUMBUS project, in 2015, the Marine Environment and Futures CN especially focused on two main challenges: (1) **marine litter** and (2) **climate change**. Within these two main challenges specific needs were identified (D3.2). Additional topics like the environmental impacts of DSM, innovative marine automated observing technologies and environmental aspects with regard to ballast water were also considered. However, due to the overlap with other COLUMBUS CNs, those topics were agreed to be covered in other CNs for the KO collection process. Besides the manifold scientific needs, described in several overarching strategic documents (published by the EU-COM, JPI-Oceans, IOC-UNESCO or the Belmont Forum), there is a general need to consider the **involvement of stakeholders from policy**, **industry or society in the planning stage of a project**.

Projects and Knowledge Output Collected: meeting the needs identified

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Fourteen projects with 110 KOs were collected. Of these, 7 projects with 77 KOs were considered for this study. The project selection was based on the relationship between the identified challenges within the focus areas of marine litter and climate change; projects which seemed to provide approaches or suitable solutions in meeting the identified gaps and needs were favoured. Together with the CN team, further aspects were taken into consideration in the selection process, including how innovative the result was and the potential for a successful Knowledge Transfer (from the perspective of the End User).

Regarding the marine litter topic, **raising societal awareness on urgent and upcoming issues as an essential element to foster a change in human behaviour thus protecting our seas and coastlines** was mostly met by the KOs collected. On climate change, projects with a special focus on the Arctic region met the challenges on **impact of climate change on the environment, particularly the seas and oceans**. Projects MONARCH-A (Monitoring and Assessing Regional Climate change in High latitudes and the Arctic) and FIELD_AC (Fluxes, interactions and environment at the land-ocean boundary - Downscaling, Assimilation and Coupling) specifically targeted the need to **predict sea ice developments and sea level changes**.

Envisaged End Users were mostly stakeholders from science and policy, rather than industry related, although in marine litter Knowledge Transfer was primarily geared towards societal actors. As Knowledge Transfer to society is a long-term process, COLUMBUS could only realistically progress them part of the way down the Pathway. However, when promising, Knowledge Transfer to industry was envisaged too, although obstacles like Intellectual Property Rights (IPR) and low TRL had to be addressed. For instance, in CHIBIO (Development of an integrated biorefinery for processing chitin rich biowaste to specialty and fine chemicals) and n-CHITOPACK (Sustainable technologies for the production of biodegradable materials based on natural chitin-nanofibrils derived by waste of fish industry, to produce food grade packaging) an industrial End User was included directly in the project.

Concerning marine litter projects, the KOs were very mature and deemed ready-to-use by science and policy End Users. Projects MARLISCO (MARine Litter in Europe Seas: Social AwarenesS and CO-Responsibility) and CLEANSEA[7](Towards a Clean, Litter-Free European Marine Environment through Scientific Evidence, Innovative Tools and Good Governance) contained mature and ready to use KOs by the respective End Users; interdisciplinary and transdisciplinary approaches as well as stakeholder engagement were embedded in the projects. Knowledge Transfer to society was envisaged in an early phase and partly implemented during the lifetime of the projects.

[7] The CLEANSEA KOs were selected by the CN Maritime Tourism. Due to several reasons it was decided to stop the work of this CN and to divide the results so far on the remaining CNs. Marine Environment & Futures took over the CLEANSEA transfer. Together with the partners from the Maritime Tourism CN high potential KOs were selected and a successful transfer case could be realised.

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For projects which met societal challenges, the Societal Readiness Level (SRL)[8] defined by the Danish Innovation Fund could be a criterion to measure the impact of the results in the future. Taking the SRL into account, KOs from both MARLISCO as well as CLEANSEA reached a high level (SRL 7-9).The project MARLISCO – (MARine Litter in Europe Seas: Social AwarenesS and CO-Responsibility) was considered a "champion" project of the Marine Environment & Futures CN, being a great example of implemented project results transferred to society. This project produced a large number of results which were tested during the lifetime of the project (e.g. e-learning tool, regional fora, video contest) and beyond (e.g. educational pack, beach monitoring, web-related products such as a website, web-documentary or serious game). Although the subsequent analysis and transfer phase of the case study took place in Northern Germany, actors in other European regions were actively seeking to transfer the MARLISCO results. The CN was surprised and impressed to see that the partner network was still active after the project ended in 2015. Each year teacher seminars are organised to address marine litter topic in the educational system.

