PREP4BLUE
METHODS AND TOOLS FOR MISSION OCEAN & WATERS

Preparing the Research & Innovation Core for Mission Ocean, Seas & Waters

Deliverable D4.2

Customized Knowledge Management Method for Mission Restore our Ocean and Waters.

A progress report, including lessons learned and high potential Key Exploitable Results relevant for the Mission

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The European Green Deal emphasizes the need for “knowledge for action and more concrete targets to achieve its ambitions. (…) This means better uptake and use of existing knowledge, new types of knowledge, new ways of creating knowledge, and, in some policy areas, better data and more concrete targets.”[1]

To foster the uptake of knowledge towards the ambitious objectives and targets of the ‘Mission Restore our Ocean and Waters’, the Knowledge Transfer (KT) process in PREP4BLUE (P4B), applies a tried and tested methodology, developed by Work Package (WP) 4 Leader ERINN Innovation (Ireland). The methodology is adapted to the needs of PREP4BLUE to build an effective tool for ‘Mission Restore our Ocean and Waters’.

The ultimate goal of the Knowledge Transfer Methodology by ERINN is to enhance uptake of solutions and thus foster impact. To achieve impact, the European Commission highlights that “Missions put emphasis on demonstrating, scaling up and replicating existing and new solutions including social innovations.”[2]

The WP4 activities are deeply aligned to this vision. Based on innovative AI tools, Task 4.2 provided initial direction as to potential sources of knowledge/solutions. To identify the knowledge/solutions with potential to contribute to the Mission objectives and targets, appropriate resourcing and effort was required. In Task 4.3, high potential knowledge is identified, and Key Exploitable Results (KERs) are described by a dedicated group of ‘Knowledge Fellows’ led by ERINN (Leader of Task 4.3) in collaboration with CNR and CETMAR. This is followed by expert analysis of the KERs, organised by ERINN, to draft Pathways to Impact. Transfer is then planned to take place where most appropriate, either by P4B itself or by Lighthouse CSAs/IAs, in Task 4.4.

“PREP4BLUE’s objective is to support the R&I goals of the ‘Mission: Restore our Ocean & Waters’ and facilitate its successful implementation, especially during this first phase (2022-2025). Through a series of pilots at the Mission’s demonstrator or ‘Lighthouse’ sites, PREP4BLUE will develop tools, guidelines and methodologies to be used by stakeholders on all Mission-funded projects. This co-creation approach will optimise and create synthesis across Mission activities and solutions, ensuring cohesion and connectivity across sectors, and between European citizens and stakeholders.”[3] Therefore, this report is aimed at showcasing the progress towards the customized Knowledge Management Method for ‘Mission Restore our Ocean and Waters’, to serve Mission stakeholders as a tool, as well as to highlight the KERs identified.

To pilot the KT process, partners in SDU (Denmark) launched an AI-powered search to identify over 825 projects with innovative solutions which could contribute to furthering Mission objectives. This search was further analysed and filtered in Task 4.3, applying a targeted approach to identify and shortlist potential sources of knowledge to underpin the collection of KERs. As a result, 113 projects were contacted and 36 interviews were held, leading to the identification of 92 KERs, of which 52 KER are described, and 25 validated, which are included in this document. This includes methods, tools, data, information, technologies and processes, that can be used by Mission stakeholders to help realise Mission goals.

[1] European Environment Agency: Europe's sustainability agenda needs knowledge for action and more concrete targets to achieve its ambitions — European Environment Agency (europa.eu)

[2] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on European Missions (2021): https://cor.europa.eu/en/events/Documents/COTER/ec_communication_eu_missions.pdf

[3] PREP4BLUE: Project Overview - PREP4BLUE

Collection of KER started in December 2022 and continues throughout the project, to engage the built capacities. To support this process, an interdisciplinary team of 'PREP4BLUE Knowledge Fellows' from CETMAR (Spain), CNR (Italy) and ERINN has been established to meet with the coordinators of these projects to find out more about their research and the innovative solutions developed during their projects, to identify the KER to be then transferred.

To prioritise the KERs with the most potential to impact upon the Mission, 'Analysis Workshops' are held, with the aim of the workshop to work with experts to identify pathways towards impact for each prioritised KER. Two analysis workshops were held to date, discussing 8 KERs in each. In application of the analysis criteria, 9 KER were deemed so far as having high potential to contribute to the objectives of EU Mission Restore our Ocean and Waters.

The approach applied in PREP4BLUE will ensure that innovative solutions from across Europe are identified, managed and effectively taken up by stakeholders to address Mission challenges. With a focus on capacity building, as well as efficiency and effectiveness, the co-creative and co-implementative nature of PREP4BLUE is put into practice in WP4 to prepare the 'Research & Innovation Core for Mission Ocean, Seas & Waters'.

Acronyms & Abbreviations

Figure 1. Table of abbreviations and acronyms used in PREP4BLUE and the document

Acronym / Abbreviation	Signification
P4B	PREP4BLUE
KT	Knowledge Transfer
KO	Knowledge Output
KER	Key Exploitable Result
RL	Readiness Level
DoA	Description of the Action
T	Task
WP	Work Package

Key Terms

A number of terms are regularly used in this report. This section explains how these terms relate to each other. The definitions below may differ from other sources but these are the adopted definitions for the purpose of PREP4BLUE implementation.

Knowledge Transfer: The term for the overall process of moving knowledge between knowledge sources to the potential users of knowledge. Knowledge Transfer consists of a range of activities which aim to capture, organise, assess and transmit knowledge, skills and competence from those who generate them to those who will utilise them.

Knowledge Output: A unit of knowledge or learning generated by or through research activity. They are not limited to de-novo or pioneering discoveries but may also include new methodologies/processes, adaptations, insights, alternative applications of prior know-how/ knowledge.

Pathway to Impact: This can be one step or a series of steps required to carry a Knowledge Output to its Eventual Impact. Where there are a series of steps, it will include detailed mapping, the users involved at each step and their predicted role in the pathway to Eventual Impact.

Eventual Impact: The ultimate end benefit of the application of the Knowledge Output.

Transfer Impact: The demonstrable evidence that a Knowledge Output has travelled down a single step on the Pathway to Impact.

Target User: An individual(s) who you have identified in your Pathway to Impact to whom a Knowledge Fellow will transfer the Knowledge Output.

End User(s): The individual(s) who will apply the Knowledge Output at the end of the Pathway to achieve the eventual Impact.

1 Introduction

1.1 Background

Funded by the European Union's Horizon Europe program, PREP4BLUE is a €4.9 million, three-year project that will set the foundations for co-creating and co-implementing the research and innovation required to achieve the 'EU Mission Restore our Ocean and Waters' (furthermore referred to as the Mission).

The PREP4BLUE Work Package 4 delivers 'Knowledge Management for R&I core: Identifying and Transferring Knowledge/Solutions to Support the Mission'. WP4 is aimed at showcasing at pilot scale fit-for-purpose methods to manage knowledge in support of the Mission. In WP4-Task4.3, knowledge emerging from recent European research that would be of interest to the Mission is identified, described and analysed.

This deliverable reports the results in Task 4.3 'Collect and Analyse Mission Knowledge/Solutions', including the High potential KERs relevant for the Mission.

Therefore, the following subtasks were undertaken and are described in detail in this report:

- First, analysis criteria (e.g. suitability, maturity, scale up, replicability, transformative, impact potential, systemic application) were developed, for assessing the suitability and potential of "knowledge/solutions" (e.g. methods, tools, data, information, technologies, processes) that can help achieve the Mission (see chapter 2.1).
- Using the initial results of mapping (see section 2.2) of e.g. projects and publications, partners engaged directly with knowledge owners to identify and describe their Mission-relevant "Key Exploitable Results" (KERs) in a standardised template by ERINN (see chapter 2.3).
- KERs are then assessed, using the analysis criteria by consortia and external deep domain experts and stakeholders where required (see chapter 2.4).
- KERs are categorised and tagged to Mission objectives and placed in the Mission Ecosystem DB. High potential KERs are reported in this deliverable 4.2 (see Annex 2).

1.2 Baseline Methodology

1.2.1 Philosophy

The PREP4BLUE (P4B) Knowledge Transfer (KT) process applies a tried and tested methodology, developed by WP4 Leader ERINN Innovation (Ireland).

Currently, ERINN describes KT as enabling knowledge and ideas to move from the knowledge source to the potential users of the knowledge. It consists of a variety of activities which aim to capture and pass on knowledge, skills and competence from those who generate them to those who can use them. KT is aimed at impact.

For Knowledge to have an Impact, it has to do something. It has to have an application resulting in "an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia[4]". "Knowledge Without Application is Just Knowledge[5]!"

In its broad-based innovation strategy for the EU, the importance of improving Knowledge Transfer between public research institutions and third parties, including industry and civil society organisations, was identified by the European Commission as one of ten key areas for action.[6] To be able to transfer knowledge we need to manage knowledge. Knowledge Management is the process of creating, organising, capturing/sharing/distributing knowledge to ensure its availability for future users.

1.2.2 Systemic Knowledge Management Method

The Knowledge Management methodology applied in the PREP4BLUE project is based on the methodology originally developed in the FP7 MarineTT project, and subsequently developed to its existing design by the COLUMBUS project. ERINN Innovation has led the Knowledge Management in the COLUMBUS projects and since then further trialled, tested and optimised the methodology in different national, regional and EU funded projects.

The methodology by WP4 Leader ERINN Innovation (Ireland) focuses on units of knowledge, which can be defined as follows:

"a unit of knowledge has been generated out of a scientific project. It is not limited to de-novo or pioneering discoveries but may also include new methodologies, processes, adaptations, insights, alternative applications of prior know-how/knowledge" (Definition developed by AquaTT in the context of Knowledge Management in the MarineTT project)."

The Methodology is comprised of 3 main steps: Collection, Analysis, Transfer.

In the context of PREP4BLUE it is applied as follows:

- **Collection** includes identification of potential sources of knowledge. In P4B these are EU-funded RDI projects. Through interviews with the Knowledge Owners, key actionable Knowledge Outputs (KO) are defined and Key Exploitable Results (KER) described.
- **Analysis** serves for better understanding the landscape, actors, timelines, priorities etc. of the sector and/or industry. In P4B, it is determined if KER are of high potential to the Mission Objectives and Targets. Impact Pathways for KER are defined to maximise uptake within the Mission Lighthouse (LH) Initiatives context.
- **Transfer** is about enabling application of knowledge, and understanding what key information is needed to do so; bringing the knowledge to the right person so that they can pick it up and carry it forward, moving it towards impact.

This report is limited to the collection and analysis steps, as these are the content of the Task 4.3. The tasks reported in this deliverable are still ongoing.

[4] Impact as defined by UK Research and Innovation
[5] Random author on google.
[6] European Commission (2009): EUR 23894 - Metrics for Knowledge Transfer from Public Research Organisations in Europe, http://ec.europa.eu/invest-in-research/pdf/download_en/knowledge_transfer_web.pdf

Therefore, this document is a progress report and any observation or statement should be understood as in-progress and non-conclusive.

1.2.3 The process

The process to 'Collect and Analyse Mission Knowledge/Solutions' (T4.3) is as follows:

- Sources to find knowledge/solutions were identified, using the initial results of mapping (T4.2) (see chapter 2.2 of this report).
- Interviews with the Project Coordinator or Principal Investigator are held to understand in detail the research and the findings with a view to identifying the key actionable Knowledge Outputs (KOs).
- In application of analysis criteria, the KOs with potential contribution to the Mission objectives are described. These can be termed Key Exploitable Results (KER). (see chapter 2.3 of this report)
- The KER are validated for correctness and signoff by the knowledge owner.
- To prioritise the KERs with the highest potential to impact upon the Mission objectives, the KERs validated by the knowledge owner are assessed by an Expert Panel. (see chapter 2.4 of this report)
- The expert panel moreover informs the development of pathways to impact for each prioritised KER by providing a rich understanding of drivers and barriers, including the landscape, actors, timelines, priorities etc. of the sector and/or industry.
- After analysis, P4B partners continue working with the KERs to develop impact pathways and design targeted knowledge transfer activities to maximise uptake and impact (T4.4). This step is not part of this report, as it is not part of task 4.3.

2 Method application and adaptation

The adapted process and results to date are outlined below in figure 2:

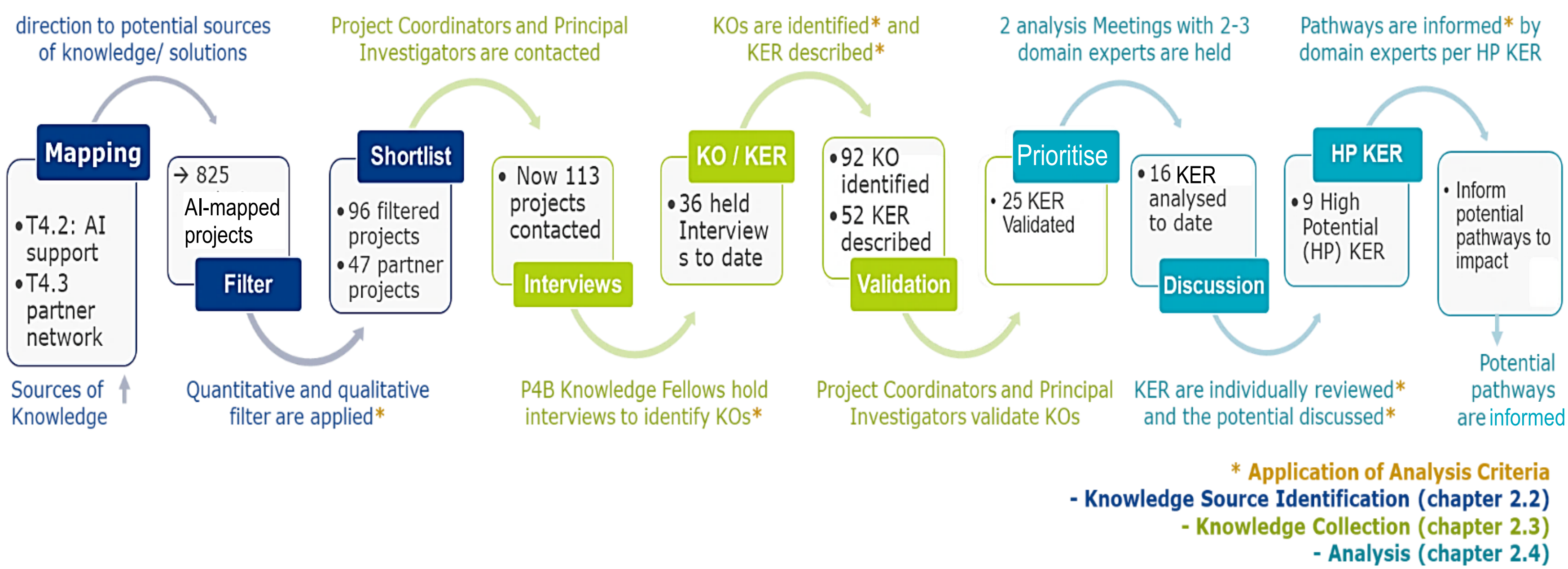


Figure 2: Knowledge Management process in PREP4BLUE
(Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

In the following, this process shall be detailed.

2.1 Analysis Criteria

Analysis criteria (e.g. suitability, maturity, scale up, replicability, transformative, impact potential, systemic application) were developed, for assessing the suitability and potential of "knowledge/solutions" (e.g. methods, tools, data, information, technologies, processes) that can help achieve the Mission.

2.1.1 Deduction of Analysis criteria

The analysis criteria were deduced based on the Mission documentation available to the time of development – 2022. The deduction and interpretation of the analysis criteria can be followed referring to ANNEX 1 'Considerations to Analysis'. In the following, main considerations are listed and explained to assess the suitability and potential of "knowledge/solutions":

- **EU Missions:** To determine if a Knowledge/ Solution/ Knowledge Output (KO) has high potential contributions to the Mission Objectives & Targets, the aims of the EU Missions need to be considered.
- **Mission 'Restore our Ocean & Waters':** To determine if a KO has high potential contributions to the Mission Objectives & Targets, the aims of the Mission need to be considered.
- **Mission Objectives, Enablers, Actions:** To determine if a KO has high potential to contribute to the Mission, it is to be assessed if the KO has potential to contribute to the 3 Mission Objectives, the 2 Enablers if it has scale-up potential, can be deployed or replicated by 2030.
- **Mission Objectives and Targets** As the aim of the analysis is to identify the KER that have high potential contributions to the Mission Objectives & Targets, considering the potential impact towards the Mission Objectives and Targets may be the most important. It can be used as a map and compass for analysis. For analysis, it is furthermore important to:
    1. Understand the Objectives and corresponding Targets well, including the linked and underlying policies, law and regulations.
    2. Be aware that the Objectives and Targets may be subject to changes by the European Commission. In order to have a valid assessment despite potential changes, the previous and following considerations need to be kept in mind, including the linked and underlying policies, law and regulations.
- **Mission Lighthouse (LH) Initiatives:** LHs pilot and lead on one of the Mission objectives […], guided by the principles of replicability and EU-wide scalability. [7]
  The LHs will thus provide access to the solutions, services and advice developed not only in the objective-respective basin (see Annex 4.1.5), but also to all interested actors from other basins and areas, so that the developed solutions can eventually be scaled up and replicated across the Union.
  The Mission will be implemented in two different phases: a "development and piloting" phase (2021-2025), followed by a "deployment and upscaling" phase (2026-2030). PREP4BLUE's

[7] European Commission (2022): European Missions Restore our Ocean and Waters Implementation Plan, https://research-and-innovation.ec.europa.eu/document/download/d6162cbd-6d09-48fd-b5b4-d7d2be69972c_en?filename=ocean_and_waters_implementation_plan_final.pdf

objective is to facilitate the successful implementation of the Mission, particularly during the piloting phase (2022-2025). The LHs will be the R&I component of the Mission, where transformative and innovative solutions will be tested, piloted and validated.
For prioritisation of the KERs, two main aspects are to be considered:

3. For the KER, custom knowledge transfer plans are developed to maximise uptake/application within the Mission LH Initiatives context. This means that a contribution to an objective in the allocated LH may be considered as aligned to the Mission.
4. A solution that was tested in one LH-area may be transferred to another geographical area and thus have a potential application and impact there also. Therefore, it is no hard criterium if a KER from another LH-area contributes to the allocated objective of another LH-area.

- **Delivering Impact** "Missions put emphasis on demonstrating, scaling up and replicating existing and new solutions including social innovations. This will ensure a tailor-made innovation approach including social innovation, in which solutions will be fully adapted to fit local circumstances. Furthermore, incremental changes will not be sufficient. These challenges require disruption, new ideas and risk-taking. Missions fully embrace out-of-the-box thinking by stimulating experimentation and bottom-up, multiple solutions to reach their objectives, also embracing education and training institutions for their key role in developing citizens' talents, knowledge and skills." (Source). Hence, the focus on knowledge/solutions, that are actionable/applicable, transferable and have potential uptake to create eventual impact is at the core of the Mission and these are important indicators to determine if a KER is of high potential.
- **Sustainable Development Goals:** The Mission shall support many Sustainable Development Goals (SDG). Restoring our ocean and waters will directly contribute to SDG 14 Life below water, and SDG 6 Clean water and sanitation. Contribution to policies, regulations or legislations, the Mission is expected to contribute to should also be considered to evaluate the potential of KER.

The Analysis Criteria and corresponding indicators were applied, trialled, tested and further developed in three main stages in Task 4.3:

1. Knowledge Sources Identification in PREP4BLUE (see chapter 2.2),
2. Collection in PREP4BLUE (see chapter 2.3),
3. Analysis in PREP4BLUE (see chapter 2.4).

The analysis criteria comprise a (non-exhaustive) summary of criteria and corresponding indicators:

Criteria	Suitability*/ MISSION FIT	Application and Impact potential* By 2030	External factors and other considerations
Indicators	Mission Objectives*, Targets*, Enablers*	Maturity*: Achievable Readiness-level (TRL, BRL, MRL,SRL, IRL)*	Market (CAGR, need, readiness) and market share (TAM, SAM, SOM)
	Policies, regulations or legislations the Mission is expected to contribute to (e.g. GreenDeal, SDG*)	Scale-up* and scale out potential to maximise impact	User (identified, known, clear need identified, gains and pains across the value chain addressed)
	Protect and restore the health of our ocean and waters, climate neutrality, nature restauration	Replicability* (Geographical, Sectorial etc.)	Feasibility (e.g. a new standard to be implemented into a member state)
	Contribution to target impacts in a specific Lighthouse area	Uptake potential (COM-B, TAM, TAC, BCW)*	Competitors (strong competitor landscape or solution easy to copy)
	Innovativeness (transformative*, incremental, disruptive)*, beyond the State of the Art	Systemic application* (sub-system, system, ecosystem)	Resources needed for scaling (time, funds)
	Not highly innovative but high value to create impact.	Negative impacts (collaterals, risks, barriers, trade-offs)	Domain-specific considerations

*Explanation in Annex for reference
*as in PREP4BLUE Grant Agreement

Figure 3. T4.3 Summary of Analysis Criteria and indicators
(Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

The Analysis Criteria fulfil the Expected Outcome "Criteria can help to identify transformative solutions for scale up/ scale out" and Expected Result "Piloted assessment criteria for knowledge/ solutions (WP4)".

2.1.2 Lessons learned

The development of Analysis Criteria is an adaptation of the base-line methodology to PREP4BLUE. A clear framework of criteria to determine the knowledge/solutions and KER with priority to the Mission turned out to be crucial for systemic Knowledge Transfer. The criteria were applied, trialled, and optimised in several phases: the identification and filtering of sources of knowledge, the selection of Knowledge Outputs per project to be described, and the determination of KER with high potential to contribute to the Mission Objectives and Targets.

Hence, for targeted Knowledge Management, the development of criteria has been proven an indispensable asset for enhanced efficiency and effectiveness, and is recommended to be considered in any replication of the PREP4BLUE Knowledge Transfer Methodology.

2.2 Knowledge Sources identification in PREP4BLUE

According to the Description of the Action (DoA), based on initial results of mapping by P4B Task 4.2 (T4.2), T4.3 partners were tasked to engage with knowledge owners to profile their Mission relevant KERs.

T4.2 provided a first list of projects identified as relevant to the Mission objectives and targets with the help of AI.[8] AI-based and manual selection went hand-in-hand in the beginning, helping the mutual improvement. The list was analysed by the T4.3 Lead, the filter criteria were refined, and a second list was provided by T4.2, which was again analysed by the T4.3 Lead and the T4.3 Fellows, and the search criteria refined again over several rounds.

Moreover, during filtering, the collection was piloted by the Fellow group, contacting projects from partner networks with Mission relevance, additionally to the sources identified by T4.2. This piloting of the methodology was to train the Fellows, adapt the method to the needs in PREP4BLUE, and to trial the Analysis Criteria. Hence, Knowledge Source identification in PREP4BLUE was two-fold: Based on the list from T4.2, plus partners were tasked to identify projects and initiatives in their own regions that they identified as being high potential sources. Combined that gave T4.3 a total list of potential sources of 158 projects. Of these, 113 have been contacted to date, 36 interviews were held, 92 KERs identified and 52 described.

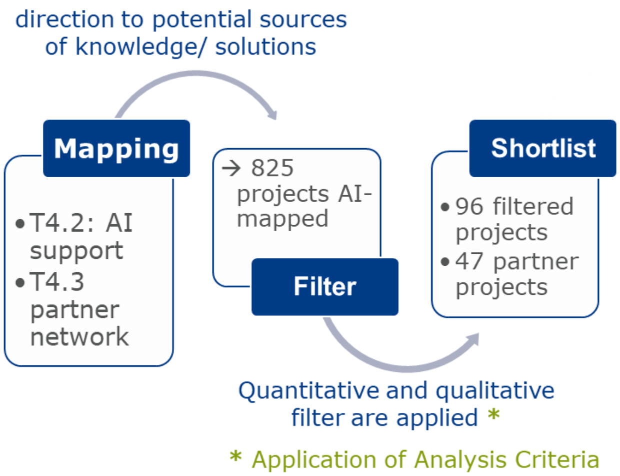


Figure 4: Knowledge Sources identification Process
(Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

T4.2 provided an initial result of mapping as "Abstract Search" of 825 projects with potential knowledge that could contribute to the Mission based on the AI tool. The projects were mapped by this mapping to the Mission Objectives. In line with the analysis criteria, in Task 4.3 filter criteria were applied to identify the Knowledge/Solutions. These filter criteria were applied successively according to four main filters, as described in the following:

2.2.1 Filter Exercise

For the purpose of identifying the most relevant and potentially impactful knowledge/solutions, a targeted approach focussing on quality over quantity was found to be more effective.

The filter criteria narrowed down the initial result of mapping by T4.2, to focus the resources on the projects with highest potential to contain Mission-relevant research outputs. Therefore, the filter criteria are specifically developed based on the initial mapping of 825 knowledge sources by 4.2.

It should be noted that efforts were made to ensure no project was contacted more than once, eliminating duplications from the initial list by T4.2 as well as projects contacted by different fellows or because of different lists of projects. After eliminating the duplications, the initial mapping was filtered from 825 to 566 projects.

[8] Read more about the AI-supported mapping of sources of knowledge: [Mapping EU Projects to the Mission Ocean Objectives and Next Steps - PREP4BLUE]

Figure 5 below in chapter '2.2.2 Filter results', shows the percentage of filter applied from one criterium to the next. This means that in our data set, a filter of 15% might seem like a small reduction. However, applied to a larger dataset or applied as first filter, it could help narrowing down the sources of knowledge with higher potential relevance to the Mission.

- **Filter Criterium 1: Projects with more than 450K€ funding:** The initial mapping results showed projects funded under a diverse and wide range of types of funding in Horizon 2020. In this specific list of projects by the initial mapping results, the projects with less than 450K€ funding were mainly SME-Instrument Phase I (SMEI-P1), which has less probability of production actionable research findings. Therefore, to identify KOs, this type of funding is not the most likely source for these types of findings. Consequently, the focus was laid on SMEI-P2, FTO, EMFF, RIA and IA funded projects, which typically have more than 450K€ funding. Based on this criterium, the mapping was filtered to 325 projects. The relatively low limit of funding was chosen to exclude on the one hand side sources with limited possibility to have actionable knowledge as outcomes; on the other hand, to include also seed-funded sources, which may have high impact despite lower funding.
- **Filter Criterium 2: projects which ended between 2017 and 2025:** Through the first phase of piloting, it was found by the Fellow group, that the outputs of projects that terminated before 2017 were too outdated for the objectives of the Mission and the projects that ended after 2025 had not yet enough time to produce KOs that would match the Analysis Criteria. Therefore, projects were further filtered based on this criterium, bringing the number of projects to be mapped to 274.
- **Filter Criterium 3: higher or equal to the AI rank of 25% fit to the Mission:** The AI tool used to provide the initial mapping results also provided a ranking of fit (in %) to the Mission Objectives per mapped project. Through manual analysis of the 274 projects against the analysis criteria, it was found that the projects ranked lower than 25% by the AI tool, indeed had limited suitability to the Mission. Based on this criterium, the mapping was filtered to 232 projects.
- **Filter Criterium 4: manual/ qualitative assessment against the Analysis Criteria:** In order to focus the interviews in the "collection phase", according to the ERINN KT methodology, a manual analysis of the projects by the Fellows of the T4.3 Core partners was undertaken. This manual analysis included in a first step, an individual assessment against the analysis criteria of all three Fellows of the remaining 232 projects. The results of the individual assessments were contrasted, and the projects of discrepant assessments qualitatively assessed through discussions and finding consensus. A qualitative assessment against the Analysis Criteria found that 96 out of the 232 had higher suitability to the Mission.

2.2.2 Filter results:

The filters described allowed a shortlisting of 96 projects with suitability and potential to support the Mission through transfer of the outputs of these projects. This included 73 RIA/IA, 23 SMEI-P2, 56 projects linked to Mission Objective 1, 14 projects linked to Mission Objective 2, and 26 projects linked to Mission Objective 3, as shown in the following figure 2:

Abstract Search		Filtered									
All Objectives		Duplicates		>450K€		end>2017<2025		>=25% rank		**Manual**	
Total	825	Total	566	Total	325	Total	274	Total	232	Total	96
Filter (%)	100%	Filter (%)	31%	Filter (%)	43%	Filter (%)	16%	Filter (%)	15%	Filter (%)	59%
RIA/IA/CSA	481	RIA/IA/CSA	317	RIA/IA/CSA	244	RIA/IA/CSA	194	RIA/IA/CSA	160	RIA/IA/CSA	72
SMEI	344	SMEI	249	SMEI	81	SMEI	80	SMEI	72	SMEI	23
Objective 1	200	Objective 1	190	Objective 1	117	Objective 1	99	Objective 1	99	Objective 1	55
Objective 2	217	Objective 2	135	Objective 2	64	Objective 2	53	Objective 2	35	Objective 2	14
Objective 3	408	Objective 3	241	Objective 3	144	Objective 3	122	Objective 3	98	Objective 3	26

Figure 5. T4.3 Filter
(Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

2.2.3 Lessons learned

The filter exercise was very time-intensive for Task 4.3. However, it was also an opportunity to optimise the results of the task:

1. Fellows of the T4.3 core partners could contrast their understanding of the Mission focus, as well as exchange their lessons learned in the piloting phase of knowledge collection thus far on a practical example, which also contributed to training in the fellow group.
2. Through the definition of the filter criteria, as well as the individual assessment and the qualitative, manual filter and discussions of potential suitability and fit by the Fellows, moreover the Analysis Criteria could be piloted and optimised.

