AQUARIUS Call Priority

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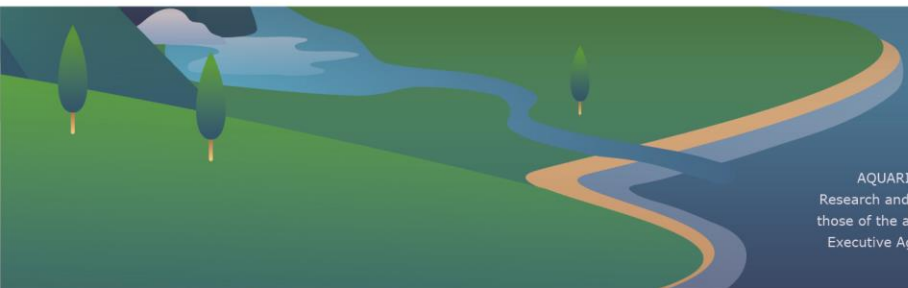

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1 Introduction

The goal of the AQUARIUS project is to provide Transnational Access (TA) to a wide range of research infrastructures to support high-impact and coordinated research in oceanic, coastal and freshwater ecosystems. AQUARIUS combines several different types of research infrastructures together for coordinated access and aims to analyse in advance the key research questions and challenges that can be supported by research projects that combine such research infrastructures. This planning requires a discussion of priorities and their definition, which are the main research subjects to be supported and how to ensure a link with other key European objectives.

From the beginning, AQUARIUS has been designed to promote and integrate research and innovation capabilities to support the development phase of the EU Mission "Restore our Ocean and Waters by 2030"[1], The European Green Deal[2] and international climate initiatives. Thus, when Transnational Access calls of AQUARIUS are planned, the research needs, data and knowledge gaps and other deficiencies already identified in the EU Mission "Restore our Ocean and Waters by 2030" need to be prioritised.

1.1 Identifying priorities for AQUARIUS TA calls

WP3 of AQUARIUS is designing, developing and managing the Calls for TA. As part of Task 3.1, we bring together scientists, RI representatives and other experts across Marine and Freshwater domains to identify the key research and innovation actions streamlining with the topical European initiatives for marine and water issues, from which the TA calls will be framed. To do this we must first analyse the challenges across Marine and Freshwater environments while considering the knowledge deficit and data gaps. Task 3.1 will work jointly with a Task 6.1 ("Analysis of data gaps"), which reviews availability of data. The final Call priorities will be iterated from the work of these two Tasks.

The overall goal of AQUARIUS is to support TA projects that integrate the use of multiple infrastructures and that have a significant impact on the realisation of the Mission's objectives. In addition, projects aligned with objectives of the Sustainable Blue Economy Partnership (SBEP), and the Green Deal are targeted. To ensure that the selected projects are truly impactful, the TA funding application process must have clear priorities to support the selection of projects to be funded. To guarantee this, the working group that sets priorities has included experts from all Mission Lighthouse regions and representing various disciplines and expertise (e.g. marine and freshwater, physics, chemistry and biology, various research infrastructure platform specialists).

In main part, the priorities have been identified from the materials available via Mission Ocean and Waters service portal and documents

- EU Mission Restore our Ocean and Waters Implementation Plan (EU 2021)
- Baseline study for Atlantic, Arctic, Danube and Mediterranean lighthouses (Alao Chanou et al 2023; Cappelletto et al 2021)
- Baseline study for the Baltic and North Sea basins lighthouses (Goba et al 2023)

In several points below, this document follows quite closely the wording of the reference documents and partly direct quotations have not been avoided. To keep the document readable, however, we have not used the general citation practice - almost every sentence would include a reference to one of the above publications. Of course, the responsibility

[1] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters_en
[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

for the interpretation of the Mission objectives and priorities, as presented in this document rests with the authors.

In this deliverable, for each Lighthouse region, we list a comprehensive number of priorities under categories of "Knowledge Gaps", "Scientific Challenges" and "Societal Challenges and Opportunities". These listings are derived and interpreted from the Mission documentation, and they form front-line topics, for the implementation of which the AQUARIUS research infrastructures can offer support via TA calls.

1.2 Introduction to EU Mission: Restore our Ocean and Waters

The objective of the Mission is to restore the health of our ocean and waters by 2030. The Mission is designed to deliver on the European Union's 2030 quantified and measurable targets for protecting and restoring ecosystems and biodiversity, for zero pollution, and for the decarbonisation and reduction of net greenhouse gas emissions towards climate neutrality, within the EU's ocean, seas and waters.