Outcomes and Recommendations:

Climate change related projects were generally very science oriented and the results were mostly valuable for a science-to-science transfer. Future research funding programmes should be improved with the **involvement of the End Users point of view**. Where appropriate it would be valuable to involve **policy stakeholders in early stages of the projects**. The methodology for the science to society transfer must also be improved in the future by **refining SRL criteria**. Future research funding programmes on climate change should emphasise on producing results which can **support coastal management** and **respective policy decisions**.

There is urgency to overcome the challenge of marine litter impacts and as the MARLISCO project demonstrated, we should start from a **change in societal behaviour**. Children are the highest potential target, being very open minded and curious; there is therefore a major **need to implement up-to-date scientific results in relation to marine science into the schools' curricula**.

4.8 Marine Governance and Management Competence Node

Description of Competence Node Sector

The regulations framework relevant for Marine and Maritime Governance and Management by definition affects and applies to every single activity carried out in the marine and maritime context. The European Union has adopted for the first time an integrated approach to ocean management and maritime governance within the Integrated Maritime Policy for the European Union ('IMP'), including, as its environmental pillar, Directive 2008/56/EC of the European Parliament and of the Council, MSFD. The European Commission also presented its vision on international ocean governance in the 2009

[8] https://innovationsfonden.dk/sites/default/files/societal_readiness_levels_-_srl.pdf

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Communication on 'Developing the international dimension of the Integrated Maritime Policy (IMP) of the EU' (COM(2009)536).

During the last decade, at sea basin level the corresponding strategies, action plans and agendas (for the Mediterranean, the Baltic Sea, the Atlantic including Galway Strategy, the North Sea, the Adriatic and Ionian Seas, the Black Sea and the strategy for the Outermost Regions) constitute a complementary range of policies to facilitate and increase effectiveness of the implementation of overarching regulations within a regional context. These, in combination with the EU Biodiversity Strategy to 2020 and the 7th Environment Action Programme, the MSFD (2008/56/EC) and the Maritime Spatial Planning Directives (2014/89/EU) have created a new and comprehensive legal framework within the EU aiming for good ocean governance and compliance with international commitments. Apart from the above, other outstanding European and International references form part of the policy and regulatory framework for European marine and maritime governance and management.

The Marine Governance and Management CN focused on projects and knowledge outputs that contribute to progress towards three major regulations:

- **Marine Strategy Framework Directive (MSFD)** (2008/56/EC)
- **Maritime Spatial Planning Framework Directive (MSPF)** (2014/89/EU)
- **UNGA Resolution for the "Development of an international legally-binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction"** (UNGA/RES/69/292).

In 2015, the CN identified several needs and challenges within each of the regulations and directives (Deliverable 3.2).

Projects and Knowledge Output Collected: meeting the needs identified

The Marine Governance and Management CN based the projects selection on knowledge outcomes that would contribute to progress towards the objectives of the three above mentioned regulations. The approach of the CN was therefore focussed more on addressing policy strategies rather than meeting specific needs identified within each directive. In order to prioritize KOs, a list of prioritization criteria was used. These criteria determined the real chances of a KO to be transferred and yield meaningful impact. Some of the criteria applied to inform prioritization were described in the Knowledge Output Table for each KO (e.g. type of end-user and type of KO). The use of a set of criteria to the prioritization of KOs to fully analysis is described in D 5.1 Knowledge Output analysis including Knowledge Output Pathway generation and results, and in their update (D 5.6). Fifty-five projects were selected by the CN, with 491 KOs; thirty FP7 projects with 392 validated KOs were considered for the analysis.

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The selection process was not straightforward: many projects produced scientific publications that could contain relevant KOs, but with limited time and resources it was not feasible to explore in depth the potential of all of them (e.g. science to science projects). Other criteria considered for the selection were the type of End Users, status of KO and type of KO. Each project was scored in accordance with each of the criterion, meaning project selection was guided by a final score value awarded to each project.