Overall, the filter exercise provided the time and ground for a systemic selection of sources of knowledge, with the value of filtering any large dataset to identify and prioritise where would be most appropriate to invest resourcing in the Mission context. Another key lesson learned is that it is important to plan time for partners to align the processes to the specific project needs, between linked tasks, and between the different partners. For replication in the LH-areas, we foresee the DB (T4.2) and ontology (T4.1) will be useful ways to identify sources of knowledge for the Mission.

2.3 Collection in PREP4BLUE:

2.3.1 Collection process

As described in chapter 2.2, potential knowledge sources, with a first focus on European-funded projects, were identified and filtered in application of filter criteria and Analysis Criteria. The Knowledge Owner is then identified and contacted. This may be a Principal Investigator, a project/task Coordinator, an SME-owner etc. The ERINN Methodology determined that interviews are the most efficient and effective way to identify knowledge, as well as to pave the way for future analysis and transfer. During and following the interview, Knowledge Outputs (KO) are identified.

Most of the identified projects represented a significant investment and therefore could be expected to generate a large number of Knowledge Outputs. The Analysis Criteria were applied to identify the KOs with potential contribution to the Mission. Only these Knowledge Outputs were described. Focus was placed on quality over quantity in application of Analysis Criteria.

Figure 6 shows the P4B Knowledge Collection Process.

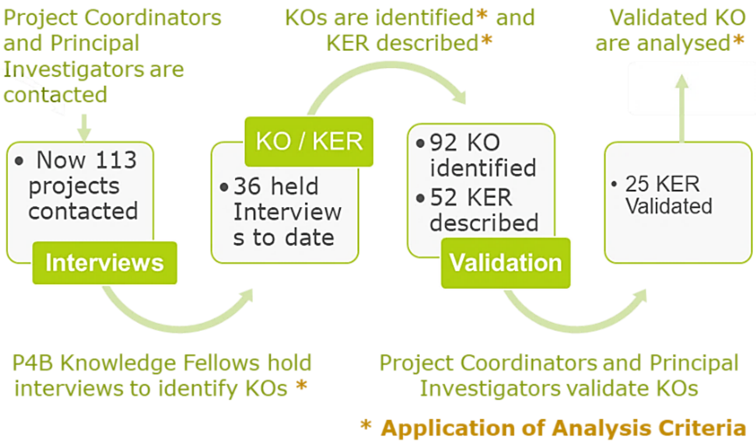


Figure 6: Knowledge Collection Process
(Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

For the Knowledge Collection, a Fellow group among the T4.3 core partners (ERINN, CNR, CETMAR) was established so three Fellows (one from each organisation) would undertake collection and so the Fellows could share their lessons learned among each other.

Over the course of the work being carried out, significant capacity building was required to enable quality collection of KERs. Internal training and quality control was implemented as well as mentorship to ensure competence was built. While this process took longer than originally foreseen, it is a worthwhile investment for future Knowledge Transfer work.

This quality-focused and capacity building approach was chosen to put into practice the co-creative nature of PREP4BLUE in collaboration between the core partners in Task 4.3. Moreover, this way T4.3 is comprehensively aligned to the ideals of Horizon Europe, facilitating international collaboration and supporting the creation and better dispersion of excellent knowledge, fully engaging the EU talent pool.

2.3.2 Results

Up to November 9th 2023, the core partners of Task 4.3 – namely CETMAR, CNR and ERINN – have contacted 113 projects. This includes projects from the shortlisted 96 projects with identified suitability and potential to help achieve the Mission through their outputs, plus the initial trials during the filtering phase, contacting "low hanging fruits" via contacts from the partner networks and networking sessions. With an average response rate of 32%, 36 interviews were scheduled and undertaken.

Based on these 36 interviews, more than 90 KOs were identified. However, during the trialling phase it was decided to apply a very targeted approach in PREP4BLUE, to describe only the KOs that meet the Analysis Criteria. Due to the limited capacities and short timeframe of the project, the focus on identifying KER, rather than describing all KOs generated in the project, was needed. This was achieved through application of the Analysis Criteria. With this targeted approach, 52 KOs with priority to the Mission Objectives and Targets have been described. As these KOs meet the Analysis Criteria, and being of priority to the Mission objectives and targets, these 52 KOs can be termed KERs, as the targeted approach is geared to identify the KOs with priority to the Mission Objectives and Targets - and to only describe these. The effort of identification and description of KER is ongoing.

As this report was written, the core partners of Task 4.3 have identified 52 relevant and promising solutions, KERs, to inform the Mission Objectives.

After description of the KER by the Knowledge Fellows, these are reviewed and validated by the KER-Owner. To date, 25 KERs are validated by the Knowledge Owner for correctness of the description and determined open for publicly sharing the units of knowledge generated. These are included in the present Deliverable 4.2 Annex 2, and are to be included in the Mission Ecosystem Database, as soon as it will be live. The Launch is foreseen by WP4 Partner SDU at the Blue Mission Banos Arena in Gothenburg on 14-16 November 2023.

The 25 validated KER-descriptions are included in the Annex II of this deliverable and are listed in the below figure 8, and tagged to the Mission Objectives (see annex chapter 4.1.4.), as listed as follows:

Three Mission Objectives (MO):

MO1: Protect and restore marine and freshwater ecosystems and biodiversity, in line with the EU Biodiversity Strategy 2030.

MO2: Prevent and eliminate pollution of our ocean, seas and waters, in line with the EU Action Plan Towards Zero Pollution for Air, Water and Soil.

MO3: Make the sustainable blue economy carbon-neutral and circular, in line with the proposed European Climate Law and the holistic vision enshrined in the Sustainable Blue Economy Strategy.

It is important to note, the association per KER to Mission Objectives (MO), based on the corresponding targets (see annex chapter 4.1.4) depends on the target user, application and pathway defined, which is not part of this deliverable. Moreover, the Mission Objectives are interlinked, such as for example pollution reduction (MO2) or a carbon neutral circular blue economy (MO3) may indirectly also contribute to ecosystem restoration (MO1). However, the tagging of KER to MO in the below figures 7 and 9, shall provide an indicative approximation of the main contribution to MO per KER.

KO Code	KO title	MO
770469 - KOa	Big-data collection, organisation and presentation toolbox for Mission objectives assessment and monitoring	1,2,3
863702 – KOa	Artificial Intelligence (AI) for seafloor screening and monitoring	1,2,3
789059 - KOa	Restoration protocol for Cystoseira spp. forest ecosystems	1
789059 - KOb	Cystoseira meadows mapping in the Mediterranean Sea: comprehensive georeferenced database	1
789059 - KOc	Development of a High Suitability Model (HSM) for Cystoseira species to predict their occurrence at locations where no information is available in the Mediterranean sea	1
789059 - KOd	Prioritization of Cystoseira restoration sites in the Mediterranean Sea	1
863693 - KOa	'Xplotector' - Highly sensitive, automated, portable in-situ chemical and organic compound identification and analysis system.	2,3
863693 - KOb	'XploTaker' – underwater real-time chemical and organic sample collection for in-situ analysis	2,3
789391 - KOa	Marine litter inventory for knowledge sharing across aquaculture stakeholders in the North Sea, Baltic Sea and the Mediterranean.	2,3
789391 - Kob	Toolbox of solutions and measures for the good management of marine litter in aquaculture	2

789391 - Koc	Action plan and policy recommendations on existing and innovation solutions to prevent, eliminate and recycle marine litter in the ocean.	2
858805 - KOa	Efficient, modular, multistage sequential wastewater treatment system	2
862658 - KOf	Eco-intensification of inland fish farming systems through saline aquaponics	3
862658 - KOg	Precision model to map chlorophyll-a concentration in shallow water for the shellfish aquaculture industry.	3
817737 - KOa	Multiplatform tracking and wireless communication system enabling precision fish farming and ecosystem welfare	1,3
750680 - KOa	Identification of deep-sea areas to be potentially protected through the combination of two complementary approaches.	1
750680 - KOb	WebGIS maps of the spatial extent of the descriptors/criteria/indicators as well as human pressures/impacts on the Mediterranean deep-sea ecosystems	1
750680 - KOc	Integrated guidelines for the protection of the deep sea focusing on the Mediterranean Sea	1
750680 - KOd	Gaps identification to improve the Marine Strategy Framework Directive (MSFD) from a deep-sea prospective.	1
750680 - KOe	Identification and evaluation of the most promising criteria/indicators of Marine Strategy Framework Directive (MSFD) for achieving the Good Environmental Status (GES) in the deep Mediterranean Sea.	1
783773 - KOa	Cleaning multitask catamaran to clean oceans and waters surfaces fighting against any marine pollution capable of recovering hydrocarbon spills, microalgae harmful and algal blooms, dealing with marine debris, plastics and microplastics in open and confined waters.	2
863584 - KOa	Reference microbial gene-Catalogue of polluted marine sediments	1,2
863584 - KOc	A prokaryotic isolate and a microbial consortium inhabiting marine sediments with mercury (Hg) detoxification capacities for bioremediation.	1,2

Figure 7: Codes and Titles of profiled Key Exploitable Results (KER) (Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

Note: two KER had to be removed from this list for this public deliverable due to delays in publishing by the KO-owners

In summary, figure 9 at the right shows the contribution per validated KER to date to the indicative contribution to the Mission Objectives: 44% contribute to MO1, 31% to MO2, and 25% to MO3.

Figure 7 provides an approximation of the current focus of the validated KER to date to the Mission Lighthouse (LH) Areas: 21% to Atlantic and Arctic (AA), 35% to the Mediterranean (MED), 26% to the Baltic and North Sea (BANOS) and 18% to the Danube River Bassin (DANUBE).

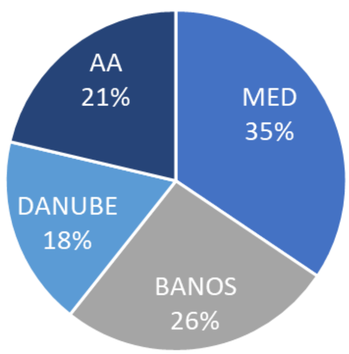


Figure 8: Approximation to current focus of validated KER to LH-area (Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

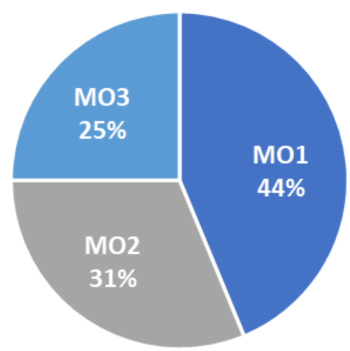


Figure 9: Indicative contribution of validated KER to Mission Objectives (Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

However, although a KER might have a current focus on a specific area (e.g. tested in one or several areas), it may be transferred and applied to/in another geographical area.

The current efforts are focused on the description, validation and analysis of all KER. Periodically gap-analyses are undertaken for an equilibrated collection in terms of geographical areas and topics. To date an equilibrium is achieved (see figure 7 and 9) with minor fluctuations, which we see as causal at this stage. However, it will be monitored as progress continues and if needed efforts may be refocused for a balanced collection.

2.3.3 Lessons learned

The approach to undertake collection with a dedicated Fellow group allowed collaboration and knowledge sharing across organisations from different EU-countries, providing diverse, interdisciplinary perspectives to the process and results. Therefore, this approach was successful, not only in terms of results, but also in terms of building skills and fostering talent.

However, more time and capacity needed to be invested in the capacity building of less experienced members than originally planned. In case of limited project timeframes, it is therefore recommended to select a Fellow group of experienced personnel, in order to focus the Fellow group on knowledge exchange and to further the methodology to the project needs as well as to allow sufficient quality and quantity for the full Knowledge Transfer.

Utilising the methodology by ERINN Innovation, enabled the PREP4BLUE Task 4.3 core partners to identified 52 KERs, relevant to the Mission, so far. Time, resource and a systematic, trialled methodology are then needed to find the KERs with most potential.

On operational level, a minimalistic approach was applied among the fellow-group, to store, trace and monitor the needed, but not all possible, information. This requires an experienced task leader, such as ERINN, to know beforehand which information will be needed and a mindful development of templates. It enables efficient work-flows, effective achievement of results, while preventing over-administration.

2.4 Analysis in PREP4BLUE:

2.4.1 Analysis process

For enhanced efficiency, in P4B, the priority to the Mission per KER is determined, to draft pathways to impact per high-priority KER. The priority to the Analysis Criteria, and hence the relevance to the Mission, is determined through expert panel discussions. KERs were planned to be assessed using the Analysis Criteria by consortia, and external deep domain experts and stakeholders where required.

The analysis process in PREP4BLUE is outlined in figure 10.

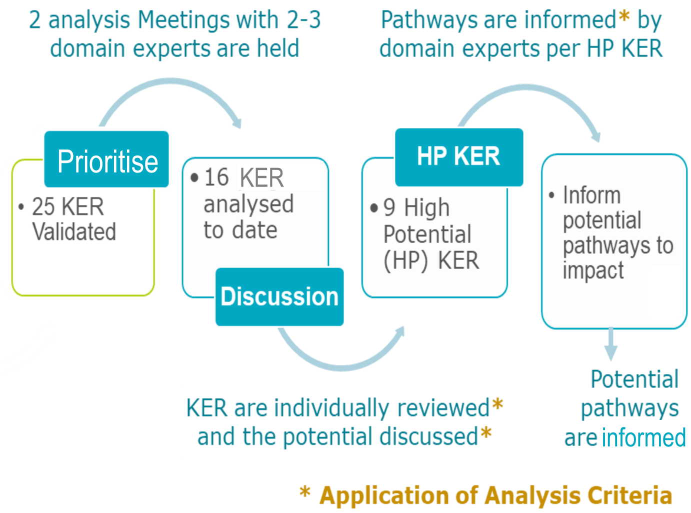


Figure 10: Analysis Process
(Credit: Task 4.3 – Horizon Europe Grant Agreement n° 101056957)

The planned approach for the prioritization of KER was applied and only operational adaptations made, based on the progress of validation of KER (e.g. the order of analysis according to domains with enough validated KERs). To date, only consortia domain experts were invited to analysis meetings, however in future, also external domain experts and stakeholders may be invited, where required.

We consider domain experts to be those with deep expertise in a specific domain, which nevertheless may be from different disciplines, sectors (e.g. academic, politics, industry) etc. For example, the first analysis meeting was on the domain of ´contamination remediation' and the experts englobed points of view from entrepreneurship to policies in the same domain; the second analysis workshop was on the domain of 'restoration and protection', including experts from social sciences, applied science and pure science. The experts are suggested by partners and selected by the task lead, to specifically englobe the needed wide range of points of view and insights per domain. The denominations of domains are based on the planning, to englobe the Mission Objectives and Targets, as well as to accommodate for a timely analysis of validated KERs. The next analysis workshop is planned on the domain of 'aquaculture', with a focus on Mission Objective 3 Target 2 "Develop zero-carbon and low-impact aquaculture, and promote circular, low-carbon multi-purpose use of marine and water space."

The targeted approach, to target a domain per analysis meeting is to gain the insights from domain experts to inform the potential pathway. Also, expertise from the respective domain is needed to identify the knowledge of high priority to the Mission Objectives and Targets, knowing the landscape in terms of State of the Art, research, industry, competitors etc. This is also the reason why experts in the same domain, but from different backgrounds and disciplines are invited to the panels, to have a rich discussion and information, as basis to draft pathways to impact, following the analysis.

The focus of the analysis in PREP4BLUE is on better understanding the landscape, actors, timelines, priorities etc. of the sector and/or industry and determining if the knowledge could positively impact it, and if so, mapping the Pathway to Impact e.g., the steps (users, application, outcome) needed to ensure and accelerate the transfer.

Therefore, appropriate experts are tasked in a facilitated manner to i) assess the potential of a Knowledge Output to have a high potential impact towards the Mission Objectives, and for those that could, ii) propose a Pathway to Impact which details the required actors, activities and outcomes.

For KT to be successful, actions have to be guided/informed, deliberate and focused. Moreover, PREP4BLUE Knowledge Fellows, partners and experts have limited time to be able to produce case studies of successful Knowledge Transfer; hence, efforts have to be efficient. Knowledge Assessment helps to identifying potential applications, End Users and Eventual Impacts for the Knowledge Output. This information enables the development of Pathways to Impact and identify a Target User.

The relevance to the Mission, with includes the potential to have impact by 2030, is explored in a two-fold process:

KERs are assessed, using the analysis criteria by consortia and external deep domain experts and stakeholders where required. This is undertaken by means of Analysis Meetings in the form of expert panels with two main aims, in line with the methodology:

1. to analyse and identify research outputs from EU-funded projects, with high priority to the EU Mission Restore our Ocean and Waters.
2. To inform the potential pathways to eventual impact.

The relevance to the Mission, which includes the potential to have impact by 2030, is explored in a three-stage analysis process:

- Step 1: Before the workshop, the expert panel is asked to briefly review a list of 4-8 Knowledge Output Descriptions (1-3 pages each) around the specific domain of expertise.
- Step 2: During the workshop, the panel of experts examines these KER, discussing their relevance and potential impact to Mission Ocean objectives.
- Step 3: Once KER are identified as high priority to the Mission, discussion will move to potential pathways to impact (e.g., where/by whom could these be transferred, what support would this require (technology, policy change, etc.)).

After the workshop, the PREP4BLUE Task 4.4 Team will continue working with the KER identified as high priority to the Mission. This includes targeted knowledge transfer activities, to maximise uptake and impact.

Please Note: the aim is not to evaluate the science behind the Knowledge Outputs or particular projects, but rather to discuss how they could be transferred, and which are of particular interest to achieving the Mission's objectives.

Guidelines for the analysis are provided to the expert panel previous the meeting, including criteria, and the task leader provides as much support as needed.

The generation of informed **"Pathway to Impact"** are at the core of the Knowledge Transfer Methodology. The analysis is crucial to gain the needed expertise. Based on this information, the Pathways to Impact will outlines potential steps, users, applications and outcomes needed to move a unit of knowledge towards achieving its potential impact, often in the most efficient manner. It is an informed stepwise approach to **gathering the right information** to **inform Knowledge Transfer Activities,** that should **result in verifiable impact.**

There may be an occasion when there is only a single step in the Pathway to Impact, whereby the End User who will apply the Knowledge Output is also the Target User. In this case, once the Knowledge Output has been transferred to this individual, also the End User, who applies the Knowledge Output, then Eventual Impact has occurred.

Typically, there are multiple steps in the Pathway to Impact. Once the Knowledge Output has been transferred to the Target User and this individual applies the Knowledge Output, then Transfer has occurred and Impact can be measured. Further Transfer Activity might then occur to carry the Knowledge Output further down the Pathway to Impact to the next User, and so on, resulting in Transfer Impact at each step. As before, once the Knowledge Output has been transferred to the End User and this individual applies the Knowledge Output, then Eventual Impact has occurred.

The success of each Knowledge Transfer Plan will be measured using quantitative and qualitative performance measures, aligned with the Technology Acceptance Model (TAM) (see chapter 4.1.9.1- in annex 1): 1. Perceived usefulness/ease of use → 2. Behavioural intention → 3. Actual system use.

2.4.2 Analysis Results

Over the course of the reporting period, two analysis meetings have taken place:

1. The pilot analysis meeting was held on July 13th 2023 on the domain of 'contamination remediation'. A news piece about this meeting was published on the PREP4BLUE Website: First PREP4BLUE Knowledge Analysis Workshop - PREP4BLUE

2. The second analysis meeting was held on September 20th 2023 on the domain of 'restoration and protection'.

In each analysis meeting, validated KER were presented to the expert panel by the facilitator and Task 4.3 team, and a rich discussion amongst the experts took place to agree on the potential impact the KER could have on the Mission Objectives and Targets, based on shared Considerations for Analysis (see annex 1), including the Analysis Criteria (see chapter 2.1). A consensus on the impact potential was then reached and recorded for each KER. Following the first analysis meeting where 8 KERs were reviewed, all were considered to be of high relevance to the Mission. For the second analysis meeting, 8 different KERs were considered and 1 was deemed to be high potential to impact upon the Mission. 4 were deemed of medium potential and three of lower relevance to the Mission Objectives. In each analysis meeting, for the KERs deemed to be high potential, further discussions took place with the experts to gain a good understanding of the steps, activities and timeframes needed to enable and accelerate that impact being achieved.

In the following, we provide insights into outputs of the analysis meeting, per analysis stage:

Step 1: Before the workshop, the expert panel is asked to briefly review a list of 4-8 Knowledge Output Descriptions (1-3 pages each) around the specific domain of expertise: To take and share notes on the review, the experts are invited to use a standardised template and comment on each of the criteria per KER, based on the indicators in the analysis considerations. These notes may also serve for argumentation in the panel discussion in the analysis meeting.

The table shows three examples of such notes, which build the basis for the analysis meeting and potentially inform the pathways to impact.

Individual review example to KO 'Cleaning multitask catamaran to clean oceans and waters surfaces fighting against any marine pollution capable of recovering hydrocarbon spills, microalgae harmful and algal blooms, dealing with marine debris, plastics and microplastics in open and confined waters.'		
Suitability/ MISSION FIT (Contribution to target impacts…)	**Application and Impact potential by 2030**	**External factors and other considerations**
This KO directly contributes to objective II of the Mission (and consequently to objective I, Green Deal and ODS 16). It can support the implementation of the Marine Strategy Framework Directive programme of measures regarding several descriptors of the Good Environmental Status (GES) and contribute to implement the requirements of the International Convention on Oil Pollution Preparedness,	This KO has achieved the highest TRL and BRL but may benefit from further actions to improve MRL or to improve TRL in the case of new components or services. It can potentially be applied in any geographical area and has high potential for scaling out by developing new formats and functionalities (e.g., retrieval of derelict fishing gears and seafloor litter). The implementation of monitoring and detection capabilities onboard may be considered for scaling it out and may contribute to	Potential users have already been identified. The need for this kind of systems to tackle oil spills is stated in MS regulatory frameworks derived from OPRC convention that requires the implementation of contingency plans and associated means at different territorial levels to respond against accidental pollution. This includes national and local authorities in charge of response, coastguard services, ports and coastal and offshore industrial facilities. In the case of marine litter,

Response and Co-operation (OPRC) in terms of providing means for oil spill response against accidental pollution. It could be allocated in a Mediterranean LH objective but could also feed the LH of the Atlantic Sea and to some extent the North Sea and Baltic Sea basin LH. The main innovation comes from the multi-target cleaning system that can clean and store marine pollution in a continuous non-stop process.	the Mission enable Digital Twin of the Ocean.	the polluter is not known in most cases and the lack of clear responsibilities for removing it may reduce the number of potential clients. However, for most municipalities, the potential economic impact of marine litter on tourism may provide a strong motivation for removing litter. Given that Ocean Cleaner Technologies is a SME It would be important to identify how to respond to a potential strong market demand of the vessel by establishing alliances and partnerships with shipbuilding companies.

Individual review example to KO 'Efficient, modular, multistage sequential wastewater treatment system'		
Suitability/ MISSION FIT (Contribution to target impacts…)	**Application and Impact potential by 2030**	**External factors and other considerations**
This KO contributes to objective II of the Mission (and consequently to objective I, Green Deal and ODS 16), tackling chemical pollution from a range of industrial sector companies but also waste water treatment plants and small municipalities. As the process produces biogas, it can also contribute to circular economy making the wastewater sector energy-neutral thus contributing to Objective III. It could be allocated in Mediterranean LH objectives but could also feed the LH of the Atlantic Sea and to some extent the North Sea and Baltic Sea basin LH. Highly innovative for the combination of anaerobic, aerobic and photocatalysis processes in one digester and the possibilities of adaptation to customer needs.	This KO has achieved the highest TRL and BRL (9) and can be combined with other solutions to complement functionalities. It can potentially be applied in any geographical area. End users and target sectors have already been identified but there is potential to widen the range of end users and probably the contaminants tackled. For scaling out, it could be worth exploring the capabilities and potential of improvement of the system to remove emergent contaminants such as pharmaceuticals, cosmetics, illicit drugs, pesticides, surfactants and microplastics that often occur as traces in complex organo-mineral mixtures and will be target of future regulations.	Two key Directives are currently being reviewed and the expected requirements will increase the relevance of this KO. The Urban Waste Water Treatment Directive is being reviewed in order to tackle pollution that is not covered by the current regulation. It will expand its scope of application to cover smaller cities (from 1000 inhabitants) and will introduce criteria more rigorous regarding the elimination of emerging pollutants such as pharmaceuticals, cosmetics, and microplastics. The revision introduces a binding energy neutrality target for the whole sector and will introduce extended producer responsibility. The revision of the Industrial Emission Directive provides a framework for the operation of EU industrial installations in line with the European Green Deal, the zero-pollution action plan and increase the focus on energy, water and material efficiency and reuse.

Individual review example to KO 'Marine litter inventory for knowledge sharing across aquaculture stakeholders in the North Sea, Baltic Sea and the Mediterranean'.		
Suitability/ MISSION FIT (Contribution to target impacts…)	**Application and Impact potential by 2030**	**External factors and other considerations**
This KO directly contributes to objective II of the Mission (and consequently to objective I, Green Deal and ODS 16) by tackling litter originated by aquaculture activities and facilitating prevention, removal, and recycling. It can support the implementation of the Marine Strategy Framework Directive programme of measures regarding descriptors 10 (marine litter) of the Good Environmental Status (GES) and. It also contributes in some extent to Objective III, facilitating recycling. It is also aligned with Enable II, as it supports Citizen Science, the participation of the public, and the testing of these solutions in other contexts. The KOs are valuable and relevant as they have gathered and provide user friendly access to comprehensive information about aquaculture that has not been paid as much attention as other sea based or land-based sources of marine litter.	The three KOs (KOa, KOb and KOc) are complementary and for the purpose of this analysis, they may be assessed/considered as a full package to address marine litter from aquaculture with a holistic approach as it includes a marine litter inventory, graphical and factual material on measures and solutions and action plans and policy recommendations aimed at supporting a sound management of aquaculture waste. It has the potential to be applied to other geographical areas. Although the project has been mainly focused on the North Sea, Baltic and Mediterranean, the KOs could clearly be applied in the Atlantic and feed the Second OSPAR Regional Action Plan (RAP ML 2) that addresses marine litter within the North-East Atlantic. It defines key actions to reduce sea-based sources of marine litter and among them, there are two actions that could clearly benefit from these KOs. Action B4.2: Stimulate circular design and developments in waste management of fishing and aquaculture gear and Action B 4.7: Prevent and reduce marine litter from aquaculture. OSPAR may act as a key actor to foster and multiply the impact of these KOs.	Based on project information, the potential users identified include aquaculture farmers; professional clusters, associations and platform representatives; policy makers; port authorities; aquaculture gear and equipment producers; engineering, system design and construction companies; plastic manufacturers; waste managers; researchers; environmental and social consultancies and NGOs Classification and certification bodies. Project impact may benefit from a stronger communication and capitalization plan through suitable mechanisms and channels based on the identified users. The approach could benefit from a stronger involvement of stakeholders by developing future pilot tailor made actions or demonstrators addressed to specific aquaculture sectors and built on Aqua Lit results. Fostering marine litter project to project collaboration and clustering of relevant marine litter results may lead to higher impact and uptake.

Figure 11: Examples of Expert KER review

__Step 2:__ **During the workshop, the panel of experts examines these KER, discussing their relevance and potential impact to Mission Ocean objectives.** The individual reviews are contrasted, discussed and conclusions drawn per KER, whether it is of high, medium or lower priority to the Mission, according to the Analysis Criteria and underlying indicators. This process usually took half of the time of the analysis workshop and provided ground for knowledge exchange among the experts.

The set-up and moderation of the analysis meetings allowed for that freedom, in order to capture the different expertise by the domain experts, which were composed of interdisciplinary panels. In each analysis meeting, experts the specific domains were invited, to cover a broad range of angles, including policy, technology, pure- and applied science, natural- and social science etc. Diverse organisational, geographical and gender representation was considered as well.