The Mission will pilot and test ground-breaking research and innovation to map, monitor, protect and restore biodiversity under adverse climate change and anthropogenic pressures. Building on the excellence of EU research and innovation and European research infrastructures, it will aim to regenerate the ocean and waters and reduce pollution through monitoring, assessment and then implementation of prevention, elimination, and remediation measures from source to sea. The EU's ocean, seas and waters are being degraded as a result of human activities. Often, necessary data for assessing the state of the environment are not available. The degradation of Europe's marine and freshwaters is mainly driven by three interlinked factors:

- Unsustainable exploitation of marine and freshwater resources and land/sea use
- Pollution affecting the water system from source to sea, notably plastics and microplastics, nutrients, chemicals, and underwater noise
- Human-induced climate change altering the physical and biological state of the ocean, seas, and waters and disturbing their ecosystems

This Mission will provide a systemic approach for the restoration of our ocean and waters, with following elements:

1. Set-up of 'lighthouses' for the major European sea and river basins, based on existing structures, as the Mission sites to promote basin-wide cooperation, commitment and deployment of solutions addressing the three Mission's objectives.
2. A core of scalable and replicable, excellent, and impact-driven research and innovation solutions (technological, business, social and governance) and demonstration activities tailored specifically for each of the three specific Mission objectives.
3. Scale up projects throughout European sea and river basins to achieve the Mission objectives and targets.
4. A digital ocean and water knowledge system including an environmental and biodiversity monitoring system to better understand, monitor and forecast the health of the water system as a whole and measure progress towards the targets of this Mission.
5. Public mobilisation and engagement: with tried and tested deliberative democracy mechanisms and social innovation practices, participatory governance approaches, mobilising and empowering citizens for the co-design and co-implementation of solutions.

The Mission will be implemented in two phases. In the first 'development and piloting' phase (2022-2025), foundations will be laid for the implementation of the three Mission objectives and enabling actions.

This will be complemented by new knowledge and data for monitoring and forecasting services, methodologies and pilots for biodiversity mapping, and new frameworks for citizen science and engagement, training, and education.

In the second 'deployment and upscaling' phase (2026-2030), the solutions developed and piloted in the first phase to deliver on the Mission objectives will be further deployed, replicated, and scaled up through rounds of open calls for scale up actions.

These scale up actions will see digital knowledge, monitoring and forecasting services implemented at a large scale.

Excellent and impact-driven R&I efforts will continue also in the second phase, by boosting the scale, scope and availability of the knowledge and data, improving monitoring and forecasting services, DNA sequencing, and mapping and modelling of biodiversity in a context of climate change and anthropogenic pressures.

1.3 Introduction to other relevant initiatives related to AQUARIUS TA calls

Besides EU Mission: Restore our Ocean and Waters AQUARIUS TA calls are streamlined to support the objectives of several other related international initiatives, like:

- **EU Marine Strategy Framework Directive** (MSFD)[3] facilitates protection of marine ecosystem and biodiversity, thus also contributing to human health and sustainable use of marine resources. The main goal of MSFD is to achieve Good Environmental Status (GES) of marine waters in EU. MSFD sets out 11 qualitative descriptors which are monitored as indicators of GES. MSFD is a backbone of many national and regional marine monitoring programmes.
- **Integrated Maritime Policy** (IMP)[4] of the European Union is a policy framework for sustainable development of all sea-based activities including following policy fields: Blue growth and blue economy, Marine data and knowledge, Maritime spatial planning, Integrated maritime surveillance, and Sea basin strategies. The aim of IMP is better and wholistic coordination of different policy areas.
- **European Digital Twin of the Ocean** (European DTO)[5] utilises real-time and historic data in a digital space and models simulating the ocean and its processes. Development of European DTO is done through several projects, some funded under the Green Deal calls. Though big data volumes already exist for various regions and disciplines, several topics will still benefit from new data collection.
- **United Nations Decade of Ocean Science for Sustainable Development 2021-2030**[6] is a framework to improve scientific knowledge and partnerships to better understand the world ocean system. The key outcomes include: A clean ocean, A healthy and resilient ocean, A productive ocean, A predicted ocean, A safe ocean, An accessible ocean and An inspiring and engaging ocean. The UN Ocean Decade supports transnational activities across the objectives and emphasises collection and open availability of new marine data.
- **The European Green Deal**[7] is a collection of policy initiatives which aim to make EU climate neutral in 2050. Several of the policy areas included have a marine

[3] https://research-and-innovation.ec.europa.eu/research-area/environment/oceans-and-seas/eu-marine-strategy-framework-directive_en
[4] https://www.europarl.europa.eu/factsheets/en/sheet/121/integrated-maritime-policy-of-the-european-union
[5] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters/european-digital-twin-ocean-european-dto_en#what-is-the-european-digital-twin-of-the-ocean
[6] https://www.unesco.org/en/decades/ocean-decade
[7] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

dimension, including priorities for protecting biodiversity, reducing pollution, moving towards circular economy, and ensuring sustainability of blue economy and fisheries.

- **The Sustainable Blue Economy Partnership**[8] is a grouping of 60 institutions and the European Commission to integrate research and innovation investments. It aims to restore ocean's health, resilience and services by boosting climate-neutral and sustainable economies. They will perform complementary actions with thematic programmes and research infrastructures and aim to streamline additional funding.