Most of the selected projects were considered relevant to the **MSFD**. DEVOTES (DEVelopment Of innovative Tools for understanding marine biodiversity and assessing good Environmental Status) was clearly orientated to better understand the relationships between pressures from human activities and climatic influences and their effects on marine ecosystems, including biological diversity, in order to support the ecosystem based management and fully achieve the Good Environmental Status (GES) of marine waters. Although the MSFD focuses in different aspects of marine ecosystems, in DEVOTES project the work focused on the four biodiversity related descriptors (D) for assessing the GES of marine waters (biological diversity (D1), non-indigenous species (D2), food-web (D4) and seafloor integrity (D6). STAGES (Science and Technology Advancing Governance of Good Environmental Status) had the aim of improving **scientific knowledge base to support the implementation of the MSFD,** while PERSEUS (Policy-oriented marine Environmental Research in the Southern EUropean Seas) and VECTORS (Vectors of Change in Oceans and Seas Marine Life, Impact on Economic Sectors) were MSFD policy oriented projects which already included the End User perspective within the project aim. These above-mentioned projects were considered "Champions" for three main characteristics: high maturity of KOs, knowledge holders strongly engaged and projects directly addressing specific challenges of MSFD. However, many other projects that in principle looked as potentially relevant for the target regulations might not be in the right stage of maturity or did not have a clear orientation to produce applicable results in support of the implementation of marine and maritime regulations.

Only a **few projects were addressing the MSPD** namely COCONET (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) and AIM-HI (Acoustic Imaging of Macrophytes and Habitat Investigation). During the FP7 programme the EU supported this regulation with other type of actions and mechanisms[9].

Outcomes and Recommendations

Among the MSFD related projects collected, KOs addressed knowledge gaps for reaching the Good Environmental Status Descriptors, which are the main goals of the MSFD. Descriptor 1 (Biodiversity), Descriptor 2 (Non-indigenous species), Descriptor 10 (Marine Litter) and Descriptor 11 (Underwater noise) were the most addressed. However, the **underwater noise** descriptor seems to be challenging in terms of implementation and still demands **research oriented to facilitate its implementation**.

[9] https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en

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Concerning **Marine litter**, there have been a number of research projects at EU and national level addressing different relevant issues, but it is still a hot topic that must be prioritised by research funding. The Joint Research Centre and the MSFD-Competence Centre pointed out their interest to develop a **Marine Litter knowledge database** in order to establish a continuous process of capturing and transferring relevant marine litter knowledge in support of policy implementation. A key step is to be able to gather the KOs, not only of EU projects, but of national projects.

In order to have the correct tool for supporting policy implementation, it is really important to **include the perspective of the End Users within projects aims**, in order to develop a specific tool that can be used by policy makers or Member States, with the final aim of implementing MSFD and reaching all the Good Environmental Status Descriptors. Even if the Marine Spatial Planning Directive was not directly addressed by any of the selected FP7 projects, over 21% of FP7 marine and maritime projects (263 projects out of 1242) have been flagged relevant for marine spatial planning purposes" as described in D 5.4. Furthermore, research investment should be made in research and innovation to **support the UNGA Resolution** for the "Development of an international legally-binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction" (UNGA/RES/69/292).

5. CONCLUSIONS

The aim of this report was to provide an overview of if and how clearly identified needs - as documented in Deliverable 3.2, in science, policy, industry and society - have been met by the KOs selected by each CN. Furthermore, it aimed to identify knowledge gaps and provide recommendations for the future research and priority needs of each sector, based on the fellows´ experience gathered over the lifetime of the COLUMBUS project.

The process of project selection and prioritisation was carried out by all CNs under the umbrella of the COLUMBUS framework, but different selection and prioritisation criteria were applied by the CNs. Each CN applied what it believed was the most appropriate strategic approach for identifying relevant projects, with KOs that could be highlighted and eventually brought further in the value chain. Some of the CNs focused their selection on KOs that specifically addressed some clearly identified priority needs; others focused on particular areas within their sector which were considered more promising and a number prioritised those KOs where they themselves had good thematic expertise and network connections. Given these considerations and the fact that projects considered for this analysis were restricted to only validated FP7 ones, only a limited number of the needs identified in the Deliverable 3.2 have been addressed by specific KOs in Deliverable 4.5. It is therefore inappropriate and would be misleading to present any quantitative analysis of identified needs (D3.2) met by the KOs selected.

Nonetheless, the CNs successfully managed to collect a significant number of KOs. Many addressed some of the needs identified with the potential to address a number of the challenges within each of the sectors. Other KOs collected showed high potential, although not specifically addressing the needs identified in D3.2. The analysis methodology applied here focused on cross-referencing the challenges

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and needs with the validated KOs collected followed by structured interviews with each CN Fellow to delve deeper into the issues of needs met and remaining gaps. Following the consolidation of material and an analysis across all CNs it has been possible to identify specific knowledge gaps and future high potential areas for development for each sector. A summary of these gaps and areas of high potential are provided in Table1.