Step 3: Once KER are identified as high priority to the Mission, the discussion will move to potential pathways to impact (e.g., where/by whom could these be transferred, what support would this require (technology, policy change, etc.)). The discussion evolved around the identification of actions, users, channels, applications, outcomes and other details, including considerations on drivers and barriers. For each KER that was deemed high priority to the Mission, these categories were defined per KER, per pathway. Based on this part of the analysis workshop with the domain experts, the first step shall be made to inform the Pathways to Impact.

2.4.3 Lessons learned

The analysis is an indispensable step to inform pathways to impact, as even domain experts may disagree. This also allows for a rich discussion and informed pathways. Based on the current analysis meetings it was found that a panel of 3 interdisciplinary experts on one domain but with diverse backgrounds provides the rich discussion needed to assess the KER and to inform the pathways, in the limited time.

3 Conclusions

The first steps in the customised Knowledge Management Methodology, "collection" and "analysis" confirmed that highly relevant solution to the Mission objectives are available. It takes significant resourcing and planning to identify, collect, describe, assess, map impact pathways and identify the best transfer activities to ensure impact can take place. In PREP4BLUE, we invested these resources, to support the much-needed successful uptake of these solutions.

With this report, PREP4BLUE provides a Method and lessons learned for Knowledge Management, to support a coordinated systemic approach to the Mission implementation, optimising investments and maximising the likelihood of developing transformative solutions that can achieve the Mission Targets. The improved capacity to identify solutions for scaling up is hence supported by the Systematic Knowledge Management methodology, which is piloted in the Tasks 4.3 and 4.4. Identification, analysis and transfer of Key Exploitable Results (KERs) to potential target users (future LH demonstrators, other Projects, funders at all scales, other stakeholders including business community) helps support KERs along their Pathways to Impact. The systematic methodology as well as the Mission Ecosystem DB (see deliverable 4.4), including all KERs, is this way openly available.

3.1 Summary of Results

Based on the sources of solutions identified by D4.2 and in application of Analysis Criteria, 113 innovative projects were contacted. Based on these, 36 interviews were held, 92 novel R&I solutions/ KER identified and 52 KER described to date. This includes methods, tools, data, information, technologies and processes, that can be used by Mission stakeholders to help realise Mission goals. To identify the high potential KER, 2 panel analysis workshops were held, with 2-3 domain experts each, analysing total of 16 KER, of which 9 are deemed with high potential to contribute to the Mission Objectives and Targets. The next steps will include the development of Pathways to Impact for the KER with high potential to contribute to the Mission 'Restore our Ocean and Waters' Objectives and Targets.

The key lessons learned in the development and application of Analysis Criteria (chapter 2.1), Knowledge Source Identification (chapter 2.2), Knowledge Collection (chapter 2.3) and Analysis (chapter 2.4) can be summarised as follows:

3.1.1 Key insights from Analysis Criteria (chapter 2.1)

For targeted, systematic Knowledge Management, the development of Analysis Criteria has been proven an indispensable asset for enhanced efficiency and effectiveness and is recommended to be considered in any replication of the PREP4BLUE Knowledge Transfer Methodology, especially within the Mission context.

3.1.2 Key insights from Knowledge Source Identification (chapter 2.2)

To identify sources of knowledge relevant to the Mission, the piloted AI-support (by T4.2) was needed, to have a short list of sources – in the case of the pilot in PREP4BLUE, EU funded RDI projects. However, the combination with manual quantitative and qualitative filtering was needed to fine-tune the shortlisting process. To date, AI could not replace a person in this process.

In this sense, for replication in the LH-areas, the Mission Ecosystem Database (T4.2) and Ontology (T4.1) are good ways to identify sources of knowledge. Time, resources and a systematic, trialled methodology are then needed to find the KERs with most potential.

3.1.3 Key insights from Knowledge Collection (chapter 2.3)

The approach to undertake collection with a dedicated Fellow group allowed collaboration and knowledge sharing across organisations from different EU-countries, providing diverse, interdisciplinary perspectives to the process and results, providing considered decisions and results, as well as knowledge sharing for capacity building and fostering talent. Moreover, the targeted, minimalistic approach enables efficient work-flows, effective achievement of results, while preventing over-administration.

3.1.4 Key insights from Analysis (chapter 2.4)

Interdisciplinary panels within a defined domain have been proven as very efficient and effective to gain the needed rich information to identify the KER with high priority (HP) to the Mission Objectives and Targets; and to inform potential Pathways to Impact for the HP-KER, gaining a good understanding of the steps, activities and timeframes needed to enable and accelerate that impact being achieved.

3.1.5 Fazit

Mindfulness and the extensive experience of the Work Package and Task Lead ERINN Innovation, were indispensable for the application and adaptation of the methodology, as well as development of templates and guidance for effective and efficient workflows and capacity building amongst the partners.

This way, a customized Knowledge Management Method for Mission 'Restore our Ocean and Waters' is provided with this progress report, including lessons learned and high potential Key Exploitable Results relevant for the Mission.

3.2 Next Steps

The next steps will include the development of Pathways to Impact for high potential KERs. End-users will be identified, and a custom Knowledge Transfer plan will be developed per KER to maximise change of uptake/application within the Mission LH Initiatives context. The custom Knowledge Transfer plans developed will be supported by a Knowledge Transfer online showcasing module (D4.5). T4.4. will benefit from outputs in other P4B-WPs, such as potential barriers within impact pathways (WP5), follow on funding options identification (WP1,5), the stakeholder engagement activities planned (WP1,3,5,6) as well consortia links to stakeholders via existing networks/ forums (e.g., CPMR); and the LH based procurement activities. Collaboration in Knowledge Management across the LH-CSAs, namely BlueMissionBanos, EcoDALLI, BlueMissionMed, BlueMIssionAA and the Mission Implementation Platform have been suggested in an informal meeting at the European Maritime Days 2023 by EcoDALLI and thereafter initiated by PREP4BLUE through the Task 4.3 Lead, ERINN Innovation.

3.3 Acknowledgements

We would like to warmly thank all persons and organisations involved in the work for Task 4.3 and contributors to this deliverable, notably the Knowledge Owner, Principal Investigator, Project Coordinator and SME-Owner who explained their knowledge, taking the time to meet for one or several interviews and to revise and validate the Knowledge Output descriptions, making our work possible.

Moreover, we would like to thank the PREP4BLUE Partners and the PREP4BLUE granting authority, the European Climate, Infrastructure and Environment Executive Agency (CINEA) for all support. The collaboration between the Task 4.2 Team (lead by SDU) and the Task 4.3 core team in collaboration between CNR, CETMAR and ERINN was very intense and fruitful. We would like to heartily thank you all for the professional, benevolent, and inspiring collaboration! In the Expert Panels for analysis, we have had the honour to meet members of CETMAR, CNR and UCC. We would like to sincerely thank the experts for their time and deep insights into the domains discussed.

Last, but not least, we would like to thank all persons and organisations involved in this generous knowledge sharing, in particular ERINN who provided the courtesy of basing the PREP4BLUE Knowledge Management Method on their tried and tested methodology.

These contributions will build the basis for the PREP4BLUE best practice knowledge management system, to ensure innovative solutions that can support the goals of the Mission and protect the health of our waters are identified, managed and effectively transferred to Mission stakeholders.

4 ANNEXES

4.1 ANNEX 1: Considerations to Analysis

4.1.1 EU Missions

To determine if a Knowledge/ Solution/ Knowledge Output (KO) has high potential contributions to the Mission Objectives & Targets, the aims of the EU Missions need to be considered. Please find the description of the EU Missions as well as a (non-exhaustive) list of corresponding meanings for the analysis of KOs in the table below.

European Commission Description (source):	Meanings for the analysis of KOs
'EU Missions are a new way to bring concrete solutions to some of our greatest challenges. They have ambitious goals and will deliver concrete results by 2030.'	The KO needs to be transferrable within the established time-frame, delivering potential impacts by 2030.
'They will deliver impact by putting research and innovation into a new role, combined with new forms of governance and collaboration, as well as by engaging citizens.'	KOs needs to have impact. To have an impact KOs needs to be applicable and be applied.
'EU Missions are a novelty of the Horizon Europe research and innovation programme for the years 2021-2027.'	Being the Missions relatively new, they still are subject to adjustments and potential changes.
'They support Commission priorities, such as the European Green Deal […]' and more, incl. international agenda , such as the SDG.	The Missions have specific Objectives and Targets. However, if a KO does not contribute specifically to these, but to priorities the mission is expected to support, the KO still may be of high priority to the Mission.
'EU Missions are a coordinated effort by the Commission to pool the necessary resources in terms of funding programmes, policies and regulations, as well as other activities.'	The Mission englobes a wide range of policies and regulations. The analysis is focused on the Mission 'Restore our Ocean and Waters' Objectives and Targets. However, a broad scope is to be kept.

Figure 1. EU Missions in Horizon Europe and Meanings for the analysis (Credit: European Commission and Prep4Blue Consortium – Horizon Europe Grant Agreement n° 101056957)

4.1.2 Mission 'Restore our Ocean & Waters'

To determine if a Knowledge/ Solution/ Knowledge Output (KO) has high potential contributions to the Mission Objectives & Targets, the aims of the Mission need to be considered. Please find a description and meanings for the analysis of KOs in a (non-exhaustive) list below.

European Commission (EC) Description (source):	**Meanings for the analysis of KOs**
"[The Mission] aims to protect and restore the health of our ocean and waters […] and play a key role in achieving climate neutrality and restoring nature"	If a KO contributes to these aims, it can be considered with potential to contribute to the mission. The analysis may be understood as prioritization.
"The Mission's new approach will address the ocean and waters as one"	A KO may contribute to the mission, despite no direct relation to the marine environment.

Figure 2. EU Mission: Restore our Ocean and Waters and Meanings for the analysis (Credit: European Commission and Prep4Blue Consortium – Horizon Europe Grant Agreement n° 101056957)

Based on the Mission Factsheet, the main challenges and opportunities identified are listed below. The EC targets 'concrete solutions for our greatest challenges' and the overall goal to 'Restore our ocean and waters by 2030'.

CHALLENGES

Man-made changes are putting our ocean and waters at a serious risk, leading to:

- Pollution;
- Biodiversity loss;
- Extreme weather events such as floods, droughts and heatwaves.

OPPORTUNITIES

- **Climate neutrality**: the ocean and waters are major carbon sinks and are essential for adaptation to climate change
- **Biodiversity**: the ocean and waters are home to a rich diversity of species.
- **Economic prosperity**: the ocean is estimated to generate €2.5 trillion per year by 2030

Figure 3. Mission Factsheet (Credit: Directorate-General for Research and Innovation (European Commission))

4.1.3 Mission Objectives, Enablers, Actions

The Mission has 3 Objectives, 2 Enablers and 5 Actions:

The Mission Charter calls for joining efforts to achieve the three objectives of the Mission to:

I. Protect and restore marine and freshwater ecosystems and biodiversity, in line with the EU Biodiversity Strategy 2030

II. Prevent and eliminate pollution of our ocean, seas and waters, in line with the EU Action Plan Towards Zero Pollution for Air, Water and Soil

III. Make the sustainable blue economy carbon-neutral and circular, in line with the proposed European Climate Law and the holistic vision enshrined in the Sustainable Blue Economy Strategy.

To reach these objectives the Mission is also putting in place two enablers:

i. Digital Ocean and Water Knowledge System, known as Digital Twin of the Ocean

ii. Public mobilisation and engagement.

Actions include Mission related policies, programmes, initiatives and projects to support:

a. Research and innovation
b. Evidence-based knowledge and data and/or access provision to knowledge and data, in line with FAIR principles for the Mission Ocean and Waters Knowledge System
c. Upscaling, deployment and replication of solutions
d. Citizen engagement, citizens-science, youth-led initiatives, communities of practice, ocean and water literacy, outreach, awareness raising and participatory approaches
e. Education and training.

For the PREP4BLUE WP4 Task 4.3 action C is of specific relevance. To determine if a KO has high potential to contribute to the Mission, it is to be assessed if the KO has potential to contribute to the 3 Mission Objectives, the 2 Enablers if it has scale-up potential, can be deployed or replicated by 2030.

4.1.4 Mission Objectives and Targets

Actions and KOs shall contribute to and create the conditions to achieve the Mission objectives (I-III) and targets (a-i):

I. **Protect and restore marine and freshwater ecosystems and biodiversity, in line with the EU Biodiversity Strategy '30**

a. Protect a minimum of 30% of the EU's sea area and integrate ecological corridors, as part of a true Trans-European Nature Network.
b. Strictly protect at least 10% of the EU's sea area.
c. Restore at least 25,000 km of free-flowing rivers.
d. Contribute to relevant upcoming marine nature restoration targets, including degraded seabed habitats and coastal ecosystems.

II. **Prevent and eliminate pollution of our ocean, seas and waters, in line with the EU Action Plan Towards Zero Pollution for Air, Water and Soil**

e. Reduce by at least 50% plastic litter at sea.
f. Reduce by at least 30% microplastics released into the environment.
g. Reduce by at least 50% nutrient losses, the use and risk of chemical pesticides.

III. **Make the sustainable blue economy carbon-neutral and circular, in line with the proposed European Climate Law and the holistic vision enshrined in the Sustainable Blue Economy Strategy**

h. Eliminate greenhouse gas emissions from maritime economic activities in the EU and sequester those emissions that cannot be avoided (net zero maritime emissions).
i. Develop zero-carbon and low-impact aquaculture, and promote circular, low-carbon multi-purpose use of marine and water space.

As the aim of the analysis is to Identify the Knowledge/Solutions/KOs, that have high potential contributions to the Mission Objectives & Targets, this list of Mission Objectives and Targets may be the most important. It can be used as map and compass for analysis.

For analysis, it is furthermore important to

5. Understand the objectives and corresponding targets well, including the linked policies, law and regulations.
6. Be aware that the Objectives and Targets may be subject to changes by the European Commission. In order to have a valid assessment despite potential changes, the previous and following considerations need to be borne in mind.

4.1.5 Mission Lighthouse (LH) Initiatives

'Lighthouses (LH) pilot and lead on one of the Mission objectives […], guided by the principles of replicability and EU-wide scalability.

The lighthouses will thus provide access to the solutions, services and advice developed not only in their basin, but also to all interested actors from other basins and areas, so that the developed solutions can eventually be scaled up and replicated across the Union.' (See source)

The Mission will be implemented in two different phases: a 1st "development and piloting" phase (2021-2025), followed by a 2nd "deployment and upscaling" phase (2026-2030). PREP4BLUE's objective is to facilitate the successful implementation of Mission, particularly during its first piloting phase (2022-2025). The LHs will be the R&I component of the Mission, where transformative and innovative solutions will be tested, piloted and validated.

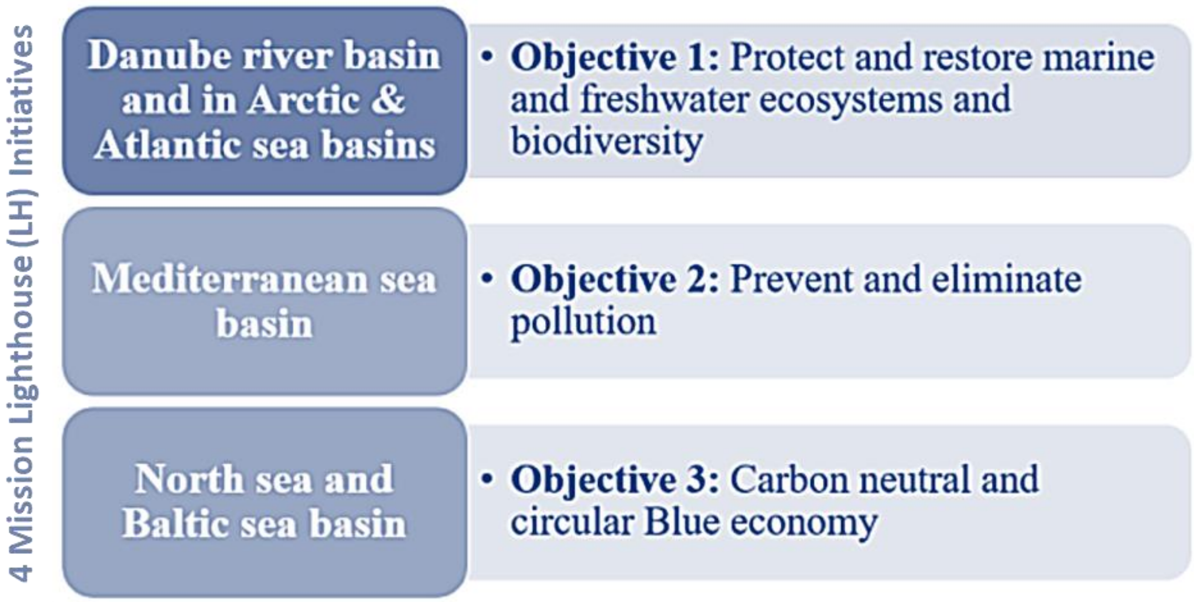


Figure 4. 4 Mission Lighthouse (LH) initiatives (Credit: Prep4Blue Consortium – Horizon Europe Grant Agreement n° 101056957)

For the analysis of the KOs, two main aspects are to be considered:

1. For the KER, custom knowledge transfer plans are developed to maximise change of uptake/application within the Mission Lighthouse (LH) Initiatives context. This means that a contribution to an objective in the allocated LH may be considered as aligned to the Mission.
2. The scope of the LH and the lead on specific objectives may be subject to changes by the European Commission. Therefore, the allocation of objectives per LH is no hard criterium. Also, a solution that was tested in one LH-area may have a potential application and impact in another LH area.

4.1.6 Delivering Impact

"Missions put emphasis on demonstrating, scaling up and replicating existing and new solutions including social innovations. This will ensure a tailor-made innovation approach including social innovation, in which solutions will be fully adapted to fit local circumstances. Furthermore, incremental changes will not be sufficient. These challenges require disruption, new ideas and risk-taking. Missions fully embrace out-of-the-box thinking by stimulating experimentation and bottom-up, multiple solutions to reach their objectives, also embracing education and training institutions for their key role in developing citizens' talents, knowledge and skills." (Source). The following figure shows a pathway to impacts for the Mission 'Restore our Ocean and Waters', the KOs should contribute to.

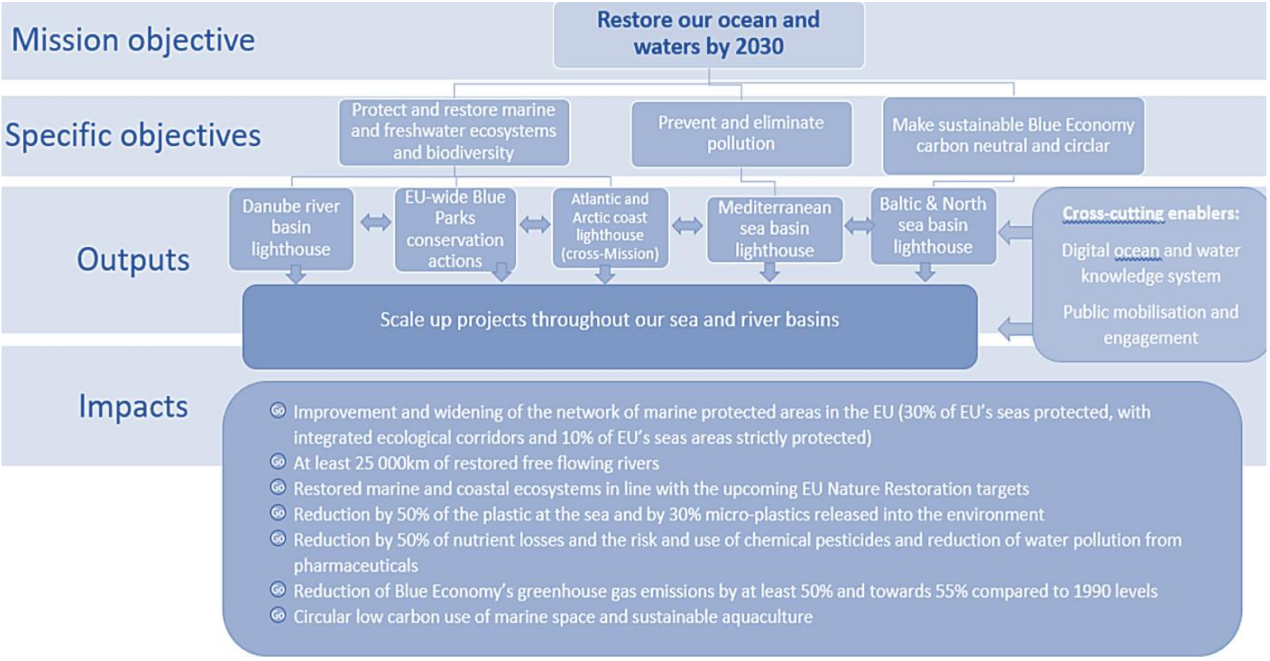


Figure 5. Mission Intervention Logic (credit: European Comission - European Mission Restore our Ocean and Waters Implementation plan, source: https://research-and-innovation.ec.europa.eu/document/download/d6162cbd-6d09-48fd-b5b4-d7d2be69972c_en?filename=ocean_and_waters_implementation_plan_final.pdf)

4.1.7 Sustainable Development Goals

The Mission shall support many Sustainable Development Goals (SDG). Restoring our ocean and waters will directly contribute to SDG 14 Life below water and SDG 6 Clean water and sanitation. Restoring our ocean and waters will interact and indirectly support most of the other SDGs.

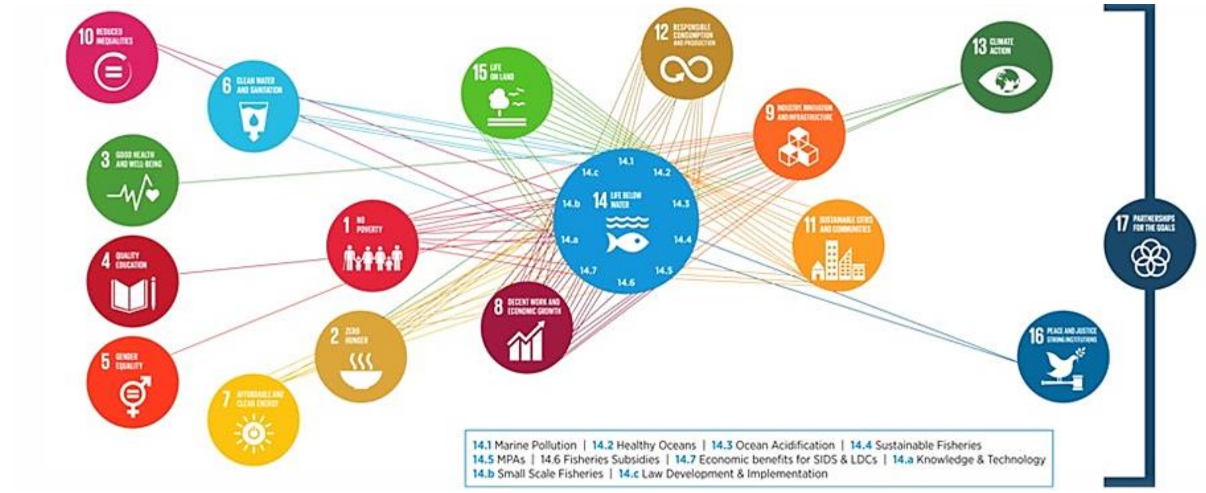


Figure 6: SDG 14 within the SDGs (Credit: Schmidt et al. 2017. "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" in International Council for Science, 2017. A Guide to SDG Interactions: from Science to Implementation. International Council for Science: Paris, Source: https://research-and-innovation.ec.europa.eu/document/download/d6162cbd-6d09-48fd-b5b4-d7d2be69972c_en?filename=ocean_and_waters_implementation_plan_final.pdf)

Amongst other, the hydrosphere plays a central role in the Earth and climate system, thus affecting climate action (SDG 13) and life on land (SDG 15). Healthy ecosystems provide food security (SDG 2) and sustain livelihoods (SDG 1). A decarbonised blue economy can provide affordable and clean ocean energy (SDG 7), foster circular and responsible production and consumption patterns (SDG 12), thus improving the sustainability of cities and communities (SDG 11) and providing decent work and economic growth (SDG 8). Moreover, the Mission will provide strong innovation (SDG 9) and quality education (SDG 4) and global partnership for sustainable development (SDG 17). (Source)

4.1.8 Readiness levels

Readiness Levels (RL) are indicators on the maturity of an actionable research finding.

In discussions among the Task 4.3 partners, it was suggested that for the purpose of PREP4BLUE Tasks 4.3 and 4.4, a RL of about 5-6 may be the most appropriate, as it may reach final RL until 2030 and needs advice on the further pathway towards this final RL. However, different knowledge has different time-frames. For example, a software may advance faster across the RL compared to industrial applications. Therefore, **RL are indicator, but no hard criterium** to evaluate "Application and Impact potential By 2030".

In the following, most common RL are presented for reference. This is a non-exhaustive listing.

- Technology Readiness Levels (TRL)
- Business Readiness Levels (BRL)
- Market Readiness Levels (MRL)
- Societal Readiness Levels (SRL)
- Impact Readiness Levels (IRL)

4.1.8.1 Technology Readiness Levels (TRL)

TRL 1 – basic principles observed

TRL 2 – technology concept formulated

TRL 3 – experimental proof of concept

TRL 4 – technology validated in lab

TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 7 – system prototype demonstration in operational environment

TRL 8 – system complete and qualified

TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Figure 7: Technology Readiness Levels (TRL) (Credit: https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en)

4.1.8.2 Business Readiness Levels (BRL)

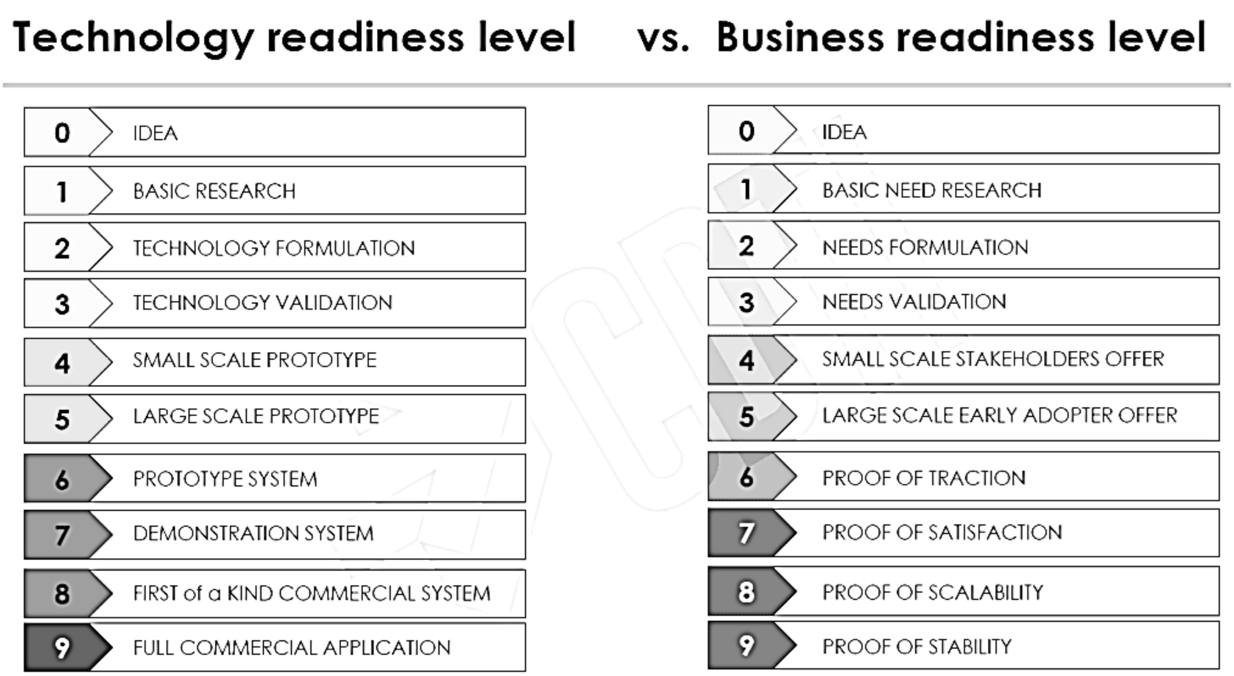


Figure 8: Business Readiness Levels (BRL) (Source: https://subvencionespublicas.com/pilar-3-horizon-europa/)

4.1.8.3 Market Readiness Levels (MRL)

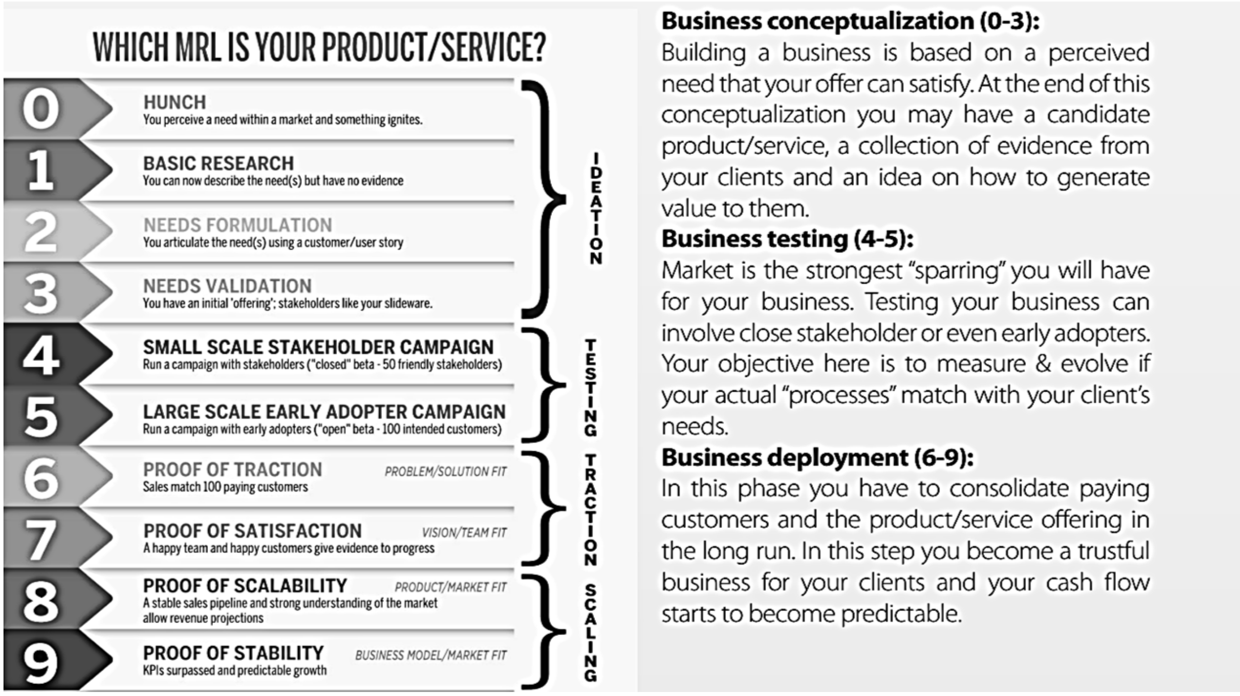


Figure 9: Market Readiness Levels (MRL) (Source: https://access2eic.eu/wp-content/uploads/2020/09/A2EIC-Toolbox-Guidelines)

4.1.8.4 Societal Readiness Levels (SRL)

TRL (Technology Readiness Level) TRL 1 (basic research) up to TRL 9 (sales and use by the customer).