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Table 1: A summary of remaining gaps and areas of high potential for each of the COLUMBUS CNs.

Remaining Gaps/Areas of improvements	CN	Area of high Potential
Ballast water treatment	**Maritime Transport and Logistics**	Flexible vessels (in terms of flexible use for different purposes, e.g. an offshore supply vessel which is not needed for its usually purpose could then be used for other operations)
Reduce underwater noise		Exploration of new potential routes (e.g. Polar route)
Reduce emissions (pollution)		
Safety at sea		
Increase the use of renewable energies		
Managing, curating, archiving and making project outputs visible	**Marine Monitoring and Observation**	Biological sensor and biological observations (specifically for species abundance and distributions and seabed habitats)
Create Database with what has been developed by all the various EU projects		Investments in Marine litter and microplastic solutions
Regulatory framework to facilitate the use of new technologies		Investments in Sensor technology for climate change monitoring
Improve availability of data (need of more data sharing strategies)		
More transparency and cooperation among data owners and between sectors		
Involvement of society in the data collection (citizen science)		
Improve availability of data (need for more data sharing strategies)	**Marine Biological Resources**	Solutions for fighting micro-plastics
Improve Industry access to science innovation		Investment in research of polymer degradation
Improvement in dissemination of success and failures in research		Investment in research of Biofuel
Incentives by funding agencies for more collaboration between industry and science		Advancing KOs of already completed projects within Pharmaceutical field –more Knowledge Transfer needed

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Remaining Gaps/Areas of improvements	CN	Area of high Potential
Implementation of new technologies and solutions in gear selectivity	**Fisheries**	Investment in research of unutilized species (e.g. deep-sea species) which could be used for high potential biomedical purposes and fish feed
Landing obligation regulation implementation		
Fish disease impact	**Aquaculture**	Integration of disruptive technologies (AI, Big data, sensors, smart technologies etc.) from other sectors would help to address many aquaculture sector needs.
Competition in the marketplace (principally from imports)		Knowledge brokerage / innovation amplifier companies or groups for implementing a continuous loop of innovation translating research results to tangible products and services to industry
Address the sustainability issues in fish nutrition and alternative nutrient sources		
Improve aquaculture public perception		
Lack of national and international standards	**Marine Physical Resources**	The DSM community is still small, but there are great opportunities in terms of results sharing and collaboration
Many interesting outcomes are still in an early phase of development and need incentives to be brought further.		
Involve policy stakeholders in early stages of projects	**Marine Environment and Futures**	Adapt up-to-date scientific results for inclusion in schools' curricula
Change in societal behaviour (more awareness)		
The methodology for the science to society transfer must also be improved in the future, refining SRL criteria		
Production of results which can support coastal management and respective policy decision		
Research oriented to facilitate implementation of research on underwater noise	**Marine Governance and Management**	Create Marine Litter knowledge database
Research investment to support the UNCLOS-UNGA RES/292- (conservation and sustainable use of marine biological diversity)		

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Based on a review of the gaps and areas of high potential, it is possible to identify a number of **common topics** among several of the CNs.

Marine litter strongly emerges as a cross-cutting topic which has been identified and addressed by four of the CNs (Biological Resources, Marine Environment & Futures, Monitoring and Observation, Governance and Management).

Specifically, within the Marine Biological Resources CN new bio-discovery research, such as polymer degradation, was highlighted as an area which should see future research investments; KOs from different projects were therefore identified and found with really high potential, firstly for **science to science** transfer to be subsequently followed by transfer and implementation to **industry,** for a development and commercialisation of tools fighting marine litter.

The Environmental and Futures CN targeted **society** with the aim of behaviour change in relation to the marine litter issue; for example, the MARLISCO project results were implemented and transferred to society through educational packs, beach monitoring and web-related products.

Both the Governance and Monitoring CNs highlighted the need of meeting **policy** requirements. In order to better implement such policy requirements, a solution to share the information of KOs on marine litter and plastic was considered. One way of addressing this would be through the creation of a Marine Litter Knowledge database which would establish a continuous process for capturing and transferring relevant marine litter knowledge in support of policy implementation.

This analysis demonstrates how a particular need can be tackled by many sectors through different tools and approaches. Furthermore, it demonstrates that the COLUMBUS Knowledge Transfer Methodology is suitably flexible to be successfully applied across many sectors, with different stakeholders, End Users and tools. As mentioned above, this analysis is based on FP7 projects only. Since the conclusion of that programme, the marine litter issue has continued to grow as a very "hot topic", and some of the needs may have been addressed through subsequent projects funded under other programmes.