There are many non-technological i.e. human factors which need to be considered before it can be said that an innovation can create impact.

SRL (Societal Readiness Level): level of knowledge about the stakeholders' interests and concerns as well as to what extent the product/service impacts on society (from the recognition up to the involvement of the stakeholders)

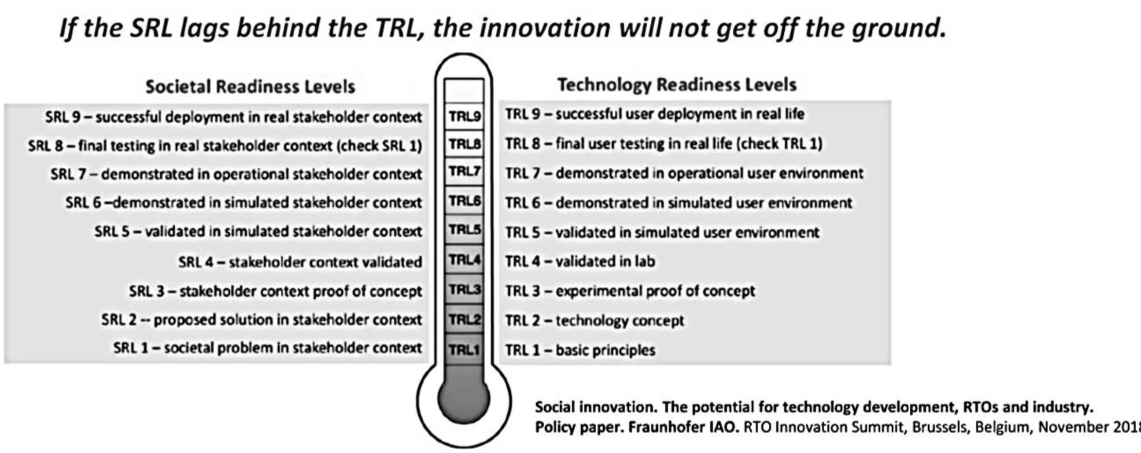


Figure 10: Societal Readiness Levels (SRL) (Source: https://www.doa.go.th/plprotect/wp-content/uploads/2020/08/4.9-Societal-Readiness-Levels-SRL-and-Techology-Readiness-Levels-TRL.pdf)

4.1.8.5 Impact Readiness Levels (IRL)

An alternative option is to use Impact Readiness Level (IRL) Model (see Table below). This was first conceived by the EU-funded DANDELION[9] Project in 2018 and has been adapted by ERINN Innovation to incorporate elements of the impact pathway model arising from the EU-funded RI-PATHS[10] project. The IRL Model below allows an assessment of how 'actionable' knowledge is in the societal and policy context.

Impact Readiness Levels explained				
IRL 1	SRL 1	TRL 1 TRL 2 TRL 3	Conception	• Generation and/or identification of new knowledge awaiting validation through experimentation or peer-review • Research concepts or proposals generated following identification of stakeholder knowledge and evidence needs • Research knowledge requiring further definition to allow evaluation of the potential value chain • Anticipated research outputs require further development to enable progress along the value chain
IRL 2	SRL2 SRL3	TRL 4	Discovery	• Mapping and analysis of the stakeholders' landscape in order to grasp the value chain of the envisioned research outputs • Definition of knowledge outputs and strategic planning of Knowledge Transfer activities in order to create value • Successful communication of research to key target audiences at a medium/late stage of the project • Research agenda and process are co-designed with the potential stakeholders
IRL 3	SRL4 SRL5 SRL6	TRL 5	Outcome: Engagement	• Organisation of and/or participation in multi-stakeholder events with a common agenda • Successful outreach and systematic, planned involvement of various media channels • Scientific knowledge circulates along various channels in a stakeholder sensitive language • Early systematic exploration with specific stakeholders about requirements, barriers, opportunities for potential application
IRL 4	SRL7 SRL8	TRL 6 TRL 7	Outcome: Implementation	• The basis for research application is established through an iterative co-creation process • Consolidation and validation of 'actionable' results of research by stakeholders in practice • First implementation efforts can be demonstrated as single one-off events in a concrete societal context of application • Societal and political stakeholders are engaged in research evaluation and support learning feedback loops for researchers
IRL 5	SRL9	TRL 8	Impact: Uptake	• Demonstrable uptake of research results and their advancement through policy influence and/or entering an enduring partnership with stakeholders • Sustainability of the multi-stakeholder process is planned for in previous stages and appears highly probable • Beneficial outcomes on target stakeholder groups are verifiable • Research leverages additional research funding and/or a change in the visibility and the positioning of the research organisation
IRL 6		TRL 9	Impact: Sustained Change	• Demonstrable scale-up and follow-ups both in regional and sectoral terms; emergence of spin-offs • The initiators/researchers are recognised as innovators and are consulted for advice for replication of good practices • Long term research contracts/further commissioned work with Departments/Agencies for sustained policy influence • The application of research in different contexts generates additional demand with funding organisations for further innovative research • Beneficial outcomes are measurable and introduce not merely a change in practice/policy but moreover a sustainable change in mindsets, culture and/or regulation

Figure 11: Impact Readiness Levels (IRL) (Credit: Adapted by ERINN Innovation through the EPA-IMPACT project funded by EPA Ireland, 2021-2023).

4.1.9 Uptake potential models

Uptake Potential is another indicator for Application and Impact potential.

Uptake potential models help making underlying assumptions explicit and may therefore be considered, to determine Application and Impact potential.

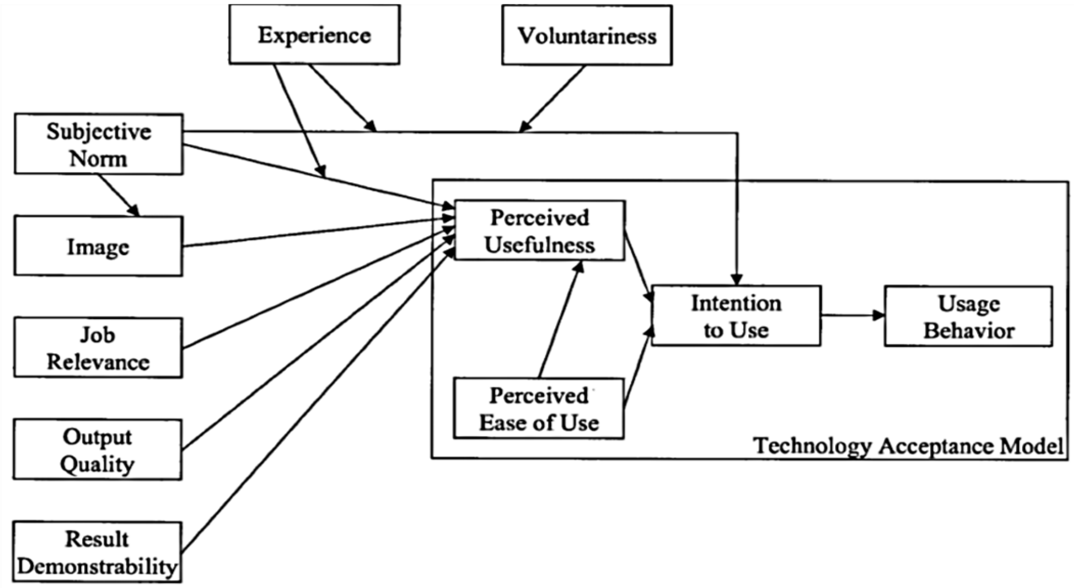
In the following, most common uptake Potential Models are presented for reference. This is a non-exhaustive listing.

- Technology Acceptance Model (TAM)
- Technology Adoption Curve (TAC)
- COM-B
- Behaviour Change Wheel

[9] *DANDELION – Promoting EU funded projects of inclusive, innovative and reflective societies, see http://www.dandelion-europe.eu/en/, see also http://www.dandelion-europe.eu/imagem/IIRS_sensitive_Valorisation_Concept.pdf.*

[10] *RI PATHS – Research Infrastructures' Impact Assessment Toolkit, Griniece, E., et.al., RI-PATHS, https://doi.org/10.5281/zenodo.3950043)*

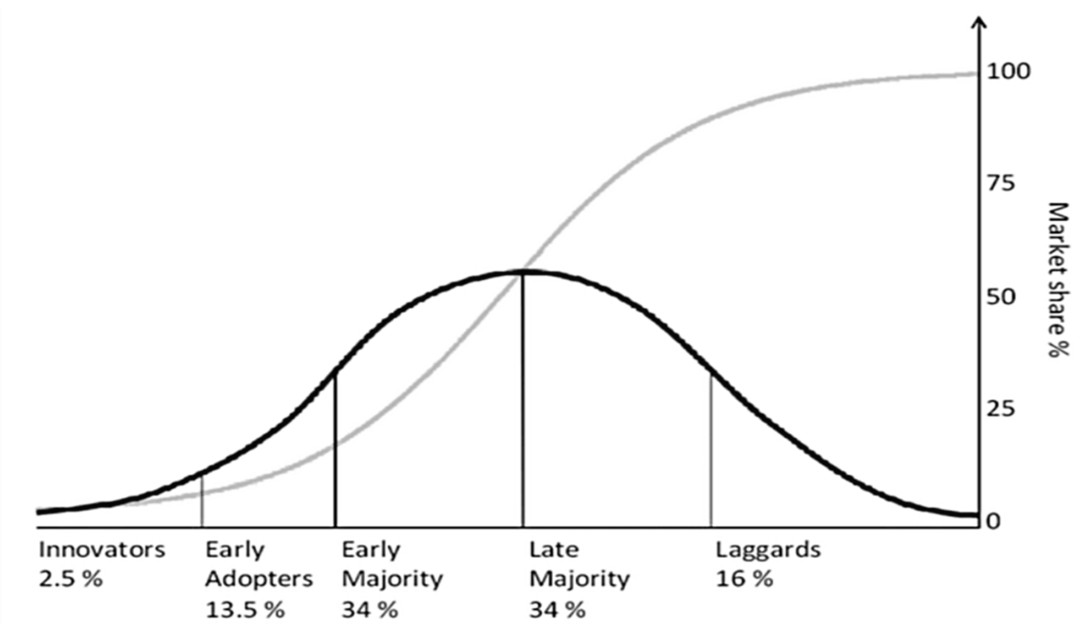
4.1.9.1 Technology Acceptance Model (TAM)



Technology Acceptance Model 2 (Venkatesh and Davis 2000: 188) Figure 1 shows the TAM2 and the proposed directional effects of components on other components, including the original TAM. Although comprehensive, this model is limited by its supporting methodology, relationships implied and theoretical foundation (Chuttur 2009).

Figure 12: Technology Acceptance Model (TAM) (Source: ttps://www.researchgate.net/publication/325195832_Avoidance_Attitudes_towards_Virtual_Assistants)

4.1.9.2 Technology Adoption Curve (TAC)



Technology Adoption Bell-Curve (Rogers 2003)

Figure 13: Technology Adoption Curve (TAC)(Source: https://www.researchgate.net/publication/325195832_Avoidance_Attitudes_towards_Virtual_Assistants

4.1.10 COM-B

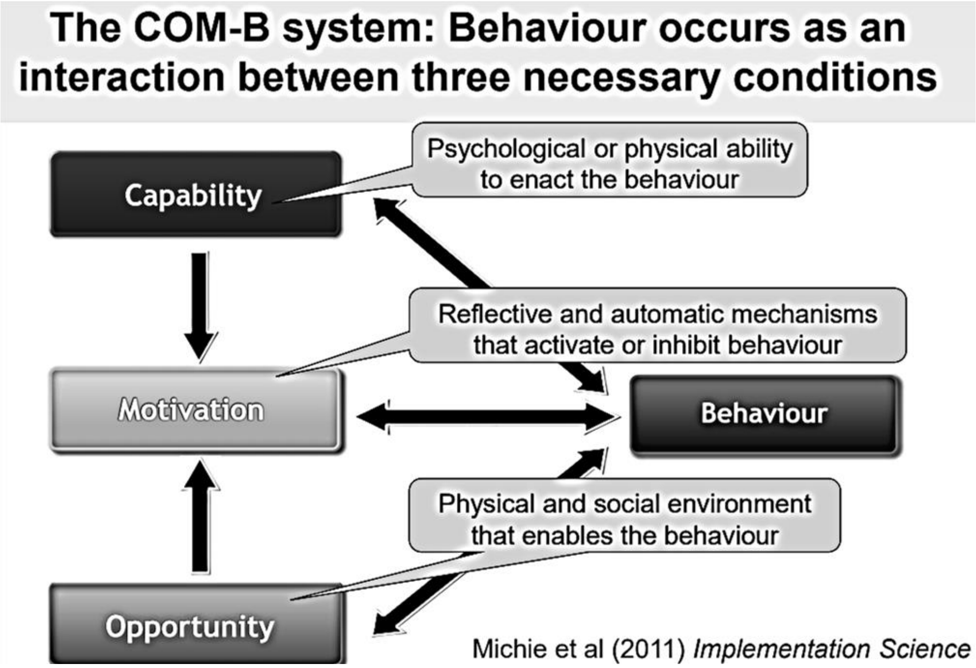


Figure 14: COM-B (Source: https://ktcanada.org/wp-content/uploads/2016/03/Susan-Michie-slides_nov_12_2015.pdf)

4.1.11 Behaviour Change Wheel

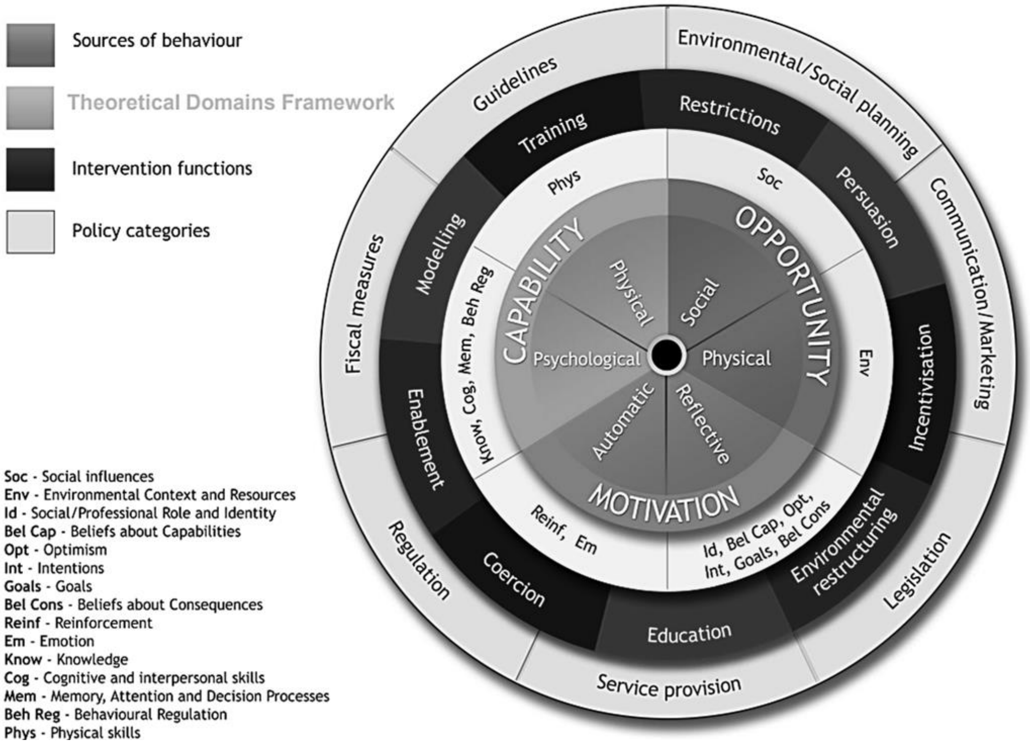


Figure 15: Behaviour Change Wheel (Source: https://ktcanada.org/wp-content/uploads/2016/03/Susan-Michie-slides_nov_12_2015.pdf)

4.2 ANNEX 2: Key Exploitable Results

4.2.1 Validated KERs

Note: two KER had to be removed from this list for this public deliverable due to delays in publishing by the KO-owners

Table of Contents

Knowledge Output Reference Number: 858805 – KOa
Knowledge Output Title: Efficient, modular, multistage sequential wastewater treatment system
Project Link: https://cordis.europa.eu/project/id/858805

Knowledge Output Description:

Background

Wastewater treatment converts wastewater into a useful effluent that is safe and can be returned to the water-cycle for reuse. Through treatment, the concentration of pollutants needs to be reduced but that often comes at a high cost and involves an energy-intensive process. For example, the agro-food industrial sector is required to treat large volumes of wastewater (20,000 l /product kg) rich in organic matter content (30 kg Chemical Oxygen Demand – COD – per m3 wastewater). Anaerobic digesters treat high COD wastewater and produce biogas, which can be used as a renewable energy source. Nevertheless, even the most advanced high-rate treatment systems present important technical and economic hurdles: 1) Post-treatment (usually aerobic) is still required for wastewater discharge on surface water (COD elimination rates are in the range of 60-80% for current technologies), 2) Digester investment costs are high (€300,000 for the smallest reactors), 3) The efficiency of biogas production is low (35-50%). The regulatory framework varies on a territorial basis. In case of effluent discharging on the sewage system, regional/local legal requirements must be considered. On the other hand, if the effluent is directly discharged on surface waters, it should be considered the transposition of the Directive 91/271/CEE on each country. The above confirms that the industry is demanding low-price digesters and high efficiency biogas production solutions that will increase COD elimination rates.

Technical description

Ingeobras and Proycon, a project partner involved in this development, have developed ANAERGY, a Multiphase Sequential Anaerobic Digester, being the first demonstrated solution **able to combine anaerobic, aerobic and photocatalysis processes in one digester**. This multi-system wastewater purifier is composed by:

- Homogenisation tank (2 m^3) to maintain the water entering the biological treatment stable since biological processes are sensitive to drastic modifications in water parameters (e.g., pH, conductivity, nutrient concentration, pollutant concentration, solid concentration, etc.).

- Prefiltration system: The test bench has its own complete pre-treatment system with its own rake bar with its own screw for compacting the solids for working inside the real industry. It includes a bypass in case it is not necessary to use it.

- Post-filtration system: After rake bar and considering biofiltration requirements (low concentration of solids), the ANAERGY test bench includes a specific filtration system filled with a specific high-porosity material. It includes a bypass in case it is not necessary to use it.

- Sludge treatment system: this enables to dewater the sludge and recover all the drained water from the sludge. One of the technology's advantages is that it generates less sludge than other systems.

- Biofiltration: Two biofilters capable of working together (one after the other) or as a single biofilter using only one of them by only using the automation system touch screen (for cases in which the end-user already has a biofiltering system but needs to improve the end product as environmental laws are stricter). Both biofilters are fixed-bed technology and with the capacity for working in aerobic or anaerobic conditions. Biofilters are designed considering a hydraulic retention time of around 30 hours in anaerobic conditions and from 2 to 10 hours in aerobic conditions.

ANAERGY provides to users (currently, in a first step small municipalities and livestock farms) a tailor-made and plugin system as an innovative solution for treating wastewater. The most innovative aspects of ANAERGY are related to:

- SIZE: The reduced size of the system (~75%) makes it unique and makes it highly adaptable to small industries' premises and/or for small villages.
- MODULAR COMBINATION: it is a modular solution and the only one in the market to combine anaerobic, aerobic and photocatalysis processes in one digester.
- CUSTOMIZABLE: is a 100% customisable technology as it can integrate different wastewater treatments (see the point above) into the same optimized design (size and modularity), based on several types of customers' (i.e. winery or fruit juice industries, as examples) needs (i.e. adaptive treatment of different wastewater composition).
- EFFICIENCY: The system is capable to reduce up to 80-90% COD in sludge from the industry.

The benefits that ANAERGY can provide to users include:

- REGULATORY COMPLIANCE: It will allow the users to compile with current regulatory directives in the treatment of wastewaters, avoiding misconducting behaviours that may lead to fees and fines and, ultimately, jeopardizing environmental health.
- ADAPTABILITY: The system is also capable to filter low flow/small volumes (from 45 to 450 litres per hour), but its adaptability and modularity allow to reach large flows (900 litres/per hour) using the two pumps available. A high flow range means very different hydraulic retention time inside biofilters and very different water speed inside pipes.
- TWO-WAY REMOTECONTROL: ANAERGY is a fully digitalised and automated technology, allowing for its online remote control by both the end-user and the engineering company (Ingeobras) enhancing trust between the customer and the service provider while allows Ingeobras the remote monitoring and operation of the system.
- EASY-INSTALLATION: The installation is user-friendly and supervised by the technical team of ANAERGY who perform daily water samples analyses to monitor (COD reduction, total and volatile solids, conductivity, alkalinity, and nutrient consumption- i.e., nitrates, nitrites and phosphates) the commissioning process and results, to ensure its optimal performance.
- REDUCES OPEX AND CAPEX: the system optimizes capital expenditures by reducing up to 50% installation, acquisition and assembly costs. Also, the residence time is shorter, going from days to hours, so the size is smaller and therefore the investment is lower (OPEX ~0.10€ m^{-3}). In addition, the smaller size maintains the operating temperature and avoids heat losses, reducing the energy demand and thus, saving operational costs.

Potential Impacts and Applications

The system is clearly linked to the Mission Objective (MO) 2 as it reduces in 90% the chemical pollution derived from target industries to the aquatic environment as the water outflow can be directly discharged in the environment. There is also a possible link it to the target "Reduce by at least 50% nutrient losses, the use and risk of chemical pesticides" In this context, regulatory bodies can be identified as potential stakeholders as supporters of stronger regulations not possible to implement without the ANAERGY system. It has been tested in both wineries and fruit-juice industries with excellent results. The technology is commercialized as BIOBOX (R) Organic Matter, and it is currently at TRL9. The system currently targets (small- to mid-size) farm industries with high concentration of organic products. It produces N_2, CO_2, and biogas (which can be further used for generating electricity). The further development to higher TRLs was paused in 2022 as the methane market for electricity production is still not well developed in Spain (main target country due to business placement). This system can also target other agri-food industries and paper industries.

In addition, the company has developed different solutions to combine with the ANAERGY technology following the modularity of the system. The most advanced technology (at TRL9) is PUREMUST (R) for the elimination of NO_3^- with a N_2 as by-product (licence number P 201830763), which can be directly released to the environment. They are also combining the ANAERGY technology with BIOH2 technology (currently TRL 4) capable to transform the organic matter from ANAERGY into H_2, which can then be used for energy production.

Knowledge Output Reference Number: 789391 – KOa

Knowledge Output Title: Marine litter inventory for knowledge sharing across aquaculture stakeholders in the North Sea, Baltic Sea and the Mediterranean.

Project Link: https://aqua-lit.eu/

Knowledge Output Description:

Background

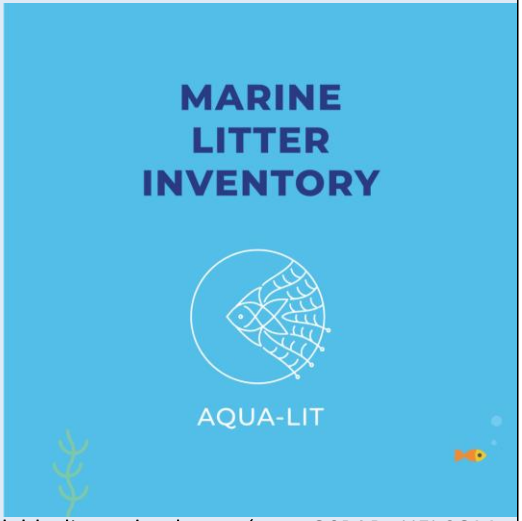
There are no global estimates of the amount of plastic waste generated by aquaculture and fisheries activities.[11] However, aquaculture is expected to be the sector that will meet future demand for food, which is expected to grow nearly 40% by 2030.[12]

In this regard, there is a gap and consequently a need to discuss and identify current barriers on marine littering from the aquaculture sector considering three different perspectives:

1. Prevention & Reduction

2. Monitoring & Quantification

3. Removal & Recycling[13]



Therefore, AQUA-LIT stemmed from two main factors: the dramatic and rapid increase of marine litter in the ocean and the boosting of the aquaculture sector, both in the EU and globally.

Technical description

In the framework of this preliminary research, there was a compilation of available knowledge on marine litter originating from the aquaculture sector and registered in the coastal ecosystems of the North Sea, the Mediterranean and the Baltic region.

The marine litter inventory is an interactive tool produced on the basis of a comprehensive literature review and the available litter databases (e.g., OSPAR, HELCOM, Marine Litter Watch) and can be complemented by practitioners and other stakeholders, like aquaculture farmers.

Together with **a toolbox** (KOb) and set of **practical solutions** (KOc), the catalogue enables increased public awareness, more informed knowledge and actions to ensure that the expected growth of aquaculture does not lead to an increase in marine litter in the ocean.

In particular, this inventory consists of quantitative and visual content of an informative and educational nature, coupled with the identification of suggested actions for the sound management of aquaculture waste.

It is an open access resource listing the quantities, types and sources of marine litter generated by aquaculture as well as fisheries at global, regional and EU level. It contains action plans and documents related to marine litter, in order to better understand the gaps in these policy tools. It also includes regional maps linking landfills to nearby aquaculture facilities.

The absence of a systematic and interactive platform for sharing knowledge between practitioners and other stakeholders across Europe, makes AQUA-LIT inventory a pioneering platform. By showing the crossovers between different "blue sector" activities and identifying the gaps where further efforts are needed in terms of actions and research, the inventory appears as a unique tool.

Potential Impacts and Applications

In fact, the inventory has been presented at conferences and shared within the AQUA-LIT community, reaching over 750 unique visitors of the inventory since its launch.

The inventory has a multitude of applications, including further target users and impact channels, beyond the complementary toolbox. Moreover, the inventory can serve as a basis for the Policy Report, KOc).

It therefore contributes to meeting the specific objective of the EU Mission "Restore our Oceans and Waters: prevent and eliminate pollution," by providing informed and detailed knowledge on how aquaculture activities have an impact on marine pollution.

The inventory can be accessed on the AQUA-LIT website, where the end-user can browse the marine litter data by typology, geographical location, sea basins, and also view the data table online. There's also the option to download the inventory for higher visibility.

Moreover, it has been included in international reports, such as:

- Best Practice Framework for the Management of Aquaculture Gear (Global Ghost Gear Initiative)
- European Report on Marine Litter

Knowledge Output Reference Number: 789391 – KOb
Knowledge Output Title: Toolbox of solutions and measures for the good management of marine litter in aquaculture
Project Link: https://aqua-lit.eu/
Knowledge Output Description: **Background** There are no global estimates of the amount of plastic waste generated by aquaculture and fisheries activities.[14] However, aquaculture is expected to be the sector that will meet future demand for food, which is expected to grow nearly 40% by 2030.[15] In this regard, there is a gap and consequently a need to discuss and identify current barriers on marine littering from the aquaculture sector considering three different perspectives: 1. Prevention & Reduction 2. Monitoring & Quantification 3. Removal & Recycling[16] **Technical description** AQUA-LIT stemmed from two main factors: the dramatic and rapid increase of marine litter in the ocean due to aquaculture activities and the boosting of the aquaculture sector, both in the EU and globally. Under this concern, the Marine Litter Toolbox was created **showcasing measures to prevent, monitor, remove and recycle marine litter from the aquaculture and fisheries sectors**. This online platform targets the aquaculture sector to assist the industry to develop in a more sustainable way, by providing a platform and a toolbox for addressing the consequences of its activities on the oceans. It also **maps port reception facilities for marine litter in Europe, as well as funding, grant and investor opportunities available to aquaculture stakeholders at EU, national and trans-regional level.** It also features

[11] Lusher, Amy & hollman, peter & Mendoza, Jeremy. (2017*). Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety*.
[12] FAO. 2022. The State of World Fisheries and Aquaculture 2022. *Towards Blue Transformation.* Rome, FAO. https://doi.org/10.4060/cc0461en
[13] AQUA-LIT Website, https://aqua-lit.eu/
[14] Lusher, Amy & hollman, peter & Mendoza, Jeremy. (2017*). Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety*.
[15] FAO. 2022. The State of World Fisheries and Aquaculture 2022. *Towards Blue Transformation.* Rome, FAO. https://doi.org/10.4060/cc0461en
[16] AQUA-LIT Website, https://aqua-lit.eu/

an open space for stakeholders to submit inputs on solutions for marine litter management. In addition, a simplified version of the Toolbox has been created in the form of a mobile app, allowing citizens to access information conveniently and directly about marine litter on the field.

While this toolbox is intended to channel the inventory developed (Koa) , it is also designed to facilitate the transition of the aquaculture sector towards growing in a way that does not lead to an increase in marine litter in the ocean.

Therefore, this open access resources includes not only a marine litter inventory, but also graphical and factual material on measures and solutions, together with action plans and policy recommendations aimed at supporting a sound management of aquaculture waste.

So far, the absence of an online interactive tool for sharing knowledge between practitioners and stakeholders from different “blue sector” activities across Europe, makes this knowledge output a pioneering toolbox.

All these findings are also the result of a community-based process supporting Citizen Science, with a space in the toolbox inviting the participation of the public through resources, and testing the transferability of these solutions in other contexts.

Potential Impacts and Applications

In fact, the Toolbox has been presented at conferences and shared within the AQUA-LIT community, reaching a number of 77 users of the platform since its launch.

The Toolbox has great potential to be used in workshops and capacity-building activities to train aquaculture stakeholders to manage waste generated by their activities, with the aim of preventing and eliminating ocean pollution, in line with the EU Mission "Restore our Oceans and Waters" objective of cutting pollution and supporting a sustainable blue economy

The Toolbox is available online (https://aqua-lit.eu/toolbox) and through a mobile app, where practitioners can browse marine litter data.

Moreover, it has been included in international reports, such as:

- Best Practice Framework for the Management of Aquaculture Gear (Global Ghost Gear Initiative)
- European Report on Marine Litter
- Portfolio analysis, EU mission “Restore our Ocean and Waters by 2030

Knowledge Output Reference Number: 789391 – KOc
Knowledge Output Title: Action plan and policy recommendations on existing and innovation solutions to prevent, eliminate and recycle marine litter in the ocean
Project Link: https://aqua-lit.eu/

Knowledge Output Description:

Background

There are no global estimates of the amount of plastic waste generated by aquaculture and fisheries activities.[17] However, aquaculture is expected to be the sector that will meet future demand for food, which is expected to grow nearly 40% by 2030.[18]

In this regard, there is a gap and consequently a need to discuss and identify current barriers on marine littering from the aquaculture sector considering three different perspectives:

1. Prevention & Reduction

2. Monitoring & Quantification

3. Removal & Recycling[19]

Following the new EU Strategy for Plastics in a Circular Economy, with aquaculture activities growing at 8% per year, it is crucial to:

1. To develop a comprehensive strategy for monitoring and quantifying the impact of aquaculture activities (separate from fishing activities) on the ocean.
2. To provide effective prevention measures to avoid litter reaching the ocean as a result of this booming industry.
3. To offer solutions for minimising existing marine litter, including pilot testing of available techniques for aquaculture facilities.
4. To propose recycling solutions supporting a more circular economy.
5. To identify policies to assist the implementation of these actions.

Technical description

AQUA-LIT stemmed from two main factors: the dramatic and rapid increase of marine litter in the ocean and the boosting of the aquaculture sector, both in the EU and globally.

Based on the inventory (KOa), a comprehensive analysis on marine litter from aquaculture and fishing activities was carried out with two main objectives. Firstly, to identify the shortcomings of these policy tools. Secondly, to check the transferability of the proposed solutions to other contexts.

In particular, constraints and solutions for marine litter management were identified through Learning Labs with stakeholders in the aquaculture production chain (more than 400 potential solutions and measures, filtered by phase, measure, sea basin and type of aquaculture). The outcome of these activities is summarised and collected in two different formats:

a) A brief factsheet with existing good practices on marine litter management

b) A detailed report with policy recommendations from a forward-looking perspective on what else can be done.

In-depth brief reports were produced to assist the "blue sector" in improving marine litter management, through existing best practices and a vision for the future that identifies current barriers to marine litter management.

These reports offer in total more than 400 potential measures on (1) how to prevent marine litter from aquaculture activities, (2) how to have better monitoring systems in place, and (3) how to remove and recycle waste from aquaculture facilities before and after it reaches the sea.

All these findings are the result of the group consultations from aquaculture stakeholders, coming from all stages of the fish and crustacean aquaculture life cycle (fish farmers, equipment manufacturers, academic researchers, NGO representatives) in the Mediterranean, the Baltic Sea and the North Sea regions.

The absence of an action plan for managing marine litter arising from "blue sector" activities, together with the lack of research regarding gaps in the governance of marine litter, makes this knowledge output a pioneering tool for supporting policy-making in this subject.

Potential Impacts and Applications

These measures are expected to assist all stakeholders involved in the aquaculture chain to improve their understanding, awareness and availability of solutions for a sustainable transformation of the aquaculture sector towards a cleaner industry.

By assessing existing policies and recommendations for better decision-making in the aquaculture sector, AQUA-LIT outputs contribute to reversing the degradation of Europe's oceans and waters, interrelated drivers of hydrosphere exploitation, such as pollution and climate change, and addressing knowledge gaps and lack of citizen engagement. By doing so, the process of restoring our oceans and waters is accelerated.

In fact, the Action Plan and policy recommendations have been included in the AQUA-LIT Marine Litter Toolbox, which has been presented at conferences and shared within the AQUA-LIT community, reaching a number of 77 users of the platform since its launch.

Knowledge Output Reference Number: 863693 – KOa
Knowledge Output Title: 'Xplotector' - Highly sensitive, automated, portable in-situ chemical and organic compound identification and analysis system.
Project link: https://www.explotect.eu/
Knowledge Output Description: **Background** Both offshore resource development and environmental protection are challenged by the presence of Unexploded Ordnance (UXO) and relic munitions on the seafloor. The problematic UXOs bring is two-fold: 1. Explosion and security risk for off-shore infrastructure installations and maintenance; 2. Munitions contain cytotoxic, genotoxic, and carcinogenic chemicals associated with conventional explosives, chemical warfare agents, and munition structural components, which are released to the ocean/water of location, when munition is damaged, e.g., through corrosion.

[17] Lusher, Amy & hollman, peter & Mendoza, Jeremy. (2017*). Microplastics in fisheries and aquaculture: Status of knowledge on their occurrence and implications for aquatic organisms and food safety*.
[18] FAO. 2022. The State of World Fisheries and Aquaculture 2022. *Towards Blue Transformation.* Rome, FAO. https://doi.org/10.4060/cc0461en
[19] AQUA-LIT Website, https://aqua-lit.eu/

As the European coasts, and specifically the Baltic-, North- and Adriatic seas are heavily UXO loaded (e.g., due to the World Wars and dump-sites of munition after the wars), all installation of infrastructure on/anchored to the sea-bed needs UXO detection and clearance.
Direct sensing of explosive chemicals provides an unequivocal signature for objects requiring clearance and chemical contamination release from munitions. Real-time chemical munition identification at sea was not yet possible as existing methods cannot detect multiple compounds simultaneously and are subject to interferences from non-target compounds.

Technical description
The "Xplotector" is a full shipboard automated analytical system (TRL7), capable of water sample processing and dissolved explosives analysis, composed primarily of off-the-shelf components including
- robust online Solid Phase Extraction (SPE) system
- reliable High-Performance Liquid Chromatography (HPLC) compound separation
- Mass spectrometric detection.

The Xplotector is a standalone unit for automated analysis of dissolved organic chemicals in seawater.
The Xplotector final unit weighs approximately 60 kg and is designed for mounting in a standard 19" electronic rack mount. Practically, the unit is installed in a ruggedized case for deployment on ships. The mass spectrometer is supplied with nitrogen from a generator installed in a separate 19" rack mount case.
Until today, UXO detection is largely based on manual processing and visual interpretation of underwater datasets (side scan sonar, magnetic etc.) and divers. However, these are limited in terms of visibility, range, depth and time spent under water. The Xplotector automated system for monitoring and measuring chemicals in seawater was tested in operational environments (TRL 7) and goes beyond the State of the Art (SoA) in terms of sensitivity, speed and portability:
SENSITIVITY: A unique fluidic system gives the system unprecedented sensitivity for dissolved explosives (e.g., 2 ng TNT). ExPloTect partner KUM developed and manufactured an upgraded compact HPLC column heater that was mounted immediately before the inlet to the mass spectrometer and integrated with the Xplotector software. The heater maintains the column temperature within 0.01°C of the target temperature, which is critical to achieve reproducible chromatography. Although external and internal standards provide good quality control, stable HPLC chromatograms are key for reliable system performance. The HPLC was upgraded to enable separation of natural organic matter from the compound of interest. This is a unique and indispensable capacity to gain the needed sensitivity for the first underwater real-time chemical and organic compound extraction for in-situ analysis.
SPEED: The system reduces the sampling and analysis time from several months of very intense laboratory work to now being able to do it on a ship in minutes (providing data points approximately every 10 min.), due to the possibility of in-situ sampling and analysis. The data-processing time is no bottle neck, as chromatograms are automatically processed to provide quantitative concentrations immediately after analysis. The data needs integration and calibration at ca. few kilobytes per sample which is not processing intensive, but effective.
PORTABILITY: The system is compact and portable, and can be easily loaded into an inspection vessel, with limited installation needed. Current systems are static, placed on a specific site. Due to this characteristic the ExPloTect System is unique and apt to early response, ready to use everywhere in Europe in terms of hours (as it fits into an airplane in case of urgent need).
With the highly sensitive, automated, portable in-situ organic chemical detection and analysis system, this process is less expensive (costs are reduced to ¼ compared to current SoA manual UXO detection), can work around the clock, at high frequency (providing data points every ~10 min.) and reliability.

Potential impacts and applications

The Xplotector was originally developed to identify and quantify dissolved chemicals released from explosives contained in UXO (TNT, RDX, DNB, and ADNT). However, applications beyond these compounds are equally possible and found as more promising in terms of take-up and impact.
As outlined above, chemical release identification and analysis is important for munition clearance, to avoid the release of chemicals into the ocean and waters. Especially the Baltic- and North-sea, but nearly all EU

coastal areas, are heavily loaded with munition and munition dumpsites from the World Wars. Previous installation of any infrastructure, such as offshore renewable-energy-plants, aquaculture, pipelines, etc. munition clearance needs to be undertaken.
With its unique sensitivity, speed and portability, the Xplotector effectively facilitates installation of carbon neutral and circular blue economy infrastructure at sea; thus, contributing to the Mission Objective 3. Particularly, ExPloTect can contribute to low-impact aquaculture, detecting and monitoring pollution levels, potentially including fertilizers, pharmaceuticals, and pesticides. This is of clear need e.g. in kelp-forest management. In direct connection to this, the ExPloTect solutions contribute to the Mission Objective 1 and 2 as, (1) to protect and restore marine and freshwater ecosystems and biodiversity, pollution sources (UXO or any other (potential) source such as litter, transport vessels, industries releasing wastewater etc.) need to be detected and monitored; (2) to prevent and eliminate pollution of our ocean, seas and waters, detection and monitoring is key. ExPloTect can contribute especially to detection and monitoring of organic chemicals such as pesticides. This includes possible application in regulation enforcement (e.g. if industries release more chemicals to the waterbodies than allowed by regulations).

Stakeholder events such as workshops were held, in collaboration with BASTA, a sister project to ExPloTect.

The BASTA project focusses on the geophysical side of UXO detection, whereas ExPloTect on the chemical.

The BASTA project developed tools to find munitions. Therefore, the projects complement each other greatly and synergies have been used: joint cruises were undertaken where BASTA mapped the distribution of litter on the sea floor and ExPloTect mapped thereafter the chemical distribution in relation to the presence of the underwater munitions. In addition to the technical development, the ExPloTect project also had the objective to evaluate the usefulness of the technology for commercial UXO survey and clearance activities. Project partner RPS Explosives Engineering Services (UK) brought the technical expertise to conduct this evaluation.

Liaisons with different target users was effectively undertaken, to learn about different user needs:
- Collaboration with a company that developed a sea floor munition collection crawler system is taking place in spring 2023, using the XploTaker, a prototype underwater sample collection device that interfaces directly with the Xplotector.
- After munition detonation tests by the German military, the ExPloTect system was used for detection of residual explosives directly after detonation and the German military representatives showed high interest in future collaborations.
- NGOs have confirmed interest in the ExPloTect system for environmental monitoring, contamination monitoring and source detection, as the Xplotector may be useful to monitor industrial pollutant discharge.
- In collaboration with research institutes, the Xplotector can be useful for any kind of chemical and organic compound analysis where highest sensitivity and fast analysis is required. Interest was shown for chemical contaminant monitoring and mapping, identification of plankton metabolites, and toxicology.
- For aquaculture farmers, such sensitive analysis is of use in multiple ways: monitoring for low-input, the natural nutritional values at the site, contamination from own activities, as well as from other sources.
- Governmental organizations need to identify contamination and its sources to prevent, mitigate and recollect, as well as to prioritize clean-ups. In the ExPloTect project it was found that the munition from the World Wars is a special source of contamination, and the source can be effectively eliminated by removing the munitions. However other sources (such as from wastewaters) can include much more harmful/toxic chemicals for human and biodiversity. Measuring, analysis and monitoring these levels can help prioritization of remediation targets for evidence-based decision making.

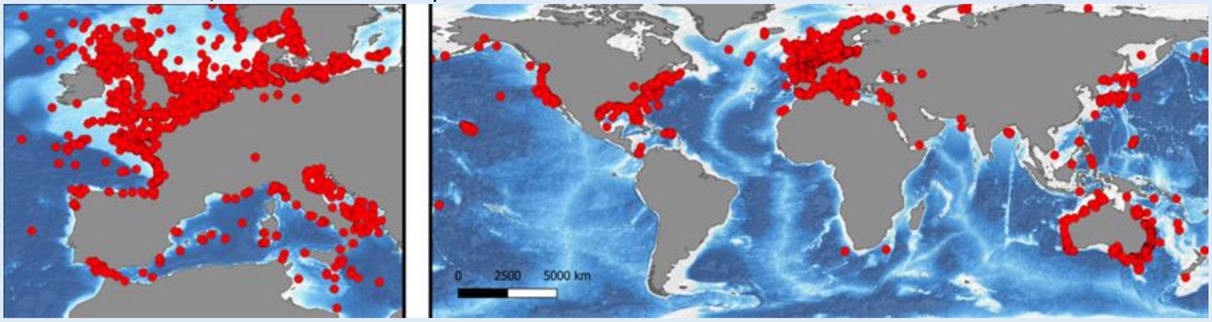
The non-munition applications were not the focus of the ExPloTect project, but towards the end of the project, these were found to have more potential for uptake and impact.

Knowledge Output Reference Number: 863693 – KOb
Knowledge Output Title: 'XploTaker' – underwater real-time chemical and organic sample collection for in-situ analysis
Project link: https://www.explotect.eu/

Knowledge Output Description:

Background

Particularly in the North and Baltic Seas, the Mission Objective 3 shall be tackled towards a carbon neutral and circular blue economy. Therefore, infrastructure for e.g., renewable energy production often needs to be placed or anchored on the seafloor. Currently, each of the aimed sites in this Mission Lighthouse area needs to be screened for Unexploded Ordnance (UXO) or other relic munitions. The need for munition detection is very high in the Baltic and North Seas, as UXO from the World Wars, such as large-scale disposal of the leftover ammunition material led to highly impacted areas. German parts of the North Sea and Baltic Sea alone contain some 1.6 million metric tons of munitions. However, across many European and global coasts span wide UXO contaminated sites, as shown in the maps below:



In addition to the explosion and security risks, conventional munitions contain and release (in case of damage, e.g. through corrosion) cytotoxic, genotoxic, and carcinogenic chemicals. There is a critical need to clear undersea munitions due to the hazards associated with accidental detonation and leakage of toxic chemicals. The UXO-released pollution is certainly an unusual point source because munition dumpsites act as a continuous point source of this contamination, compared to one-time events e.g., due to shipment accidents.

Technical description

The XploTaker collection system is an underwater solid phase extraction unit designed to interface with the shipboard Xplotector analysis system. The XPloTaker incorporates aspects of a fluidics module, with a large HPLC pump to pump water samples through an inline T-filter to a battery of 10 SPE columns that are accessed sequentially via two switching valves. Thus, up to 10 samples can be collected during a single deployment. The fluidic connections allow column backflushing with ultrapure water before analysis and direct connection to the Xplotector without opening the pressure housing. The controlling software allows automatic pre-cleaning and analysis of the collected samples. All components are protected within a watertight pressure housing rated to 10 bar (100 m depth).

The XploTaker was tested during multiple field campaigns since spring 2021 (TRL7). It was designed to sample near underwater targets during at-sea activities, e.g., during commercial UXO, or any other source of pollution, clearance. During testing in the ExPloTect project, it was deployed as a standalone unit, or mounted on a CTD-Niskin rosette. In the latter case, this allowed discrete water samples to be collected and simultaneously preconcentrated. The unit is designed to collect sequential samples by cycling power on and off. Upon retrieval, a communication cable from the unit is connected and two fluidic ports attached to the Xplotector switching valve at the position of the sample SPE column. Samples are then automatically transferred to the second, analytical SPE column, and processed exactly as for normal samples. The sample size depends on the target chemical. Explosive compound analysis typically requires 500 ml of seawater.

Depending on the filter back pressure, the system runs at ca. 100 to 200 bar. This type of pressure management was a development challenge because it exceeds the capability of most pump types. The final prototype relies on a prep-scale HPLC pump capable of achieving high flow rates at high pressure. This system is deployed from a vessel into the water. It is specialized for located, specific sea-water analysis at highest sensitivity (e.g., 2 ng TNT) and can for the first-time extract and analyse dissolved explosives at sea and in near real-time. This enables to develop close to real time maps of contamination with both manned vessels or AUVs.

The collection and analysis systems are composed primarily of off-the-shelf technologies, which are combined uniquely (which is subject to protected IP). The advantage is that this makes the system relatively easy to upgrade as technology advances. ExPloTect aimed at munition detection automation. However, it was found that the ExPloTect solutions can likely be used for other types of chemical analysis, including halogenated organic compounds, pesticides, pharmaceuticals, and aromatic and polyaromatic hydrocarbons. Adaptation to other compounds is estimated to require 2-6 month to increase the target list substantially.

Potential Impacts and Applications

The original objective of the ExPloTect project was to try and follow chemical traces to find munitions. However, if UXO are completely intact and no chemicals released, then the ExPloTect solution is not able to trace it. Therefore, the continuous sampling of seawater for that purpose did not meet the needs for UXO clearance companies. However, the ExPloTect partner RPS Explosives Engineering Services (UK) keeps collaborating with GEOMAR to explore further how the solution can meet the needs of UXO clearance companies. Target users could be public authorities or NGOs. Moreover, it was found as highlight relevant for the Mission Objective 2. As for prevention and elimination of pollution of our oceans and waters, detection and monitoring is key. The XploTaker can contribute specially to monitoring of nutrients, pesticide, antibiotics and toxic substances. The XploTaker automatizes the sampling and reduces it from manual sampling more than 100-fold in time and cost.

Knowledge Output Reference Number: 863702 – KOa

Knowledge Output Title: Artificial Intelligence (AI) for seafloor screening and monitoring

Project link: https://www.basta-munition.eu/

Knowledge Output Description:

Background

The BASTA project aimed a.o. at detecting Unexploded Ordnances (UXO) aka munition, through advanced geophysical magnetic mapping using AUVs und 3D sub-bottom profilers, smart data integration and Artificial Intelligence (AI) workflows. Strongly UXO affected areas in Europe are for example the North-, Baltic and Adriatic Sea due to WWII activities and munition dumping after the war. The findings in the BASTA project are also of high importance for litter and contaminant source detection (any anthropogenic objects), but more generally they deal with highly detailed seafloor observation that can support the establishment of protected areas and biodiversity monitoring as well as enabling the transition towards a carbon-neutral blue economy by clearing areas of munition.

Current practice in Explosive Ordnance Disposal (EOD) services is to screen for UXO first in large areas to detect potential targets and then survey around these targets in a small area, mostly limited to the few square meters where new offshore infrastructure is supposed to impact the seafloor later on, and construction activities need to be safe. However, active, detection of UXO and UXO dump sites gain currently more and more attention, including in EU funding mechanisms. To this aim, the BASTA solutions are highly valuable. Until today, UXO detection is largely based on manual processing and visual interpretation of underwater datasets (side scan sonar, magnetic etc.). However, these methods are very time-consuming during acquisition, verifications and data analyses. Currently AUVs are not yet smart enough for reliable automation of the process in the water, but their use will strongly benefit verification and identification measurements of UXO targets.

Technical description

An important Knowledge Output from the project is the AI and software developed within the project, to analyse multibeam sonar data and to create photogrammetric reconstructions of images from the sea floor taken by AUV. The AI and Software are composed combining different open-source blocks. In parallel possibilities to assess even in very large data quality factors for certain UXO mapping techniques (SSS, MBES, magnetic) have been uniquely developed within BASTA.

The BASTA AI, software and models can be advanced and used to cover all types of objects in Oceans and other waters if further training of the AI is done. A new nationally funded project aims at providing a more advanced research and commercial software version (project ValidITy July 2023 to June 2025). A parallel running project SAM aims at making AUVs with magnetic sensors smart(er) and autonomous.

Potential impacts and applications

The AI for seafloor screening and monitoring is of relevance for the Mission 'Restore our Ocean and Waters", contributing to Objectives 1 and 3:

1. Protect and restore marine and freshwater ecosystems and biodiversity: For new protected areas it is very important to detect and retrieve objects with pollution potential, such as UXO or litter. Old, decomposing, and damaged munition release chemicals to the sea. However, scaling the technology all kind of bodies can be detected. Visual observation techniques of the sea floor are needed for habitat mapping, which is the base for investigating and monitoring biodiversity over time. Physically sampling the seafloor in protected areas can be reduced. When using acoustic or optic imaging

3. Make the sustainable blue economy carbon-neutral and circular: blue infrastructure, such as off-shore wind farms, wave-farms, cables, pipelines, aquaculture, etc. often require anchoring or installation in/on the seafloors. As the European Oceans and waters are in parts strongly contaminated with but also contain areas that need protection (stone reefs, oyster banks, …) they need to mapped before any impact is done.

With these innovations, BASTA's AI for Seafloor screening and monitoring also contributes to the two enablers of the Mission:

1. The detail, volume and accuracy of the data can contribute to enhancing the Digital Ocean and Water Knowledge System.

2. 3-D visualizations of the data can be used to support public mobilisation and engagement.

Knowledge Output Reference Number: 770469 – KOa
Knowledge Output Title: Big-data collection, organisation and presentation toolbox for Mission objectives assessment and monitoring
Project link: https://cordis.europa.eu/project/id/770469
Knowledge Output Description: The Mission "Restore our Oceans and Waters by 2030", as well as any other EU funded programme (and project), sets some key indicators that need to be reached. This toolbox offers a complete automatised, software-based solution to gather data regarding the identified indicators (or proxies), systematise and visualise them in an organised way which also helps suggesting policy adjustments and complementary measures. The CUTLER project's objective was to create a software-based system to help municipalities, especially those located along marine and coastal areas (waterfront municipalities), to support the assessments (ex-ante and ex-post) and planning of urban development policies based on data rather than intuition. For this end, the CUTLER has developed a series of interlaced IT tools and guidelines aimed at gathering, refining, storing and presenting relevant data in an accessible and understandable way for policymakers or consultants. The big-data collection and visualisation tools includes a series of tools and protocols which, used together, have the potential to set up a monitoring system that is able to keep track of changes occurring in those values (indicators or proxies) that are identified prior to its implementation.

Since the KO is composed of open-source software and is conceived to collect and analyse big-data, the system is extremely adaptable to different contexts.
The toolbox includes:

1- 42 data crawlers (see below for specifications);
2- Guidelines and recommendations for data privacy in public administration;
3- A framework for the collection, cleaning, integration & anonymization of big data;
4- A specific methodology for decision-making involving big-data (so-called IAMER methodology further explained below);
5- A cloud infrastructure including security protocols;
6- A platform to visualise the gathered data (see below);
7- A handbook and specific guides to the utilisation of the above-mentioned tools.

(1) A data crawler is a software designed to browse resources and indexing or gathering information. The project has produced 42 open-source crawlers designed to gather information from specific data sources and social media. The developed crawlers refer to:

- 32 crawlers gathering environmental data;
- 6 crawlers gathering social data;
- 4 crawlers gathering economic data;

The crawlers were designed to draw from different and heterogeneous data sources, including social media, GIS data, hard-wired sensors, simulation, official reports and economic data. They are stored in the following GitHub repository: https://github.com/CUTLER-H2020/DataCrawlers.

(4) The IAMER (Inform, Advise, Monitor, Evaluate, Revise) methodology is an iterative method designed for policy-making based on big-data. It consists of 6 steps, i.e.:

1. Inform, i.e. effectively visualize and present available social, economic and environmental data;
2. Advise the estimated impact of planned policy measures with respect to city resiliency;
3. Implement the decided policy;
4. Monitor the enforced measure progress and ensure objectives compliance by visualising data in real time;
5. Evaluate policy effectiveness by examining social, economic and environmental KIPs
6. Revise the policy based on evaluation results

(6) The platform's front end is an innovative data-driven decision-support system for public administrations that offers both a standardized way to design high-quality decision-support interfaces but also a standardized way of presenting the decision-making process to policy makers and visualizing the necessary evidence in each step of the process. Its flexible architecture allows easy adaptation to the needs of different cities in terms of examined policies, decision-making processes, and IT infrastructure. The software is designed for being deployed in a cloud environment, and it is delivered as a multi-tenant and multi-lingual service (SaaS). Additionally, it is integrated with Open-Source software such as the Camunda business process engine, the Kibana big data visualisation tool and other third-party components information on which can be found in the relevant manuals (available at https://github.com/CUTLER-H2020/CUTLER-Platform-V2 and https://github.com/CUTLER-H2020/Front-end-v2).

The CUTLER Data Crawlers have been used and tested to gather data regarding 5 city pilots (Thessaloniki, Antalya, Antwerp, Cork and Vicenza), and are therefore to be considered at TRL7.
The whole documentation presented is open-source and available through the project website (https://www.cutler-h2020.eu) or in GitHub (https://github.com/CUTLER-H2020).