The **main barriers** to effectively addressing needs and sectoral challenges were highlighted by CNs; however, some **opportunities** for overcoming these barriers were identified and suggested by the Fellows:

1. From a **policy**-perspective, a lack of up-to-date policy frameworks for regulating the use and the commercialisation of brand new technologies was identified by a number of CNs (Transport, Physical Resources, Biological Resources, Fisheries, and Monitoring). For example, when new prototypes or technologies in ocean observing are ready to be commercialised, there is a **lack of a regulatory framework** which could allow the use of these innovations in the field. In the fisheries sector new technologies have to pass through many regulatory and patenting

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processes before being utilised, which makes exploiting the results arduous and sometimes impossible. **Streamlining of processes and more reactive policy development** could help mitigate these issues.

2. The **low maturity Level** of many KOs was for COLUMBUS a barrier to their transfer (Physical Resources, Biological Resources, Transport, and Monitoring). The main reason of not achieving higher maturity was often due to financial and time constrains necessitated by time-bound project contracts. This results in numerous early-stage non-commercially viable prototypes that require further developments. A valuable approach would therefore be a **comprehensive expert analysis of the wide range of European project results** in order to allocate resources prioritising the highest potential ones. A **compilation of the results developed by all the various projects** could be created, containing ancillary information such as maturity level, IP conditions, so that interested parties can more easily take it forward.

3. **Limited data and outputs access** due to poor Research Data Management & FAIR Sharing by past projects was highlighted by three nodes (Monitoring, Biological and Physical Resources). Although data sharing is dealt with by other EC initiatives, our findings demonstrate the strong complementarity and interdependence between EC Priorities on Open Science and Knowledge Transfer.

4. Awareness of "**low readiness levels/potential high-payoff**" KO's among industry is low (Biological Resources, Physical Resources) yet research outputs hold potential for added-value pharmaceutical products and ocean energy developments, for example. In addition **sharing of non-patentable results** (and negative research results) can increases chances of awareness (and investment) and reduce duplication of effort.

5. Incentivising more systemic reliance on **co-creation and project co-design with end-users** can in the immediate-term optimise science-to-society transfer and science-based policy formulation (Marine Environment & Futures); in the long-term making **Ocean Literacy** part of standard education can lay the ground for better ocean stewardship.

Despite the relatively limited number of projects considered and the COLUMBUS project constraints in terms of financial and time resources, this analysis demonstrates how the identification of challenges and needs followed by a strategic selection of project results that can address these needs brings concrete information on what has been addressed by EU funded projects and also what should be prioritised for future research. It also highlights the need for post-project analyses of outputs to inform future calls, in order to build on and advance what has already been achieved.

It is interesting to note that there is a disconnect between high level 'needs', to which proposals often respond, and actual user needs or indeed actual users. This may explain why many interesting outputs are not taken any further.

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6. ANNEX 1: EXAMPLE OF MATRIX UTILISED FOR THE ANALYSIS

Example of the matrix utilised for the analysis, showing matches between KOs of project BENTHIS and needs of Fisheries CN.

			Project	**Project**	**Project**	**Project**	**Project**	**Project**
			BENTHIS	BENTHIS	BENTHIS	BENTHIS	BENTHIS	BENTHIS
			KO1	**KO2**	**KO3**	**KO4**	**KO5**	**KO6*[10]**
Target Group	**Challenges**	**Needs**	Development and test of a lighter mussel dredge	Seabed pressure estimates from demersal trawls, seines, and dredges	Testing otter board hydrodynamic performances in wind tunnel facilities	Model to predict effort displacement under spatial restrictions	Map of trawling intensities of pan European bottom trawl fleets	Framework to assess trawling impact on the benthic ecosystem
POLICY	Improve methods and specific case studies of environmental impact assessment	Improve the methods of **environmental impact assessment**				x		x
		To make **case studies** that can be used of **fisheries managers**						
	Reduce by-catch in fisheries	Improvements of **selective fishing gear**	x					
	Optimise fisheries in spatial planning	Identify how to **optimise fisheries** in **spatial planning**				x		

[10] Due to space limitation, only six KOs among a total of eleven KOs from the BENTHIS project are displayed in this matrix example