CUTLER pushes the envelope by providing an innovative Software-as-a-Service solution that combines disparate data sources on a cloud-based big-data analytic platform, where data visualisation plays an important role in enabling policymakers to easily design, implement, and evaluate policy measures.
Unlike other solutions, CUTLER incorporates predictive analytics, trend detection, and text mining on social platforms to estimate the social consequences of policy implementation, as opposed to relying on economic or

environmental data and social consequences by incorporating them into a single platform. Furthermore, thanks to social analytics modules, it improves the effectiveness of decision-making in public administrations, enables better policy implementation and compliance, promotes sensible and ethical governance, and increases transparency by taking citizens' opinions into account when designing new policies, thanks to social analytics modules (exploiting Twitter feeds, TripAdvisor reviews, comments on news articles, etc.).

The toolbox has a strong potential to be applied to infinite locations within the lighthouse areas and guide or monitor the effectiveness of implemented measures.
In that sense, depending on the tuning given to the elements within it and especially the crawlers, datasets and visualisation tools it could contribute to each of the Mission objectives. For example, the system may be set-up to present data collected by environmental sensors, weather stations, research institutions databases, NGOs, companies, etc. regarding pollutants and plastic litters in target areas. At the same time, the system could monitor the citizens' opinions on the status of specific areas e.g. beaches or other naturalistic touristic attractions to see if the efforts are bringing about tangible results that are perceived correctly by the population.
Other adaptations that could be made is to allow access to the visualisation platform to different levels of audience, e.g. from research institutions, municipalities, NGOs or the Mission

Knowledge Output Reference Number: 789059 – KOa
Restoration protocol for Cystoseira spp. forest ecosystems
Project link: http://afrimed-project.eu/

Knowledge Output Description:

Background:

Cystoseira sensu lato (canopy-forming macroalgae) forests are one of the most extensive and productive ecosystems on rocky substrates in coastal Mediterranean areas providing many ecosystem functions and services. However, eutrophication, overgrazing, increasing coastal sediment loads, and impacts of urbanization among other causes, are causing massive losses of macroalgal forests, resulting in loss of biodiversity (1, 2).
Previous restoration attempts have demonstrated that human-induced recovery is not effective if implemented without further evaluation/actions to reduce pollutants concentration and other pressures that might influence restoration success as herbivores, biodisturbance, invasive species; another effective solution to implement effectiveness of restoration activities is to select individuals whose genotypes fit with the environment conditions (3).

Technical description

Based on experts' knowledge and previous laboratory and field test, the AFRIMED project developed ***Cystoseira***-species-specific protocols to provide researchers and practitioners with information that is important to consider when restoring macroalgae in the Mediterranean Sea (4).
Since the restoration of algal habitats is a complex task, the process is broken down into five steps (**5**):

(1) The selection of restoration sites is based on historical presence of the species to be restored in the selected area (*See KOb to the AFRIMED project*) combined with essential mitigation of factors that caused and maintained the loss of target species. Moreover, it is necessary to consider the ecological interactions with the species present at the site of restoration can play a crucial role in determining the success of restoration action (e.g., grazing pressure).
(2) The selection of target species is based on their previous presence in the area, the health status of their populations in the geographical area, the ecological relevance and with the availability of documented manipulation techniques. Knowledge of ecology and life-history traits of selected species is a key requisite for planning efficient restoration actions.
(3) The selection of donor sites is based on having well preserved conditions and genetic variability of individuals to foster new populations. Secondarily they should be as close as possible to the area to restore to minimize manipulation and optimize action cost/effectiveness.
(4) Restoration techniques can be *in situ* or *ex situ* depending on different factors; *in situ* techniques are more suitable for species with higher dispersal capacity and in low hydrodynamic conditions (e.g. depth<10m or

inside lagoons) and have been successfully tested for *Ericaria barbatula* and *Gongolaria elegans* while *ex situ* techniques tested for *Ericaria amentacea, Ericaria crinita, Ericaria zosteroides* and *Gongolaria barbata* fit better for species with lower dispersal capacity, high hydrodynamic conditions (e.g., exposed intertidal and shallow subtidal rocky reefs) and high herbivory pressures. The *ex situ* techniques have more limitations as availability of facilities and the proximity of the restoration site, considering that transport to the field could be a critical step for the success of the restoration.

(5) Complementary actions are needed to ensure the effectiveness of restoration as herbivores limitation (through herbivore removal or use of access prevention devices) and removal of competition species as turf-forming algae to provide more available substrate for new recruits.

Costs will ultimately depend on the species, its ecology, the specific characteristics of the habitat to be restored, and the availability of infrastructures.
The costs of different techniques have been estimated showing a high increase in *ex situ* methods due to laboratory culturing, complementary grazing actions and transport to the selected area.

The restoration techniques and approach proposed in the Roadmap (6) have been tested at trial level in contained target areas and have proven to be highly effective, leading to a strong increase in the algal population (reached 25 m^2 after six years, comparable to the reference sites) through a series of in-situ and ex-situ approaches specifically designed for the different *Cystoseira* species. However, to evaluate the restoration success, in line with guidelines provided by the Society of Ecological Restoration, it is also necessary to consider the recovery of ecosystem biodiversity, functioning and ecosystem resilience capacity to the state preceding the degradation; this operation needs more time.

AFRIMED project (2019-2022), was the first initiative to propose marine restoration measures to the Society of Ecological Restoration, producing species-specific protocols embedded in a roadmap for the restoration of macroalgal forests (*Cystoseira spp*.) in the Mediterranean Sea.
Other restoration actions have been conducted by other projects, however AFRIMED has for the first-time developed protocols that are adapted to each individual species; by suggesting specific conditions (e.g. temperatures, substrates, restoration methods) for each investigated species of *Cystoseira.*
The application of the protocol for restoring *Cystoseira* increases the success of restoration as it considers specific actions to be taken before and after the process in combination with the selection of appropriate algal species; therefore, the expenses associated with restoration are reduced, as they are not invested in unsuccessful actions.

Potential Impacts and Applications
This output is strongly linked to the first objective of the Mission "Protect and restore marine and freshwater ecosystems and biodiversity" as its primary application is exactly that to restore algal ecosystems; it will contribute to relevant upcoming marine nature restoration target in coastal ecosystem.

The AFRIMED roadmap was developed with the aim to maximise the delivery of conservation, societal and economic benefits by assisting researchers and stakeholders in decision-making; also guiding them to select the most cost-effective methods of macroalgae restoration, i.e. the ability to restore the greatest amount of native plant cover for the money spent, ensuring that the money is used most effectively.

The application of the protocol, in addition to reducing the costs associated with unsuccessful actions, aims to make *Cystoseira* restorations more effective by ensuring an increase in the population. Restoration in turn contributes to the improvement of the ecosystem by increasing the ecosystem services linked to it (e.g. oxygen and biomass production, nursery, foraging area, protection, biodiversity).

Knowledge Output Reference Number: 789059 – KOc
Knowledge Output Title: Development of a High Suitability Model (HSM) for Cystoseira species to predict their occurrence at locations where no information is available in the Mediterranean Sea.
Project link: http://afrimed-project.eu/
Knowledge Output Description:

Background:

Cystoseira sensu lato forests play a key role in Mediterranean coastal ecosystem as provider of multiple ecosystem services such as fish nursery, primary producer, pollution controller etc.; however, due to increasing of human pressures, it represents an example of a threatened benthic habitat featured by poor spatial information, deserving further efforts to improve the management of those pressures determining their increasing loss across the Mediterranean and elsewhere.

A network of organisations in Europe is presently collaborating to integrate and exchange information to combine existing maritime data across EU countries (European Marine Observation and Data Network, EMODnet1). Despite these efforts, the definition, distribution, and temporal trends of the status of the majority of Mediterranean habitats remain largely unquantified or limited, collected in small dataset that are difficult to compare (1); in order to fill knowledge gaps, modelling methods and extensive extrapolations are required. The *Habitat Suitability Models (HSMs)* can be a cost-effective way to incorporate actual data since they can assist in identifying where critical marine species and ecosystems are predicted to appear and anticipating potential alterations in distribution as a result of multiple stressors (2).

Technical description:

The aim of this work was to develop an HSM suitable to identify environmental predictors which are related to *Cystoseira* spatial distribution and to predict the occurrence of *Cystoseira* canopies at locations where information was not available.

Behind the state of the art, a predictive occurrence map (referred to as *Habitat Suitability Model*, *HSM*) was developed to model the distribution of *Cystoseira* species living in the shallow rocky substrate, through the Random Forest technique (RF).

From the database of *Cystoseira* species inhabiting the Mediterranean Sea, smaller dataset (transformed in a raster layer) describing the 'presence', 'absence' or 'no data' for *Cystoseira* species on shallow rocky substrate was crated and matched to 55 predictor variables (geomorphologic, environmental and anthropogenic) for the modelling procedure.

The Random Forest machine learning technique needs two subsets of data to predict the distribution of *Cystoseira* species: a *training set* to tune the model, with 80% of dataset assigned and a *test set* to validate model performances, with 20% of dataset assigned for the analysis; during this phase only regions where both 'presence' and 'absence' data of *Cystoseira* species were available were used.

A total of 132 RFs were trained, each with a unique set of parameters. The parameters tuned were:

i) the number of trees in the forest;

ii) the number of records in the trees' terminal leaves (tuned to minimise generalisation error and avoid overfitting);

iii) the number of predictor variables randomly selected at each split.

Reveiver Operating Characteristic (ROC) curve was used to optimize the unbalanced data in number of presence and absence records and the permutation importance measure (or the Mean Decrease Accuracy, MDA) was compared to the Gini importance measure (or the Mean Decrease Impurity, MDI) to assess the importance of predictor variables.

Finally, the model's outputs were utilised to assess areas defined as suitable with varying probabilities of *Cystoseira* occurrence ("Habitat suitability") and to quantify the relative value of the predictor variables ("Variable importance").

During the HSM development, the selected model performance was tested by getting the real predictions for areas where 'presence' records were available, not considering this data during from the model's formulation. Additionally, it was employed in the creation of the georeferenced map of *Cystoseira* species in the Mediterranean Sea (*789059 AFRIMED KOb*), making it considerable as TRL 9.

Potential Impacts and Applications

The model output from this study enables for further investigation of regions identified as appropriate with a high chance of *Cystoseira* occurrence, determining whether the projected status of presence matched the actual one, and therefore defining additional suitable locations for restoration efforts. As a consequence, the HSM might be viewed as a valuable baseline tool for assessing *Cystoseira* distribution and establishing future-oriented marine

planning initiatives in terms of both conservation and restoration. Moreover, it can also be applied in other regions outside of Mediterranean region.
A significant barrier to the HSM's growth and, consequently, to our knowledge of the possible distribution of *Cystoseira* forests over the whole Mediterranean coastline, is the high percentage of "no-data" recordings.
In fact, predictions for Mediterranean locations (such as the eastern Mediterranean areas), where model performances are highly constrained due to environmental uniqueness and heterogeneities, may not replicate the actual canopies distribution.
The results of the model, i.e. the areas suitable for the presence of Cystoseira, contribute to the fulfilment of Objective 1 of the Mission, "Protect and restore marine ecosystem and biodiversity", as they suggest areas where restorative actions or conservation regulations can be applied.

Knowledge Output Reference Number: 750680 – KOa

Knowledge Output Title: Identification of priority deep-sea areas for protection through the combination of two complementary approaches.

Project link: http://www.msfd-idem.eu/

Knowledge Output Description

Background

The deep-sea, area below 200m, is largely uncharted (only 0.001% is studied in terms of biodiversity), making it the largest and least explored biome on Earth.
The Mediterranean Sea is a biodiversity hotspot, including numerous rare and distinct habitats (e.g. 500 submarine canyons, deep-water coral system, ca. 100 seamounts, cold seeps, carbonate mounds, brine pools, hydrothermal vents, mud volcanoes, open slope, deep basins, anoxic system.) in its deeper areas. However, while studies of species occurrence, species distribution, and species richness of deep-sea ecosystems are lacking, there is an increasing trend in human activities and impacts (e.g. commercial fishing, oil and gas exploration and production, waste and litter etc.). (1)

Technical description

For the first time a combination of several methods was used to identify priority deep-sea conservation areas in the Mediterranean Sea. The analysis was conducted by comparing the findings of a multi-criteria decision analysis (MCDA) with expert evaluation (EE). The first one is an effective information synthesis approach for decision support that investigates the impacts of given criteria, while EE requires the involvement of stakeholders, especially policy makers, who were included in the identification process to bring socio-economic and political characteristics into the definition of territorial priorities.

- In Multi-Criteria Decision Analysis (MCDA) two sub-targets indicators were used: species distribution, substrate and habitat, reproduction areas to cope 'Nature conservation' goal and fishery effort, shipping intensity, oil and gas fields, oil and gas extraction sites to deal with 'Activities preservation'. Using these indicators with different weights, different scenarios were produced to identify areas that should be protected.
- During Expert Evaluation (EE) 11 'Ecological relevance' criteria and 12 'Anthropogenic threats' criteria were considered, in terms of level of relevance assigning a value from 0 (no information) to 3 (high relevance) for each Mediterranean area.

The innovation of this work is to combine two approaches already used to provide a more comprehensive and robust analysis than using only one. The MCDA is one of the best-practice method (2), for spatial conservation prioritization, primarily dependent upon data availability; as a lack of data has been identified in Mediterranean deep-sea ecosystem (3), to ensure a more robust analysis was combined with qualitative EE analysis that draws on the body of information accumulated by experts in the field, which is often much more extensive than that available in geodatabases. The two approaches therefore complement each other and they identified similar deep-sea areas deserving protection and suitable for the institution of new Marine Protected Areas (MPAs). (See figure below or Annex 1)
The aim of this work is to identify priority deep-sea conservation areas to suggest where new MPAs should be established to meet the EU2030 Biodiversity Strategy EU2030 Biodiversity Strategy and achieve Aichi Target 11

[(Convention on Biodiversity, CBD)] by integrating multiple methodologies and analysing current international protection measures to build an innovative, integrated, and resilient strategy.

Since the establishment of a new marine protected area appears to be a complicated, time-consuming and resource-intensive process, and since the results of the analysis identified suitable areas for new deep-sea MPAs bordering already established MPAs, annexing deep areas to existing protected areas is suggested to reduce the resources required for the process (as was the case in French Port-Cros National Park and Spanish MPAs to the adjacent deep-sea canyons and seamounts).

This new analysis includes methods that fit for areas where little data are available, such as parts of Mediterranean (southern and eastern areas) also dealing with the problem of missing data.

Potential Impacts and Applications

The identification of areas suitable for new MPAs contribute directly to the MO1, in particular to 'protect a minimum of 30% of the EU's sea area', 'strictly protect at least 10% of the EU's sea area' and to establish new deep-sea habitat protected area contiguous with already protected coastal MPAs to 'integrate ecological corridors'.

The application of the criteria (see figure above) could be also used as a map to identify areas of ecosystem importance that need to be conserved/monitored or even restored in order to 'contribute to relevant upcoming marine nature restoration targets, including degraded seabed habitats.

Authorities and policymakers could utilise the designated areas to invest economic resources in the creation of new MPAs since the areas were chosen using scientific data and methodologies based on an analysis that included the selection of appropriate indicators to accomplish the aims of the EU2030 Biodiversity Strategy agenda. In this approach, investments are directed towards regions that have previously been studied, resulting in a decrease in the expenses of measures necessary prior to the development of an MPA.

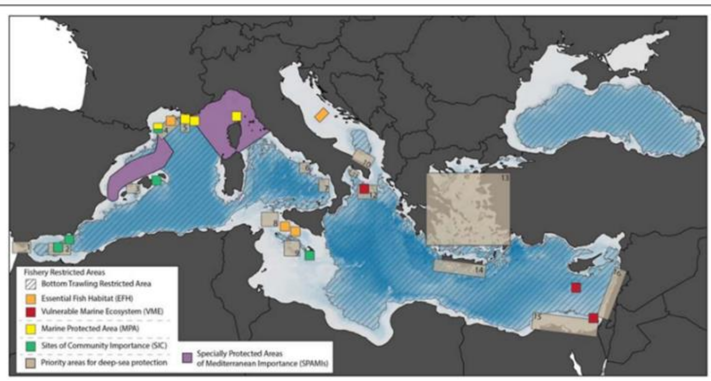


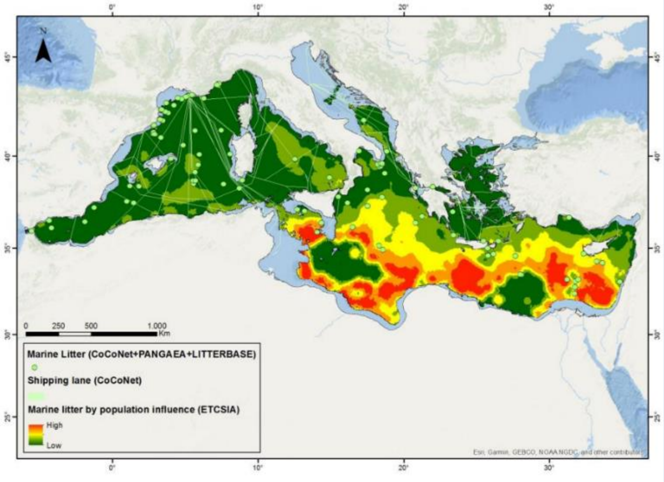
FIGURE 5 | Map of the Mediterranean deep-sea areas already under management measures and those identified as priority for conservation actions through the present work. Numbers on light brown rectangles indicate the areas identified, specifically 1. Strait of Gibraltar; 2. Alborán Sea; 3. Eivissa and Mallorca channels; 4. Canyon systems of the western Gulf of Lion and north Catalan margin; 5. Cassidaigne Canyon; 6. Dohrn Canyon; 7. Calabrian canyon system; 8 and 9. Deep basins of the Sicilian Channel; 10. Bari Canyon; 11. Apulian deep-sea bottoms, including the Bari Canyon; 12. CWC habitats of Santa Maria di Leuca; 13. Deep bottoms of the Aegean Sea; 14. Hellenic Trench south of Crete Island; 15. Deep Nile Delta Fan; 16. East Levantine canyons. VME areas banned to fishery, seamounts, and other similar features, and other fishery management measures from the FAO VME database (accessed January 2021).

Knowledge Output Reference Number: 750680 – KOb
Knowledge Output Title: WebGIS maps of the spatial extent of the descriptors/criteria/indicators as well as human pressures/impacts on the Mediterranean deep-sea ecosystems
Project link: http://www.msfd-idem.eu/
Knowledge Output Description ***Background*** In order to attain Good Environmental Status (GES) of marine waterways by 2020, the EU's Integrated Maritime Policy has created the Marine Strategy Framework Directive (MSFD 2008/56/EC). The MSFD is applicable to the portion of maritime waters that each Member State has authority over under the United Nations Convention on the Law of the Sea (UNCLOS). Deep sea waters inside the Exclusive Economic Zone (EEZ) of Europe are included, as it is the seabed and subsoil under the water column, as defined by the MSFD. Currently, the MSFD implementation falls short in capturing such a vast dimension since it focuses mostly on habitats around the shore or those that are accessible through fishing operations. ***Technical description***

The IDEM project provided the first evaluation of the environmental status in the Mediterranean deep-sea through a habitat/ecosystem/pressure GIS map.
All information on habitats/ecosystems distribution, human pressures on the deep sea, and prior projects, initiatives, and European infrastructures was gathered and incorporated into a Geodatabase. In accordance with the stated project data, policy and data management methodology (*used in 750680 IDEM KOc*), data from IDEM partners are also included.
The Geodatabase is published on the IDEM WebGIS platform with free access through the [IDEM webpage](). The portal combines intelligent web maps with graphs, charts, tables, and text to unlock, make accessible and reusable the data in a coordinated manner and allows users to navigate through different layers (biodiversity, litter, etc.), customize his view and print maps.
The different layers included in the Geodatabase were grouped following the MSFD descriptors and based on a review of available literature and data to describe the status of each descriptor. The list of thematic layers included in the IDEM Geodatabase is shown in the following table:

Group layer	Layer
D1 – Biodiversity	Species occurrences
	Habitat point
	Seamounts, knolls and mud volcanoes
	Seabed substrate
	Seabed habitat EUNIS
	Seabed habitat MSFD
	Mammals and turtles diversity
	Critical habitats
D2 – Non-indigenous species	Number of multicellular non-indigenous species
D3 – The population of commercial fish species	Potential fishing pressure along the Mediterranean Sea coast
D4 – Elements of food web ensure long-term abundance and reproduction	-
D5 – Eutrophication	Aquaculture production: fish farms influence
D6 – The sea floor integrity	Utility and service line
	Mining and extraction activity
	Impact of fisheries on the bottom from AIS data combined with habitat vulnerability
	Sulphide deposits
	Dumping zones
	Exploration and extraction of oil and gas
	Trawling areas
D7 – Permanent alteration of hydrogeographic conditions	-
D8 – Concentrations of contaminants	Contaminants monitoring stations
	Pollution point source
	Dumping zone
	Intensity of pollution by maritime transport in Mediterranean Sea
D9 – Contaminants in seafood	-
D10 – Marine litter	Marine litter
	Shipping lanes
	Marine litter by population influence
D11 – Introduction of energy, including underwater noise	-
Other	Cumulative Human Impact

As shown in the previous table, layers that fits for some descriptors are missing (as D4, D7, D9, D11) due to lack of spatial data of gap of knowledge. Moreover, the database only collects data until 2019, the year the project ended.
The Geodatabase allows for a selection of layers to be displayed simultaneously (see for reference the map below, related to D10, including the three layers as marine litter, shipping lane and marine litter by population influence).



Potential Impacts and Applications
The Geodatabase has many applications that could contribute to the Mission, in fact by selecting the right descriptors, the system can provide useful information and suggest target areas to achieve the Mission objectives.
D1, D2, D3 allow the identification of areas with high biodiversity, areas that need to be restored, areas suitable for monitoring programs or used as a base to identify new MPAs helping Objective 1; mapping D5, D8, D10 may help to identify areas with high concentration of pollutants and can, therefore, contribute to achieving the second Mission's objective 'Prevent and eliminate pollution for our ocean, seas and waters'. Moreover, the map also provides information useful to achieve the third Mission objective to 'Make the sustainable blue economy carbon-neutral and circular' by using descriptor 10. In fact, shipping lanes (D10) are mapped and show a whole view of the Mediterranean shipping. These can help revise routes to reduce emissions. Using indicator D5, it is also possible to map the eutrophication effect related to aquaculture, and in this way have an indication of where to act to make the activity more eco-sustainable by reducing the negative effect on the ecosystem.
This project provides very useful information that if addressed to the right stakeholders can have an effective result (e.g., the map of marine litter to a project/company for the collection of waste at sea).
The Geodatabase could be used as a basis for an ecosystem-assessment because it allows you to examine cumulative anthropogenic effects using multiple indicators on the map.

Knowledge Output Reference Number: 750680 – KOc
Knowledge Output Title: Integrated guidelines for the protection of the deep sea focusing on the Mediterranean Sea
Project link: http://www.msfd-idem.eu/
Knowledge Output Description ***Background*** Deep-sea ecosystems are under threat from increased human activity such as trawling, exploitation of gas, oil and methane hydrate resources, and the extraction of enormous sulphide deposits from the seafloor. The growing exploration and industrial exploitation of the vast and vulnerable deep ocean environment for a variety of biotic and abiotic resources raises global concerns about potential ecological consequences. As a result of the increasing anthropogenic impacts and their potentially synergistic effects on marine ecosystem, a precautionary approach is required for the protection of the marine environment beyond national jurisdiction. In response to this, several international legislative instruments have been put in place that are also applied in territorial waters (under national jurisdiction) (*Marine Strategy Framework Directive (MSFD) 2008/56/EC, Fisheries Restricted Areas from General Fisheries Commission for the Mediterranean, Malta MedFish4Ever Declaration*), with common objectives and principles, and to make them more effective, they should be integrated.

Due to increasing anthropogenic impacts and their potentially synergistic effects on the marine ecosystem, a precautionary approach to protecting the marine environment beyond national jurisdiction is required.
In response to this, several legislative instruments have been put in place that are also applied in territorial waters (Marine Strategy Framework Directive (MSFD) 2008/56/EC, General Fisheries Commission for the Mediterranean Fisheries Restricted Areas, Malta's MedFish4Ever Declaration), with common objectives and principles to standardise existing regulations and to make them more effective, should be integrated.
territorial waters in which the state exercises its sovereignty and may extend up to a maximum of 12 miles from the coast.

Technical description
The IDEM project analysed available documents from *Marine Strategy Framework Directive 2008/56/EC, General Fisheries Commission for the Mediterranean and Malta MedFish4Ever Declaration* as these have the same objective to protect the marine ecosystem, in particular, establishing shared goals for the preservation of the deep sea. Based on this framework, three key actions are proposed to be implemented by integrating the previously analysed directives, suggestions and criteria to provide integrated guidelines for the protection of the deep-sea marine ecosystem:

- Action 1 – Establish deep-sea protected areas *(750680 IDEM KOa)*, including representative and rare ecosystem, in particular, providing a list of Mediterranean dee-sea habitats and threatened species, through identification of biodiversity "hot-spot", unique habitat and soft-bottom habitats for strict protection and undertake a multidisciplinary monitoring of identified areas.
- Action 2 – Improvement of fishery management measures by extending FRAs (Fishery Restricted Area) to protect deep-sea habitats from overfishing and habitat destruction, creating adequate buffer zone where trawling is banned, proposing impact assessment for exploratory fishing and facilitating the accessibility of Vessel Monitoring System (VMS) and Automatic Identification System (AIS) data.
- Action 3 – Application of the precautionary approach to oil and gas exploitation and production (E&P) activities by proposing prior environment-state assessment of target area for exploration and harmonizing legislation and revise Directive 2013/30/EU and the protocol against pollution for exploitation/exploitation from Barcelona Convention.

The project dealt with the establishment of a technique to protect the deep-sea in the Mediterranean by analysing current international protection measures to build innovative, integrated, and resilient actions: whereas legislation gives objectives and targets to be attained, the project offers actions to achieve those objectives and targets.
The guidelines are the result of a review of international legislation that contributes to the conservation of biodiversity, the protection of ecosystems and a sustainable approach to the exploitation of resources. The objective is to establish a set of actions that respond to the EU2030 Biodiversity Strategy goals and may be applied to safeguard the Mediterranean Sea' deep marine ecosystem from all anthropogenic pressures as much as possible. whereas legislation gives objectives and targets to be attained, the project offers actions to achieve those objectives and targets.
These guidelines have already been proposed for the protection of additional areas as Dohrn canyon in The Regno di Nettuno, Naples and Levante canyon in Cinque Terre, La Spezia as both areas hosting Vulnerable Marine Ecosystems (VMEs) indicator species, (1), (2) during the General Fisheries Commission for the Mediterranean (GFCM) Working Group on Vulnerable Marine Ecosystems and Essential Fish Habitats (WGVME-EFH), 22-24 March 2022, online.

Potential Impacts and Applications
Legislation for the conservation of the deep-sea ecosystem and marine biodiversity, such as the MSFD, is critical to the development of a policy plan that takes into account synergistic policies between states and serves as a supplement to existing legislation. However, they just specify objectives to be met (e.g., *Good Environmental Status, GES*) without offering actual measures to be done to fulfil them; to answer this requirement, the IDEM project has developed explicit guidelines described by actions in order to meet the given targets of European 2030 Biodiversity Strategy.

Policy makers can utilise the project's recommendations to develop a protocol for action to fulfil the *Good Environmental Status* (GES) required by MSFD. For the early detection of impact signals using simple and efficient "indicators" like changes in species distribution or local extinctions, long-term data series are required *(750680 – IDEM KOb)*.
The guidelines could also be applied to the pelagic zone or water-column, integrating comprehensive protection of the sea, after integration with other indicators, analysis of legislation and further verification as different stressors acting in the area. Extending the guidelines beyond the deep sea would apply an ecosystem and biodiversity protection approach to the entire Mediterranean Sea.

The list of actions to protect deep-sea ecosystem in Mediterranean Sea is in line with the first objective of the Mission to 'Protect and restore marine and freshwater ecosystem and biodiversity'. As the recommendations of this process include the use of a precautionary approach on oil and gas exploration that assumes a reduction of pollution related to these actions, the KO contribute to achieve also the second Mission objective to 'Prevent and eliminate pollution of our ocean, seas and waters". In fact, in Action 3 of the guidelines, measures are suggested for reducing the harmful impact of pollutant release, on the benthic ecosystem.

Knowledge Output Reference Number: 750680 - KOd
Knowledge Output Title: Gaps identification to improve the Marine Strategy Framework Directive (MSFD) from a deep-sea prospective
Project link: http://www.msfd-idem.eu/

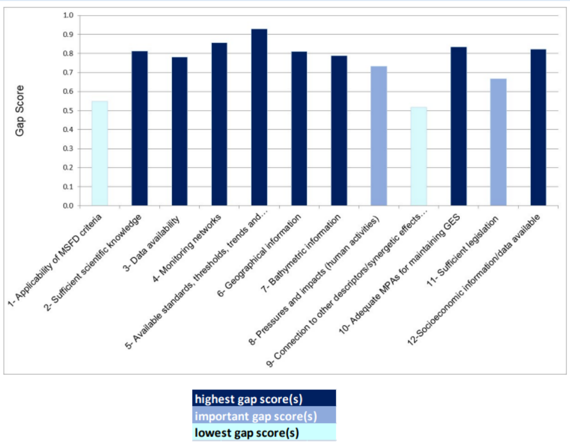
Knowledge Output Description:

Background

In the framework of European Commission decision, 2017/848/EU a list of criteria, 11 descriptors, methodological standards and standardized methods for monitoring were defined to achieve the Good Environmental Status (GES) of marine waters based on Marine Strategy Framework Directive (*MSFD*, 2008/56/EU).
In order to restore good water status and protect the health of the sea, there are several guidelines *(750680 IDEM KOc)* outlined in national and international directives, the most important of which is the MSFD. These directives provide tools (indicators/descriptors) to understand the state of progress towards our goals; however, to assess the state of progress, it is necessary to have an overall picture of the situation, using data that describe the reality.

Technical description

Through this work, the first review of the MSFD descriptors was produced, in which their knowledge and appropriateness is assessed referring to deep-sea, in order to know where they need to be implemented and funds invested to achieve the goals of the MSFD.
In order to provide a quantitative gaps assessment and illustrate the current situation of each MSFD descriptor, an overview of key parameters referring to the deep sea is carried out. Through this work, an assessment of the 11 descriptors used to evaluate the GES of deep-sea ecosystem in Mediterranean waters was produced.
Each of the 11 descriptors was evaluated using twelve semi-quantitative parameters (Table 4.1) selected by the adaptation of PERSEUS project methodologies (1). To minimize arbitrariness and subjectivity in the assessment, each item evaluated by selecting expertise of each project partner has been scored, according to a discrete numerical scale: 0 (minor gap), 1 (partial gap), 2 (major gap). Following the collection of the evaluations, the scores were aggregated per descriptor, averaged, and normalised on a scale of 0-1, in order to determine the gap concerns for each descriptor and to facilitate comparisons.



From the analysis 'available standards, thresholds, trends' emerged as the main shortcoming, followed by 'monitoring network', 'adequate MPAs to maintaining GES' and 'socioeconomic and scientific knowledge' (*see figure on the left*); the highest gaps score resulted especially for descriptor 2 (non-indigenous species), descriptor 4 (food web), descriptor 5 (eutrophication) and descriptor 9 (contaminants and human health) regarding deep-sea environment (*see figure on the right*).

Moreover, the applicability of the MSFD (evaluation parameter 1) appeared as an important issue for descriptor 2, 4, 5, and 7 (permanent alteration of hydrographical conditions) using criteria that are not appropriate to evaluate that condition in the deep-sea.

In addition, some relevant topics (as microbial communities, climate change, ecosystem functioning and connectivity, algae and phytoplankton bloom, ecosystem response resilience and remediation potential, human pressures) for GES in the Mediterranean deep-sea not considered in the descriptors of MSFD, have been identified during the IDEM project; an integration of these matters as indicators in new descriptors are suggested to improve the MSFD (*750680 – IDEM KOe*).

This analysis is established through an iterative co-creation process (IRL 4) where the process was repeat for all 11 descriptors, as the main gaps are identified and possible implementation to improve the MSFD is described.

Potential Impacts and Applications

The work carried out by the project makes it possible to know where there are gaps and where action could be taken if the process described above is to be improved and implemented, in order to assess the state of deep waters in the Mediterranean Sea.

This analysis could be used by policy makers as a general framework to understand where to invest new resources and funds, for example by setting up monitoring plans for those indicators that are less studied.

New projects can be created to fill the gaps identified by this analysis e.g., monitoring or sampling for more data that can be used in the assessment of good environmental status of deep waters; possible stakeholders could be private or public society involved in conservation, NGOs, or groups of scientists.

Moreover, the assessment process can be adapted and used in other geographic areas to evaluate descriptors efficiency in those areas; based on that a following; based on this, monitoring, threshold and available data can be implemented to make improvements in the marine environment more effective.

This work contributes to the achievement of all three objectives, as the MDSF uses indicators involved in the three mission objectives:

- OB1: many descriptors, as biodiversity (D1), non-indigenous species (D2), ecosystem and food webs (D4) contribute to 'Protect and restore marine and freshwater ecosystem and biodiversity'.
- OB2: eutrophication (D5), concentrations of contaminants (D8), marine litter (D10) estimate the pollution in the Mediterranean Sea contribute to 'Prevent and eliminate pollution of our ocean, seas and waters'.
- OB3: population of all commercially exploited fish and shellfish (D3), contaminants in fish and other seafood for human consummation (D9) contribute to 'Make the sustainable blue economy carbon-neutral and circular' helping to reduce economic losses.

Knowledge Output Reference Number: 750680 - KOe
Identification and evaluation of criteria/indicators of Marine Strategy Framework Directive (MSFD) for achieving the Good Environmental Status (GES) in the deep Mediterranean Sea
Project link: http://www.msfd-idem.eu/

Knowledge Output Description:

Background

Based on the *Marine Strategy Framework Directive* (*MSFD*, 2008/56/EU), the European Commission decision 2017/848/EU established a set of criteria, 11 descriptors, methodological standards, and standardised monitoring methods to achieve *Good Environmental Status* (GES) of marine waters.

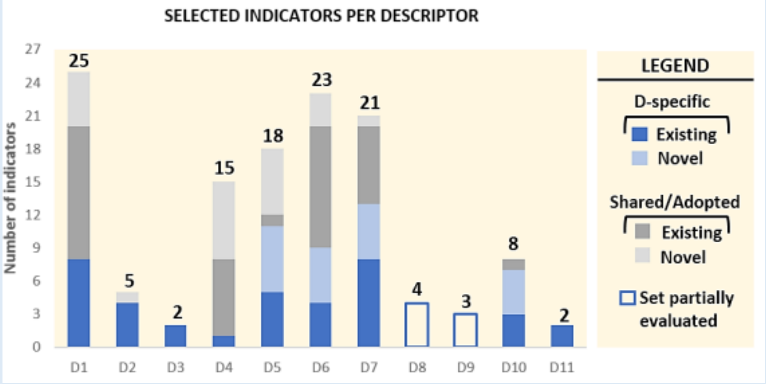
The current implementation of the MSFD is mainly focused on coastal environments, compared to deep sea areas, even though these are large marine areas.(1) To inform this background, the IDEM project undertook an analysis of indicators/descriptors of MSFD defining suitable environmental targets for the deep Mediterranean Sea.

Technical description

The IDEM system described below has been developed from the one used in the DEVOTES project for identification of GES indicators, and it has been supplemented with inputs from two additional pre-existing frameworks (1),(2). To select deep-sea indicators within MSFD, the system consists of two blocks, the evaluation steps (ES.0 – ES.5) and the evaluation parameters (EP.1 – EP.10). The first one shows the steps defining the common, standardized process to follow for completing the evaluation of the indicators, while the second describes the 10 evaluation parameters that determine which indicators characteristics are assessed.

Each indicator describing one of the 11 descriptors of MSFD were evaluated using a standardized evaluation process (1 if the indicator meets the parameter tested, 0.5 and 0 if it does not) (see the Annex I of the link for the complete process description). Results are shown in the following figure, where selected indicators per descriptor are represented depending on their characteristics (new/existing, shared with other descriptors or not); the complete list of selected indicators can be found from pag.13 at this link or in the IDEM project (2019c) Database.

This work is innovative in that it represents the first analysis of indicators suitable for the assessment of the Good Environmental Status of the deep sea; it aims to propose a database of indicators divided into the various MSFD descriptors that should be considered for the achievement of the directive's objective.



Potential Impacts and Applications

This work (similar to 750680 – IDEM KOd) contributes to the three Mission objectives as it considers different indicators for descriptors of MSFD which aim is to achieve the GES. The improvement of indicators to evaluate all the following descriptors, through selecting those most indicative for assessing the ecosystem status of the deep sea, help to restore the marine ecosystem and biodiversity (biodiversity (D1), non-indigenous species (D2), ecosystems including food webs (D4)), reduce the pollution (eutrophication (D5), concentrations of contaminants (D8), marine litter (D10)) and reduce the losses in terms of products in the aquaculture, making it more sustainable (contaminants in fish and other seafood for human consumption (D9)).

The purpose of this analysis is to suggest an implementation of the indicators used to assess the MSFD descriptors with a focus on the deep sea. Based on this overview, policy makers can include new indicators in the indicator assessment practice, and thus make the assessment of good environmental status of waters more effective, as

one of the parameters considered in the analysis is 'available data and monitoring'; considering available data in the indicator selection process provides greater robustness to the selected indicator.
The work is useful for understanding where to invest new funds because in the analysis, one of the parameters assessed is the cost-effectiveness of the indicators.

Knowledge Output Reference Number: 789059 – KOB

Knowledge Output Title: *Cystoseira* meadows mapping in the Mediterranean Sea: comprehensive georeferenced database.

Project link: http://afrimed-project.eu/

Knowledge Output Description:

Background:

Cystoseira sensu lato assemblages are being considered as habitats of critical importance for the EU (Directive 92/43/EEC; Annex I, included in "Rocky reefs") and as indicators to assess ecological status in the context of the Water Framework Directive (WFD; Directive 2000/60/EC).

There is a growing focus on the status of macroalgal forests from both a conservation (Annex II of the Barcelona Convention, COM/2009/0585/FIN) and a restoration (with MERCES and AFRIMED projects) perspective to better understand the possibilities for reversing current declining tendencies through active restoration in the Mediterranean Sea.

However, there is a lack of quantitative and standardised information on the distribution and temporal trends of the state of Mediterranean communities, due to the scarcity of available data (few studies have been conducted) and the use of different approaches for the various works conducted, which make it difficult to compare them.

Technical description:

The georeferenced database of *Cystoseira* was produced embedding catalogued grey literature, systematic review papers, EDONet (European Marine Observation and Data Network), previous database produced by FP7 EU project CoCoNet (*Grant agreement no: 287844*) and new data acquired from CARLIT (CARtography of LITtoral and upper-sublittoral benthic communities) monitoring program; however, data are missing for some areas (east and south). To overcome the lack of information, a *Habitat Suitability Model (HSM)* was developed by means of 55 predictor variables (geomorphologic, environmental and anthropogenic) using the Random Forest Machine Learning technique (*789059 AFRIMED KOc*).

This database goes beyond the state of the art as it collects various datasets and improves them with a new predicting model (*HSM, 789059 AFRIMED KOc*) to identify suitable areas for 20 *Cystoseira* species (here the list) where data were not available as well as the above mentioned predictor variables that include, among others, factors related to anthropogenic pressures e.g. *Artisanal fishing*, *Human impact to marine ecosystems* and *pollutants.*

The Habitat Suitability Model output, showing suitable areas for Cystoseira species across the Med, is described in the figure below.

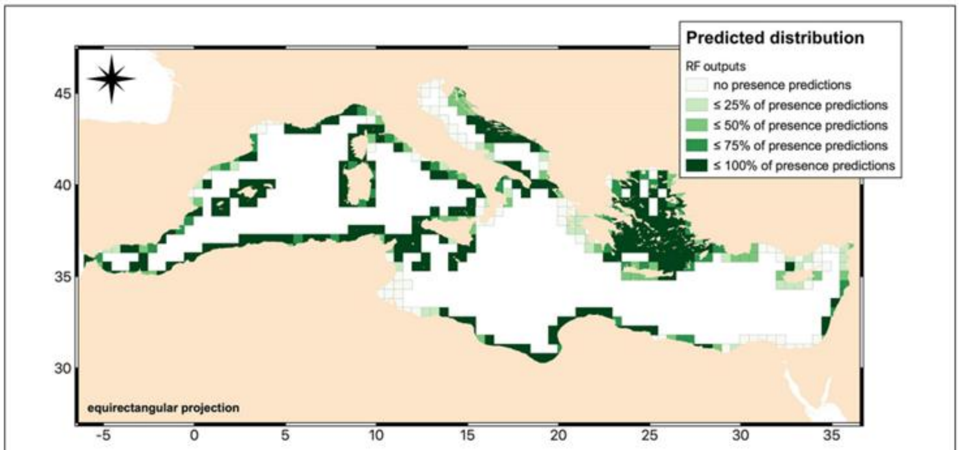


FIGURE 8 | Map of the predicted distribution of *Cystoseira* infralittoral species according to RF outputs. The map is based on a combined dataset of canopy-forming species and records of species which may not be "forest"-forming (e.g., *C. compressa*). It has been created with QGIS software (QGIS Development Team, 2018. QGIS Geographic Information System. O3.Open Source Geospatial Foundation: https://www.qgis.org/it/site/).

The georeferenced map is accessible to all and has been used for restoration actions (TRL 9) also usable through the "Business clubs" organized by the AFRIMED project.

The georeferenced map is contained in a scientific paper.

Potential Impacts and Applications

The database has potential commercial exploitation in that it may be uptaken by enterprises operating in marine restoration to determine which areas satisfy the requirements for restoration measures based on historical data and prediction model according to geomorphological features.

Other than that, the main use that can be made is to provide policymakers with an overview of areas both for restoration activity but also to implement new protected areas since macroalgal forest provide several key ecosystem functions (nursery, feeding, etc.) and services (fishing, leisure, etc) that enhance biodiversity in the area in which they are located.

Other possible applications include pre-assessments on carrying out restoration measures and assessments related to spatial planning.

The map was created by considering geomorphological variables such as soil type, environmental variables such as temperature or pH, and anthropogenic variables such as distance from ports or the presence of tourists; it thus provides us with information on the different characteristics that describe the areas of the Mediterranean Sea. It is therefore possible to know where stress factors are present that can be removed or mitigated, to make the area suitable for restorative actions, suggesting to interested parties where to act and in so doing, reducing the economic expenditure for ineffective actions.

These possible applications of the map contribute directly to the first Mission objective, to "Protect and restore marine ecosystem and biodiversity", in particular the restoration plan can '*Contribute to relevant upcoming marine nature restoration targets, including degraded seabed habitats and coastal ecosystem*' and may have a relevant application in '*Protect a minimum of 30% of the EU's sea area*'.

Knowledge Output Reference Number: 789059 – KOd
Knowledge Output Title: *Prioritization of Cystoseira restoration sites in the Mediterranean Sea*
Project link: http://afrimed-project.eu/

Knowledge Output Description:

Background:

Cystoseira sensu lato assemblages are being considered as habitats of critical importance for the EU (Directive 92/43/EEC; Annex I, included in "Rocky reefs") and as indicators to assess ecological status (WFD; Directive 2000/60/EC). There is a growing focus on the status of macroalgal forests from restoration perspective (with MERCES and AFRIMED projects) to better understand the possibilities for reversing current declining tendencies in the Mediterranean Sea.

Choosing restoration sites strategically can enhance effectiveness and return on investment in large-scale maritime ecosystem restoration, despite limited attention to spatial planning in the maritime environment, which often prioritizes economic interests over environmental goals (1).

Technical description:

While the Marxan software is the most extensively used open-source decision-support tool in conservation (2), it remains considerably constrained in its applicability to restoration, with predominant usage in terrestrial and freshwater environments. Originally developed for creating networks of protected areas that fulfil multiple ecological, social, and economic criteria simultaneously, Marxan combines advanced conservation science with human activities, facilitating a constructive dialogue between scientists and decision-makers.

As the context (degree of human impact, ecosystem type, habitat) of where the restoration activity is undertaken, occur often holds more significance for success than the specific restoration methods employed (3), the AFRIMED project, for the first time, carried out a prioritization analysis of *Cystoseira* spatial restoration efforts on a regional scale in the Mediterranean Sea. This assessment was based on specific eligibility criteria through Marxan software, including the historical presence of the habitat or species to be restored, the suitability of present and future environmental conditions, and the cost-effectiveness of restoration measures.

The Mediterranean area was defined using Planning Units (112,539 PUs, with a resolution of 400$\boldsymbol{m^2}$). Areas unsuitable for restoration actions (suitability of restoration < 0.61 through *High Suitability Models, HSM*), with high frequency of Sea Surface Temperature Anomalies (SSTA) (data from NOAA's Environmental Modeling Center database) and where forest are already present were not considered in the analysis, for a total of 70,410 PUs removed.

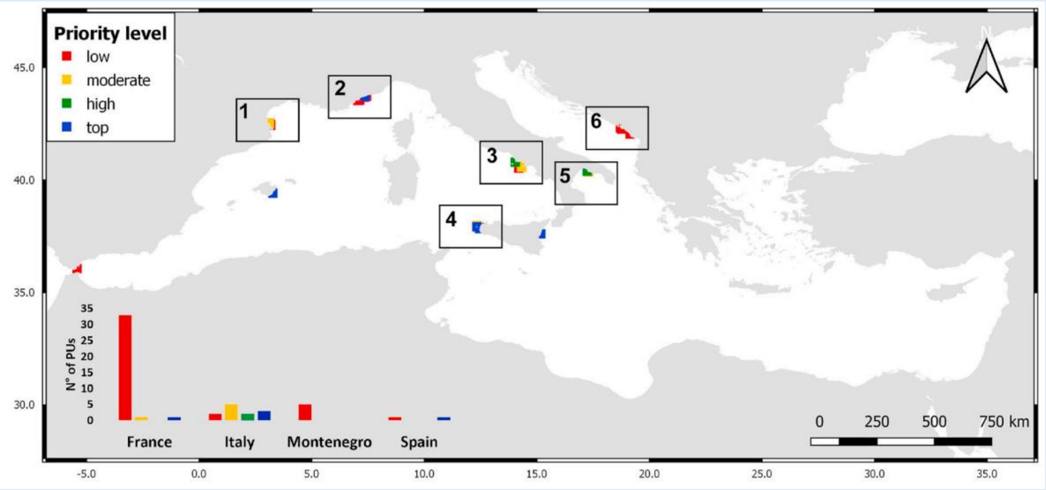
The identification of areas to be targeted for restoration efforts was achieved through a comprehensive literature review and the collection of new data as part of the project's objectives (4) to be then classified as Regressing forests (Rf) or Extinct forests (Ef); each of these forests was further classified depending on the level of Habitat Richness (HR). This classification yielded four distinct restoration features: Rf in high HR, Rf in low HR, Ef in high HR, and Ef in low HR.
In the analysis was also considered the costs of restoration of each PU:

$$PUc = Rc + (\overline{PUf} \times 0.40\ )$$

where *PUc* is the cost estimated for a PU, *Rc* is the average between in-situ and ex-situ restoration costs for a surface area of 25$\boldsymbol{m^2}$, $\boldsymbol{\overline{PUf}}$ is the distance between the PU and the nearest facility for restoration in km and *0.40* is the cost of transports per km (€/km).
By considering the selection frequency (i.e., how often a PU is chosen out of 100 runs) for each PU as an indicator of its comparative importance and evaluating different scenarios (*A. restoring 10% of forest in high HR and 5% in low HR without considering the HSMf and B. considering the HSMf; C. restoring 10% of forest in high HR and 10% in how HR without considering the HSMf and D. considering HSMf; E. restoring 30% of forest in high HR and 20% in how HR without considering the HSMf and F. considering HSMf*), the priority ranking of the selected areas was identified: low priority (1-25%), moderate priority (26-50%), high priority (51-75%), top priority (76-100%). The overlaps identified by comparing the PU selection frequency in pairs between scenarios without HSMf and those

with the HSMf (e.g., scenario a vs. scenario b, scenario c vs. scenario d, scenario e vs. scenario f) indicate areas of consensus, serving as a validation for the classification obtained from each individual scenario. 54 areas across the Mediterranean basin were identified as consensus areas and only 5 PUs resulted with top priority (3 in Italy, 1 in Spain and 1 in France).

The image below illustrates the distribution of consensus areas identified in the first pair of scenarios (scenario a and b), the only ones where all targets were successfully met.



The prioritization map is already used by the project partners as a baseline to support the selection of restoration areas for *Cystoseira* forest (TRL 8).
The approach is groundbreaking in the field of restoration, marking the first instance where a prioritization approach has been applied to evaluate the suitability of areas for restoration activities. This innovation enhances the effectiveness of these actions, incorporating cost assessment as a crucial component in the selection of sites.

Potential Impacts and Applications
The prioritization analysis has potential commercial exploitation in that it may be uptaken by enterprises operating in marine restoration to determine which areas satisfy the requirements for restoration measures.

The data employed in the analyses, coupled with the cost assessment to demonstrate the practical viability of restoration efforts, constitute pivotal components in guiding the prioritization process. They offer valuable insights for pinpointing suitable restoration objectives.

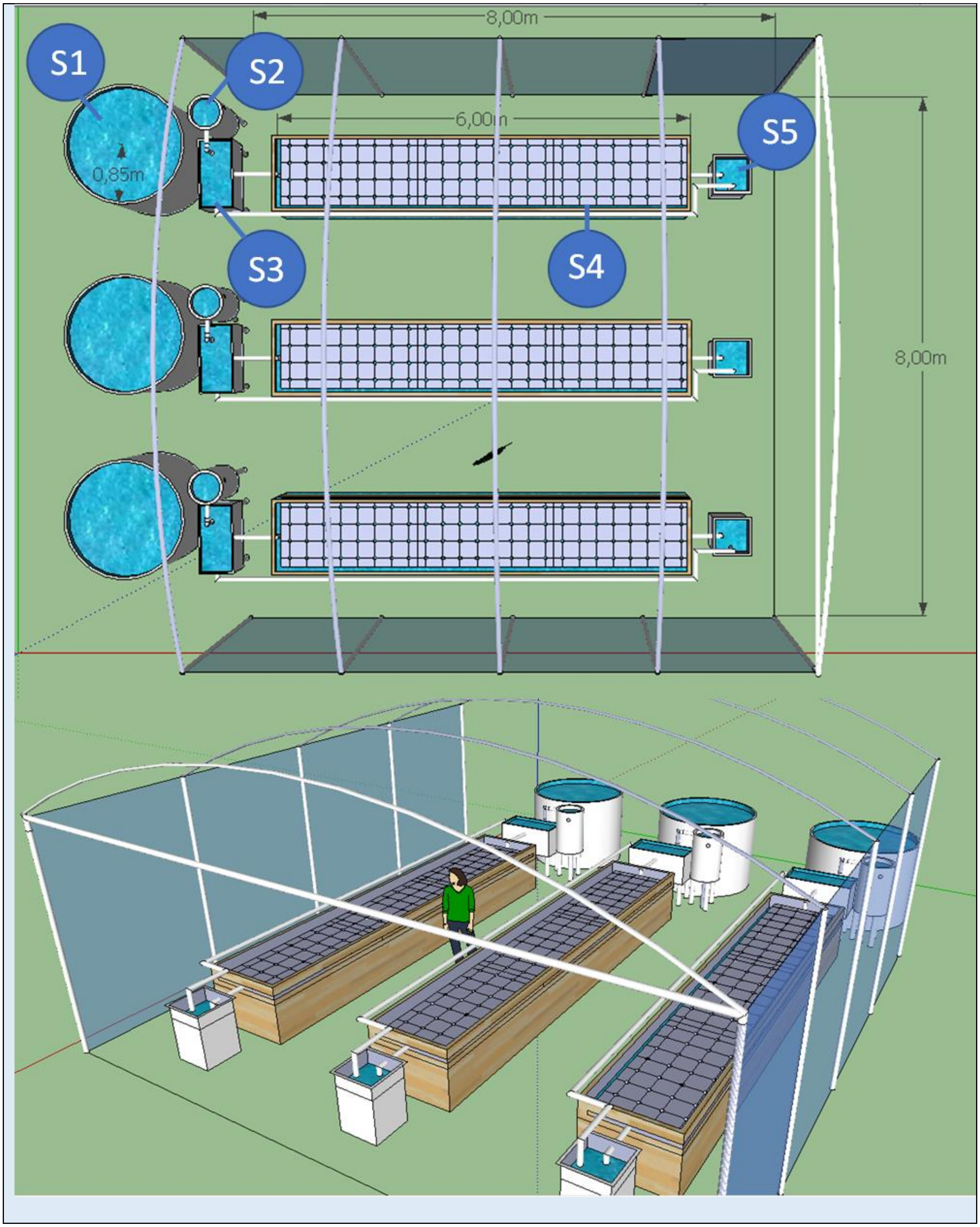
Other than that, the main use that can be made is to provide policymakers with an overview of priority areas both for restoration activity but also to implement new protected areas since macroalgal forest provide several key ecosystem functions (nursery, feeding, etc.) and services (fishing, leisure, etc) that enhance biodiversity in the area in which they are located.

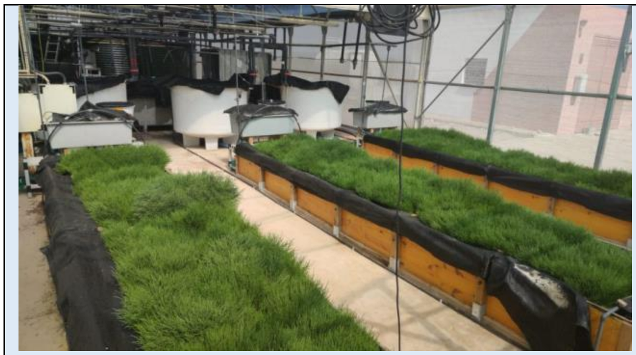
Other possible applications include pre-assessments on carrying out restoration measures and assessments related to spatial planning.

These possible applications of the prioritisation analysis contribute directly to the first Mission objective, to "Protect and restore marine ecosystem and biodiversity", in particular the restoration plan can '*Contribute to relevant upcoming marine nature restoration targets, including degraded seabed habitats and coastal ecosystem*' and may have a relevant application in '*Protect a minimum of 30% of the EU's sea area'.*

Knowledge Output Reference Number: 862658– KOf

Knowledge Output Title: *Eco-intensification of inland fish farming systems through saline aquaponics*
Project link: *https://cordis.europa.eu/project/id/862658*
Knowledge Output Description (about 1 page): **Background** *Saline aquaponics follows the principles of circular economy and can potentially alleviate the stresses of increasing soil salinization freshwater scarcity, particularly in coastal regions. However, despite the beneficial outcomes of such technique (e.g. ~17% water reduction over conventional aquaculture, minimal nutrient discharge by reutilizing 52 to 95% of nitrogen and 85% of phosphorus, etc.), very little research has been done.* **Technical description** *NewTechAqua along with IRTA have designed an aquaponic system with the flounder (Mugil cephalus), an omnivorous fish exploited mainly for recreational and professional fishing. In a first phase, the system was tested by growing lettuce and over 90kg were harvested in only three months in 18 m^2. After ensuring the proper functioning of the system, in a second phase glassworts (Salicornia sp.) is grown, harvesting ~250 kg (see harvesting video).* *The aquaponics system is based on a multi-tank system:* *1) Saltwater tank: M. cephalus fish are fed on species-specific fish feed.* *2 The experimental system used in the current study is composed of three replicate aquaponic units within a greenhouse. Each aquaponic unit is comprised of a 2,000 L cylindroconical tank where fish are hold (S1); followed by a sedimentation tank were suspended particles (uneaten pellets and fish faeces) are settled and removed (S2). Then, underground fresh water passes to a biological filter tank (125 L) full of bioballs where ammonia is converted into nitrites and nitrates by the action of nitrifying bacteria (S3). After this, water flows by gravity to the hydroponic unit (S4) (1.2 x 6.0 x 0.45 m, width x length x height; surface = 7.2 m2; functional water volume = 2.9 m3) where plants are supported in polystyrene rafts covering the whole surface of the hydroponic unit. At this level, strong aeration is provided by an air blower (0.3 Kw h) to provide enough oxygen for the growth of plant roots. Finally, water is returned from the hydroponic unit to the fish rearing tank with a water pump (0.1 Kw h) (S5). The whole volume of each aquaponic unit was 5 m3. No thermal control was provided neither for the aquaponic water or the greenhouse air, thus water and air temperature were ambient. This was an intentional choice to reduce running and maintenance costs, as well as promoting the transference of this farming technology to rural or underdeveloped areas.*


8,00m
S1
S2
6,00m
S5
0,85m
S3
S4
8,00m

The results show a two-way beneficial outcomes for both the plants and the fish. Regarding the yield of the halophyte plant Salicornia spp., plants in all systems grew very well with survival rates higher than 95% in all cases. The final yield (plant biomass) per aquaponic unit ranged from 43.1 to 50.1 kg (6.7-7.8 kg/m2). In particular, the increase in plant biomass from the beginning to the end of the trial ranged from 290 to 346 times. Salicornia sizes in weight in Unit 1 ranged from 100 g to 3,080 g with a mean value of 732 ± 601 g, in Unit 2 sizes ranged from 76 g to 3,000 g with a mean value of 811 ± 590 g and in Unit 3 sizes ranged from 20 g to 5,292 g with an average value of 678 ± 763 g.