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		Optimise **economic efficiency** of fisheries						
	Marine protected areas	Identify **further marine protected areas** to be established based on ecological and economic considerations						
	Good environmental status versus better fishing opportunities	Increase knowledge on how to **optimise multi-objective issues within fisheries**						
	Incorporate an ecosystem based approach	Gain knowledge of whether the **ecosystem approach** should supersede traditional approaches in stock and **advice to Total Allowable Catch (TAC)**						
		Improve **communication flows** on **stock assessment**						
		Further **implementation of ITQ systems**						
		Compliance on **landings obligations**						
		Search for currently **unutilised fish resources**						
		Long term management plans in order to **reach/keep MSY**						
		Tools for **Avoiding discards** in fisheries						
		Improving **safety on board** of fishing vessels						
INDUSTRY	Reduce fuel & energy consumption in fisheries	Development of more **energy efficient fishing gears**			x			
		Identify ways to **recycle the energy in processing industries**						

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	Smart, green and integrated transport	Identify possible ways to **reduce the transport** through the **value chain**						
		Identify how **regional use of seafood** products can be **increased**						
	Search for currently unutilised fish resources	Identification of possible **unutilised fish resources**, such as mesopelagic species						
		Assessment of whether it is **economically viable** to explore **unutilised fish resource**						
		Identify whether there are need for **new technologies** to **catch unutilised species**						
	Better utilisation of the landed fish	Identify **potential use** of **landed by-catch**						
	Waste of seafood should be minimised through the value chain	Identify seafood **waste reduction potentials**						
	Reduced Trade barriers	Identify whether there is a need to **lower the trade barriers** for **seafood products** in order to secure the future seafood supply						
	Improvements in environmental friendly technology	Development of **passive gears** that prevent seal consumption of catches						
		Development of **selective trawl gears**						
		Development of **energy savings** in **vessel** and **gear design**			x			

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		Analysis of the **environmental, technologic and economic effects** of **technical developments**						
SCIENCE	Optimise fishing gear, procedures and yield	Improving **sea habitat modelling** and sea habitat mapping						
		Improving **stock assessment data, monitoring and methods**						
		Improve **methods** and specific case studies of **environmental impact assessment**					x	
		Profound **knowledge about Invasive species**						
		Identification (need for **data**) of **under-utilised fish resources** – mesopelagic species.						
SOCIETY	Sustain small scale fisheries	Improve **management measures** on how to **sustain small scale fisheries**						
		Identify whether there are **initiatives** that can **sustain** these areas						
	Regional seafood systems	Identify **how regional use of seafood products can be increased**						
	Certification and traceability of fisheries	Increase the amount of **certifications** within fisheries						
		Improve **traceability** of seafood products						
	Regionalisation and stakeholder involvement	Enhance **stakeholder involvement** in the **decision making** of fisheries regulation						

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7. ANNEX 2: QUESTIONNAIRE USED FOR FELLOWS' INTERVIEWS

Below are listed the questions taken from the questionnaire used during Skype interviews with fellows:

- Specific questions for each CN for doubts clarification regarding the Knowledge Challenges and Needs matrix exercise.
- Considering all projects you dealt with (those flagged by you as relevant), what challenges and/or needs were not, in your perspective, met or addressed?
    - Why do you consider so? (Feedback for what you consider most relevant Challenges/Needs not addressed)
      Example of reasons
      i) Selected projects not relevant for challenge/need?
      ii) Identified project(s)/KO(s) not mature enough? (Dealing with a lower stage in the value chain?)
      iii) Mature project(s)/KO(s) which failed to achieve all aspirations
      iv) KO(s) not collected or not validated?
      v) Other reasons? Please detail
- Considering all projects you dealt with, what challenges and/or needs were in your perspective better addressed?
    - Why do you consider so? (Feedback for each Challenge/Need)
    - How far were the challenges/needs met? (Low; Medium; High level) Why?
        - Example of reasons
          i) Selected projects very much in line with challenge/need?
          ii) Identified project(s)/KO(s) (somewhat) mature enough?
        - iii) Knowledge producer/user strongly engaged
          iii) other reasons? Please detail
    - What project(s) would you consider to be Champion project(s)? Why?
    - What further research/steps would be needed to take this/these KO(s) further in the value chain?
    - What do you think are the next steps for research within your CN area? (can address needs not met or even others)
- Considering the non-validated project(s) and KO(s), to the best of your awareness, do they address missing specific challenges/needs? If so which ones and why?
- Were there, and if so what were, the biggest challenges in finding projects and KOs that would match the needs? (Can you give me concrete examples and reasons?)
- What do you think is a current urgent issue/ important topic / need which can be related with all CNs?

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