Potential Impacts and Applications

Glassworts is a halophilic species under protection in some countries (i.e. Spain) with high gastronomic value due to its intense salty taste. Hence, aquaponics could be an alternative enabling the continuation of the use of this plant in the culinary world with food safety conditions while wild populations are sustainably managed.

The energy cost (kW) for running each aquaponic unit based on the consumption of the water pump (0.1 kW/h/unit) and air blower (0.3 kW h/unit) for the duration of the trial (142 days) was estimated at 340.8 kW/unit for the water pump 1,022.4 kW unit. In total, each aquaponic unit consumed 1,363.2 kW, which represented an energy cost per kilogram of Salicornia spp. produced of 0.029 ± 0.002 kW/kg of the halophyte plant Salicornia spp. This KO is now at TRL 5 for Salicornia sp. and M. cephalus as it has been tested at lab conditions and qualified. By incorporating low-trophic level species in the aquaculture sector (e.g. salt-tolerant plants and crops) will directly contribute to MO3 target 2 as it also applies the circularity principle to reduce water waste, energy consumption and, therefore, minimizing the C emissions form the traditional aquaculture activity (which will be reinforced by the photosynthesis process of the grown glassworts. Moreover, reducing the use of water in the culturing tanks, but also the effluent discharge accumulation through phytoremediation or microbial processes that mineralize nutrients for the plants which could indirectly contribute towards Mission Objective (MO) 2. It will additionally alleviate soil salinization allowing for longer-lasting agricultural adaptation to climate change and improving food production.

Coupled aquaponic systems (freshwater or marine) are a sustainable strategy for the combined production of fish and plants (lettuces and Salicornia spp.) with a minimal use of water (<5% of water renewal), an efficient use of land and water, and a reduced cost in terms of electricity (aquaponics are four times cheaper in running costs than RAS units). Furthermore, growing plants coupled to fish rearing provides a sustainable economic profit to the fish farmer by producing a high quality fresh product to the consumer. Present results indicated that this technology might be applied to commercial, or community based urban food production, industrial scale production in rural areas, small scale farming in developing countries (backyard aquaculture systems) or as systems for education as different studies have postulated.

Finally, although no studies have emphasized greenhouse gas emission reductions from saline aquaponics, a 72% reduction in GHG emissions have been described in freshwater lettuce aquaponics[1]. It is, therefore, expected that saline aquaponic systems may have similar GHG reduction potential[20] and, thus, contribute to MO3 target 1.

Knowledge Output Reference Number: 862658– KOg
Knowledge Output Title: *Precision model to map chlorophyll-a concentration in shallow water for the shellfish aquaculture industry*
Project link: *https://cordis.europa.eu/project/id/862658*
Knowledge Output Description (about 1 page): **Background** *The estimation of chlorophyll-a (Chl-a) concentration in coastal waters still has some difficulties in comparison to oceanic waters due to the more complex optical properties and to the high spatial variability of the coastal environment. Atmospheric and scale corrections are necessary to remotely and accurately estimate Chl-a concentration in coastal waters, which is of main importance to evaluate the viability (based on the environmental status of water masses) of integrating bivalve (i.e., mussel) aquaculture systems in marine spatial plans; the objective of these carrying capacity models is to adapt the production to the ecological conditions of the area.* **Technical description** *A shellfish farm may exceed the ecological carrying capacity when the removal of phytoplankton biomass exceeds the renewal, resulting in a phytoplankton depleted water mass. To comply with the Aquaculture Stewardship Council (ASC) on bivalve aquaculture standards, the renewal time of each area has to be shorter than the clearance rate time. Thus, NewTechAqua, through a series of sampling cruises (n = 17) for over a year (September 2020 to October 2021) in the northern (n = 9) and southern (n = 8) embayment of the Ebro Delta (eastern Iberian Peninsula), developed a highly innovative methodology to increase the accuracy of forecasting Chlorophyll-a concentration models to estimate the best suitable placement for sustainable shellfish aquaculture farms following the ASC bivalve standards. To do so, NTA combined the use of satellite remote sensing (based on Sentinel-2 (S2) weather forecast data), in situ sampling (bottom depth, Secchi disk depth (ZSD) and profiling surface sweater temperature and salinity using a SeaBird19plus CTD, water samples were also taken for chlorophyll-a analysis), and carrying capacity models as a tool for helping the low trophic aquaculture industry to expand their activities to new suitable areas.* *The Sentinel-2 (S2) constellation consists of two satellites (S2A and S2B) operated by The European Space Agency (ESA). Each satellite has on-board the MultiSpectral Instrument (S2-MSI). The S2-MSI Level-1 (L1C, Top of atmosphere) imagery includes 13 spectral bands centred at different wavelengths from 443 nm to 2200 nm with different spatial resolutions (10, 20, and 60 m).* *Downloaded images from Copernicus (between 1 October 2019 and 30 September 2021) were visually checked for clouds and shadows (62.5% rejection) and were further processed through an off-the-shelf Graphic Processing Tool based on a multi-sensor per-pixel artificial neural network (NN) method. The parametrization for the atmospheric correction of each image included: (a) pressure (hPa) from NCEP/DOE Reanalysis II data provided by the NOAA PSL, Boulder, Colorado, USA; (b) atmospheric ozone (O3?) in Dobson units (DU) from the Aura OMI NASA dataset.* *A procedure to select match-ups between chlorophyll-a concentration measured from water samples and the satellite processed images included:* *- Selection of 3 × 3 pixel windows centred at the in situ measured coordinates for each date and location.* *- Quality check and removal of flagged pixels (e.g., negative remote sensing reflectance, windows with less than 5 remaining pixels, etc.).* *- Spectral indices in the form of band combinations were computed for valid Rrs match-ups.*

[20] https://doi.org/10.1016/j.aquaculture.2022.738173

- Chlorophyll-a models (various types: linear, polynomial, logarithmic, etc. tested and evaluated) were developed using 70% of the data used for calibration and 30% for validation.

As a result, NTA provides an innovative algorithm from satellite images for high-resolution detection (20 m) of Chl-a in shallow areas in Mediterranean (the spatial resolution of other available products is 300 m-1000 m and most of them do not cover shallow areas such as the nearshore area of the Ebro delta); so providing accurate and better information, than the information available free of charge on the Copernicus Marine Environment Monitoring Service or other free access portals. The proposed methodology can be reproduced using open-source tools (e.g., SNAP software), enabling end-users to obtain their own maps of chlorophyll-a concentration from Sentinel-2 satellite images with an estimated accuracy of over 70% which allows to rank the suitability of the different areas for shellfish aquaculture (for other nearshore areas, the products have an accuracy of 48 - 63 %).

Potential Impacts and Applications

This KO is now at MRR1 for the Delta del Ebro estuary as case study. This methodology shows the potential of the combined use of satellite remote sensing, in situ sampling, and carrying capacity models as a tool for helping the low trophic aquaculture industry to expand their activities to new suitable areas and, therefore, closely linked to Mission Objective 3, target 1: "Develop zero-carbon and low-impact aquaculture, and promote circular, low-carbon multi-purpose use of marine and water space". The methodology used help policy-makers on the decision making process by providing science-based information to marine spatial planners to identify the best and suitable areas for shellfish aquaculture, minimizing environmental impacts and maximising sustainability of the activity.

Knowledge Output Reference Number: 817737– KOa

Knowledge Output Title: *Multiplatform tracking and wireless communication system enabling precision fish farming and ecosystem welfare*

Knowledge Output Description (about 1 page):

Background

The fish farming industry needs instruments that can monitor in real time fish health and welfare objectively. The Internet of Things (IoT) can contribute to the development of sustainable and resilient aquaculture systems that ensure profitability, maintain healthy aquatic ecosystems and strengthen the capacity of the sector for adaptation to climate change.

Technical description

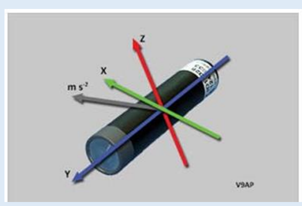
In the framework of the FutureEUaqua project, COISPA Tecnologia & Ricerca (a non-profit cooperative partner of the project) developed and tested this multiplatform tracking and communication system for simultaneously monitoring the activity and physiology of fish, as well as the main parameters of the environment where they are farmed, by using a wireless communication system. This way a real-time interaction between farms and farmers will allow a rapid adaptation of actions towards a science-based decision-making process.

Enhanced environmental (e.g. oxygen, temperature, salinity, pressure) and biological (e.g. behaviour, activity, energetic, feeding physiology) data, collected by a network of wireless electronic sensors, can provide accurate fine-scale measurements of environmental conditions, fish health, welfare and habitat use, thus facilitating predictive modelling of the rearing performances and impacts.

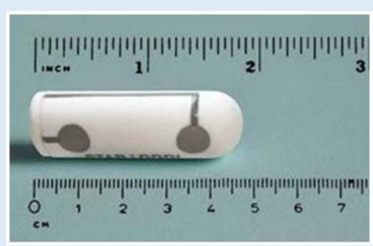
The real-time wireless communication system and sensor network envisaged for the FutureEUAqua large scale demonstration activities is the result of integrating several technological solutions to isolated demands in an innovative way. The system includes a cloud platform that communicates wireless underwater, based on the technology offered by Real-time aquaculture (www.rtaqua.com) and "AquaMeasure" (a family of compact, submersible environmental off-the-shelf sensors, with underwater and in-air wireless communications) such as AquaMeasure DO (dissolved oxygen), SAL (salinity), Turbidity, and Current. While the "AquaHub" is the core of the system deployed in the field and it detects underwater communication from nearby sensors communications (up to 100 AquaMeasure sensors within a 500m radius). The hub also supports many telemetry protocols for cloud, including Cellular, Wi-Fi and Iridium, as well as the V9AP & V13AP accelerometer pressure tags. The wireless hub also supports third-party sensors, like weather stations, via its auxiliary sensor port. The data is transmitted through a wire on a gateway device place on the surface of the cage and will be sent over the internet (4G connection) to a cloud server that will process the data and store the results enabling data-driven ocean farming where knowledge drives better decisions. The end-to-end system architecture is illustrated in the image below.

In their most basic form, electronic sensors and tags may include radio or acoustic beacons that transmit signals, which can bring specific codes to identify animals, and allow them to be tracked using receivers that detect the transmitted signals. Because the strength of radio signals rapidly attenuates in sea water, acoustic transmissions are preferred for fish tracking in marine environment, while radio transmission is commonly used in fresh water environment. More advanced tags incorporate sensors that measure and record a suite of environmental and/or biological parameters of fish, for instance:

- Accelerometer pressure tags transmit 3D acceleration of fish as they move within the receiver array, and also transmit depth data. The fish acceleration signal is measured in terms of m/s-2 and it is a vector quantity that is a result of measuring acceleration on 3 axes (X, Y, Z). This acceleration value can be used as a measure of activity of a free ranging animal in nature or captivity. Accelerometer tags can be used in a number of applications that require any measure of animal activity. Applications may include measuring swimming speed via tailbeat acceleration, detecting mortality through predation, seismic blasting, toxic spills, feeding events, spawning activity, nocturnal/diurnal activity, wave action and activity responses to changing oxygen, salinity and temperature in the environment.

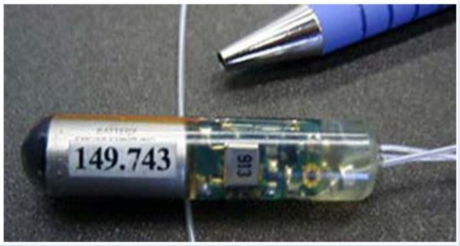


- Heart tag simultaneously monitors heart rate and temperature in the fish. The data logger has no external wires, which makes it especially simple to implant. It is made of unique ceramic housing and epoxy and is hermetically sealed, guaranteeing biocompatibility. The logger is ideal for monitoring behaviour and stresss response of the fish. The heart rate is derived from a leadless single channel ECG. The logger takes a burst measurement of ECG at the set time interval and calculates the mean heart rate for each recording. For validation purposes, individual ECG bursts can be saved.



- Electromyogram tag measures muscle activity using probes inserted into the musculature of the fish. The tag provides a powerful quantitative estimate of the energetic costs associated with physical activity. High impedance

EMG signals are processed through an integrator, digitized and then a coded radio sequence is transmitted representing unique identity and data. Electromyograms (EMGs) are records of bioelectric potentials that are strongly correlated with the strength and duration of muscle contractions. Indeed, EMG values averaged over time can be used directly as quantitative indicators of the intensity of fish activity.*



Before the large-scale demonstration, a baseline of information for the target species (i.e. gilthead seabream and seabass) was needed. Therefore, piloting tests were performed to evaluate the technology to be used as a reliable welfare indicator, not disrupting fish physiology, behaviour and performance. No significant differences in swimming performance, metabolic traits, and swimming efficiency between the tagged and untagged fish (see here). The objective was to find a calibration model of the tailbeat tag activity as a function of the i) critical swimming speed, ii) oxygen consumption and metabolic rate, iii) electromyograms. Less availability of anaerobic energetic reserves has consequences for the reactivity of stress systems, reflecting on a reduced ability of the fish to compensate stressful events. The calibration tests provided FEAq a model to assess fine-scale measurements of the fish physiological state and the ability to cope with stressful events.

Similarly, the telemetry was evaluated at COISPA laboratories in swimming chambers used to measure the physiological performances of fish. During these tests, in addition to other metabolic parameters, it was possible to measure the swimming ability, the energy budget available to face the challenges, the oxygen consumption, and the recruitment of the red and white muscles (aerobic/anaerobic activity). The fish was placed in a tube where the speed of the water could be adjusted, forcing the fish to swim upstream in different speed (see here and here).

Potential Impacts and Applications

Understanding the impacts of environmental change and human activity on farmed fish can be greatly enhanced by using electronic sensors. Enhanced biological (e.g. behaviour, activity, energetic, feeding physiology) sensor data, collected by on-board electronic tags provide accurate fine-scale measurements of fish health and welfare during the large-scale demonstration activities in the project. This integrated and interdisciplinary approach to monitor the activity pattern and physiological status of farmed fish, together with the environmental parameters in situ, will enhance the sustainability and profitability of the European aquaculture. The whole system was tested at Kefalonia aquaculture farm and, therefore, has reached a TRL7.

This KO is largely related to Mission Objective 3: "Develop zero-carbon and low-impact aquaculture, and promote circular, low-carbon multi-purpose use of marine and water space" as it will provide aquaculture facilities less dependency to in-situ monitor visits, reducing the displacements and fuel consumption, as well as the operational costs of staff and supplies. Accordingly, it also reduce the impact of aquaculture activity in the ecosystem and, therefore, influencing on MO1 and MO2.

Knowledge Output Reference Number: 783773– KOa
Knowledge Output Title: Cleaning multitask catamaran to clean oceans and waters surfaces fighting against any marine pollution capable of recovering hydrocarbon spills, microalgae harmful and algal blooms, dealing with marine debris, plastics and microplastics in open and confined waters.
Project link: https://cordis.europa.eu/project/id/783773
Knowledge Output Description:

The OC-Tech cleaning multitask vessel is the only multi-target cleaning technologies system capable to clean oceans and waters surfaces against three huge targets: 1. Biological contamination (e.g. micro- and macro algae and jelly fish plagues); 2. Solid debris (e.g. micro- and macro plastics and other debris); 3. Oil spills (e.g. hydrocarbons Standard fuels, fossil- or plant-based, very low sulphur fuel oil, high low sulphur oil, etc.).

Without chemical products, the OC-Tech cleaning system (proven in operational environment and placed under the deck of the vessel), can be fitted on any OC-Tech catamaran vessel and has the potential to be useful for cleaning any marine pollution separately (solid marine litter and oil spill).

The break-through innovation is the multi-target cleaning system that can clean and storage marine pollution in a continuous non-stop process (>8h/day), and with an efficient waste and spill output rate of several tons/hour.

Ocean Cleaner Technologies S.L. builds and commercializes the OC-Tech cleaning multitask catamaran that is ready to use, OC-Tech cleaning system equipped and fit-for-purpose designed.

The fact that OC-Tech has multi-target cleaning functions, all at highest efficiency, functioning at the same time goes beyond the State-of the Art.

It is the only cleaning system vessel currently in the market, providing the combined following characteristics:

- Cleaning daily > 12h non-stop between 2 and 4 knots in open and confined waters, without the need to constantly return to port to unload solid waste or oil spill.
- Without chemical products, mechanical cleaning in-situ with separation and collection of solid and liquid surface pollution.
- Real-time separation of solid and liquid contamination, ready to boost recycling in a blue circular economy.

Another advantage over other systems is that the OC-Tech cleaning catamaran can clean and recover surface contamination very efficiently and effectively in conditions of moderate surge/swell/waves.

The OC-Tech system was brought to TRL9 by means of the H2020 SME instrument in 2019, and was successfully tested in operational environments around the coast of the Tenerife island cleaning up toxic microalgae bloom.

From 2021 to today, the OC-Tech Horizon catamaran performs weekly cleaning (solid waste and small oil spills), in the port of Cádiz.

In September 2022, the OC-Tech clean-up vessel was once again successfully proven in operational environments, participating for several days in the collection of different oil spills (including very-low sulphur fuel oil (VLSFO)), from the OS-35 bulk carrier sunk in the Strait of Gibraltar.

The OC-Tech technology is currently taking the step to international commercialization and has been introduced into the market with two sales to the Canary-Islands' Autonomous Region's Government, therefore, it can be considered at TRL9 and BRL9.

As new challenges, the following further scale-out applications are envisioned for which the OC-Tech does not require much more development (TRL6-8):

1. For a very quick answer to an oil spill emergency, our 'Rapid' foldable OC-tech equipped vessel, for fast transportation, including via land for early response to environmental accidents, including to inland water bodies (TRL8).

2. For a huge plastics or algal blooms pollution, our floating solids chaining cleaning system can temporarily confine a large amount of floating solid waste avoiding debris from getting on the catamaran (TRL6).

Knowledge Output Reference Number: 863584 – KOa
Knowledge Output Title: Reference microbial gene-Catalogue of polluted marine sediments
Project link: https://mer-club.eu/
Knowledge Output Description: **Background** Understanding marine mercury (Hg) biogeochemistry is crucial, as some of the transformations mediated by environmental microorganisms generate highly toxic mercury species that are incorporated in the marine food web, reaching humans through fish consumption. The Methyl Hg is bioaccumulated along the food-chain, with increasing Hg concentration per trophic position (i.e., larger predatory fishes contain more Hg than their smaller fish prey). In the case of Hg, this is of special concern because high Hg concentrations in fish commonly consumed by humans have negative health effects.[21] Low Hg doses from the consumption of fish have already shown an influence on the nervous system.[22] Microorganisms also mediate other relevant transformations of this metal, such as the reduction of inorganic Hg to elemental Hg, which is volatile and is released to the atmosphere. Although ocean sediments represent an important global repository of Hg, studies on microbially-mediated Hg transformations in this system are still rare.[23] In order to tackle the problem at the source of the food-chain, novel potential solutions for decontamination of marine sediments need to be studied, such as the identification of bacterial isolates and consortia with potential for Hg bioremediation in the microbiome of sediments. **Technical description** Mercury can be found in different chemical species, and associated with different compounds in the sediments, so the bioavailability of this metal is difficult to measure. As described on the MER-CLUB website (https://mer-club.eu/) bacteria harbouring ***merB*** genes demethylate MeHg, converting it into the ionic form Hg^{2+}, while bacteria harbouring ***merA*** genes can reduce Hg^{2+} to elemental Hg^0. The Hg^0 form is volatile and is released to the atmosphere, although in bioremediation applications it can be captured in e.g., activated carbon filters. However, as previous research on Hg biogeochemistry in marine sediments is very scarce, there is a lack of knowledge of the bacteria involved in each of these steps. Thus, the development of a first-of-its-kind microbial Reference gene-catalogue of marine sediments was needed to identify the microbial players potentially involved in these processes. For the identification of the Hg bioremediating bacteria, a first step was to analyse the gene content of the microorganisms living in the sediments to understand which ones were related to the processes of Hg-

[21] See https://mer-club.eu/
[22] See Frontiers | Mercury Accumulation in Marine Sediments – A Comparison of an Upwelling Area and Two Large River Mouths (frontiersin.org)
[23] See Frontiers | Mercury Accumulation in Marine Sediments – A Comparison of an Upwelling Area and Two Large River Mouths (frontiersin.org)

transformation/detoxification and assign them taxonomically. To this aim, microbial biomass from different sediments was retrieved to isolate DNA and build entire genomes from the microorganisms. Surface coastal sediment samples were collected in the Baltic, Mediterranean and Atlantic basins (representing diverse conditions of e.g., salinity and oxygen levels), to analyse diverse microbial communities. The largely unexplored diversity of Hg detoxifiers in the contaminated marine sediments collected was studied by high-throughput sequencing. Omic tools were used (meta-genomics and -transcriptomics, Single-cell Amplified Genomes) to identify genes of microorganisms involved in Hg-detoxification. In this way, a large proportion of novel genes involved in Hg detoxification from the microbiome of marine sediments were identified.

A comprehensive catalogue of 16 million non-redundant genes from microorganisms of marine sediments has been developed, representing the first database (DB) of Hg detoxification genes from marine sediments.

Potential Impacts and Applications

This catalogue is the first step needed to identify potential bioremediators of Hg-pollution in sediments. The DB enables the identification of microbiomes with Hg-detoxification capabilities, which can then be used to 'contribute to relevant upcoming marine nature restoration targets, including degraded seabed habitats and coastal ecosystems' (Mission Objective (MO) 1 target 4) and 'prevent and eliminate pollution of our ocean, seas and waters' (MO 2).

The DB and corresponding publications will be published soon as online open-source repository. As the sediments collected were polluted not only by Hg but by other sources, this Gene-catalogue builds the basis for further identification of micro-biomes potentially associated with the remediation of different pollutants (e.g., other heavy metals, hydrocarbons, fertilizers, pesticides or other dissolved chemicals, just to name a few). Thus, the screening of genes potentially involved in the detoxification of some of these compounds could be analysed in this database, beyond the detoxification of Hg, which was the focus in MER-CLUB.
Further possible applications of the DB include ecological studies of the sediments, studies for pathogen control, monitoring etc.
Target users of the database are other research groups, but potentially also Bio-tech companies with trained personnel could make use of the gene-DB.

Knowledge Output Reference Number: 863584 – KOc

Knowledge Output Title: A prokaryotic isolate and a microbial consortium inhabiting marine sediments with mercury (Hg) detoxification capacities for bioremediation.

Project link: https://mer-club.eu/

Knowledge Output Description:

Background
Mercury (Hg) is recognised as a substance producing significant adverse neurological and other health effects. The EU sets human consumption tolerance level of 1.6 µg per kg body weight. However, low Hg doses have already shown influence on the nervous system.[24] Human activities over the past few decades have led to massive increases in Hg concentrations in the biosphere. Hg is highly persistent in the environment, and can travel over long distances in the atmosphere to be deposited at distant locations from the source. –Marine waters and sediments represent Hg repositories, with this metal affecting all living forms and bioaccumulating across the food chain. However, some microorganisms have the ability to detoxify this pollutant. By instance, bacteria harbouring ***merB*** genes can demethylate soluble MeHg, converting it back into the ionic form Hg^{2+}, while bacteria harbouring ***merA*** genes carry out a further step in mercury detoxification, by reducing the ionic form Hg2+ to elemental Hg^0.

Technical description

[24] See https://circabc.europa.eu/ui/#

In the project MER-CLUB an extensive effort has been carried out to create a culture collection (MER-CLUB culture collection, MERCC) with currently more than 2000 isolates and microbial consortia from polluted marine sediments. A large fraction of these isolates has been screened to identify those with Hg detoxifying capacities. As a result, an isolate and a consortium were selected as the best candidates for this application. These bacteria can:

- reduce mercury levels ***in vitro*** (so far in culture media, lab scale) >70%* in 24 hours, and moreover,
- thrive in different conditions of oxygen (i.e. in aerobic and anaerobic conditions) and salinity (**0.5 and 30% NaCl)**
  c) can grow in bioreactors and be immobilized for their transport
  d) expand (so far in lab-scale for the isolate) in natural sediments with high density of indigenous bacteria.

Both, the isolate and the consortium, represent promising efficient and versatile potential solutions for Hg-bioremediation.

So far, most mercury detoxification solutions have targeted the decontamination of liquid waste from industrial sources, and do not necessarily rely on bacteria isolated from marine sediments. However, due to the high complexity of this environmental matrix, a more specific solution with indigenous sediment microorganisms, would be preferred for their decontamination. Moreover, currently applied decontamination solutions are typically based on physico-chemical treatments, which have as main drawbacks high costs and the production of chemical by-products. The isolate and consortia selected in MER-CLUB originate from polluted marine sediments and therefore, are well adapted to thrive in this environment. Bioremediation is a sustainable solution which can involve less costs and has the advantage of using environmental microorganisms as decontaminating agents. At the current stage of development (TRL3),the isolate and the consortium have been applied only in laboratory assays with Hg-enriched culture media. Additionally, the isolate has been also applied ex-situ in a pilot study with contaminated sediments, and the ability to expand and survive in the sediments over 30 days has been proved, although, so far low Hg detoxification activity has been measured in the pilot plant likely due to the low bioavailability of the Hg in the sediment tested and therefore the low access of the microbes to the metal. In the future, optimization of the detoxification process in the pilot plant needs to be attained for a successful ex situ application. plant

The objective in this project is to reduce the total amount of mercury in treated sediments to acceptable levels according to European legislation. Further research will be needed to also analyze the bioavailability of Hg and specifically how to increase it during the treatment to remove as much Hg as possible.

Potential Impacts and Applications

The objectives of Regulation (EU) 2017/852 of the European Parliament and of the Council on mercury and repealing Regulation (EC) No. 1102/2008 are to ensure a high level of protection of human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. Moreover, the Minamata Convention on Mercury is a global treaty to protect human health and the environment from the adverse effects of mercury which includes measures to control the supply and trade of mercury. These regulations target the reduction of newly released Hg. However, there is currently a lack of regulation and initiative towards remediation. Compared to established standards for water, air and to some extent soil quality, the ecotoxicological thresholds for polluted sediments are less defined in national and international legislation. Therefore, advancing the interdisciplinary science of sediments contaminated with chemicals released into the environment is of high societal relevance.[25] as well as finding novel solutions for mercury detoxification. To this aim, MER-CLUB obtained a prokaryotic isolate and a consortium inhabiting marine sediments with mercury detoxification capacities, reducing ca. 70% mercury levels in culture media in 24

[25] See Sediments: sink, archive, and source of contaminants | SpringerLink

hours.. Therefore, MER-CLUB provides novel microbial agents with potential for Hg decontamination on a bioremediation-based application.

The first target group are regulatory bodies/ policy makers/ public authorities that could enforce remediation of mercury released to the marine ecosystems. Simultaneously, target user will be the companies that are willing or enforced to remediate Hg released to the environment as a product of their industrial activities. Moreover, restoration organizations will be target-user to apply the remediation solution in polluted sites.
This will primarily 'contribute to relevant upcoming marine nature restoration targets, including degraded seabed habitats and coastal ecosystems' (Mission Objective (MO) 1), as well as (secondarily) to 'eliminate pollution of our ocean, seas and waters, in line with the EU Action Plan Towards Zero Pollution for Air, Water and Soil' (MO2).

It was found that Hg-polluted sediments also present high levels of other pollutants such as other heavy metals, hydrocarbons, fertilizers and pesticides or other dissolved chemicals. It is very likely that the identified Hg-detoxifying isolate and consortium or other members of the MER-CLUB culture collection are adapted to also remediate these other pollutants. This aspect could be explored in the future.

Preparing the Research & Innovation Core for Mission Ocean, Seas & Waters

Deliverable D4.2

Customized Knowledge Management Method for Mission Restore our Ocean and Waters.

A progress report, including lessons learned and high potential Key Exploitable Results relevant for the Mission

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