In principle, the objectives of EU Mission: Restore our Ocean and Waters are tightly linked to the ones of the abovementioned initiatives, with some obvious topic-wise and geographical differences in their emphasis. While the main priority of AQUARIUS TA calls is to support objectives of the Mission, any direct link to the objectives of these other initiatives is beneficial to the success of TA projects.

2 Definition of Regions in TA Calls

AQUARIUS follows the concept of Mission lighthouses, where EU seas and major river basins are divided into four regions: the Atlantic and Arctic basin, Baltic and North Sea, Mediterranean Sea and Danube River basin (Figure 1). The Lighthouses are the sites for piloting, demonstrating and deploying the Mission activities, thus also the regions for related AQUARIUS Transnational Access projects. The Lighthouse regions are briefly described below.

[8] https://bluepartnership.eu/

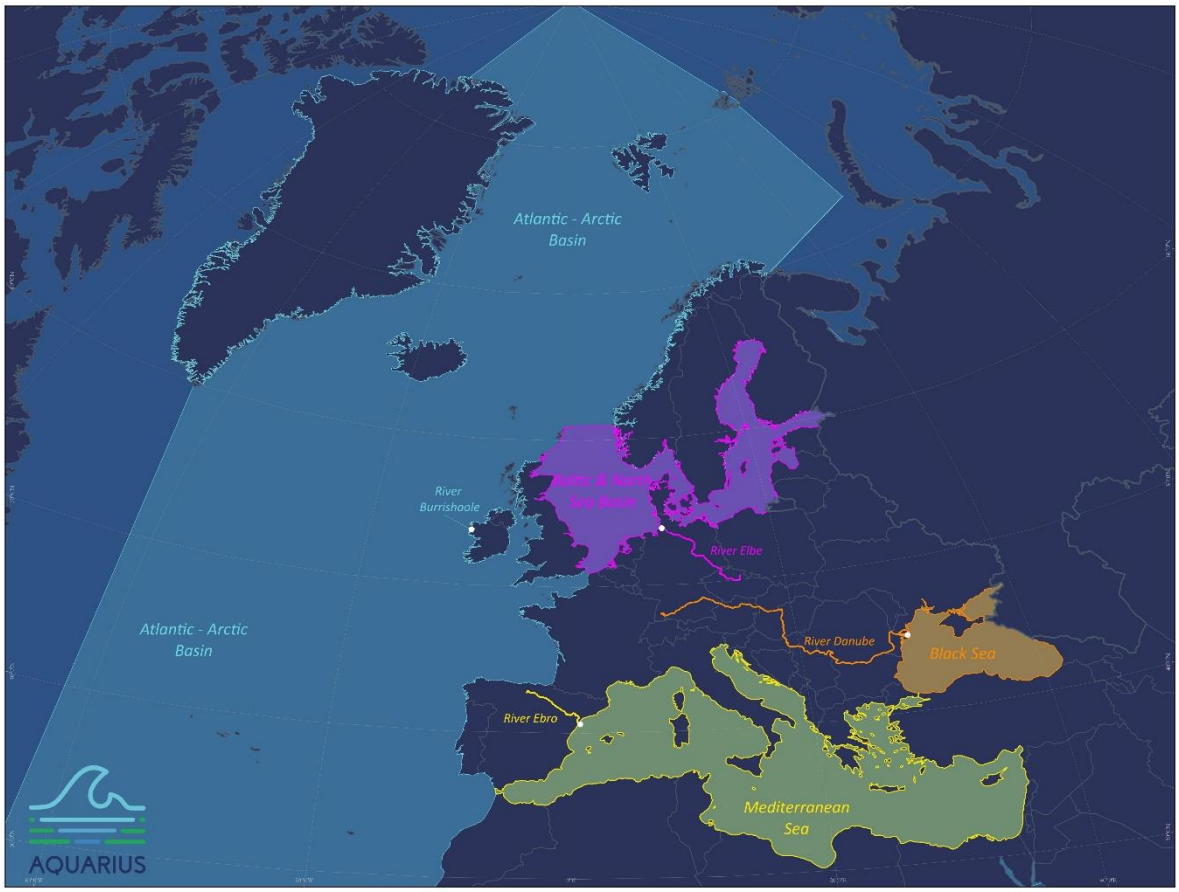

Figure 1. Regions for EU Mission "Restore our Ocean and Waters by 2030"

2.1 The Atlantic Basin

The region encompassing the Atlantic Basin is within the Atlantic Ocean. The Atlantic Ocean is the second largest ocean covering approximately one-fifth of Earth's surface and separating the continents of Europe and Africa to the east from those of North and South America to the west. The Atlantic Sea basin is situated at the western edge of the European continent. To the north, it is bordered by the Arctic Sea basin and to the south and west by the Wider Atlantic. The basin itself hosts four EU Member States: Ireland, Spain, Portugal, and France. The UK is also on its shores which includes Wales, West England, West-Scotland and Northern Ireland. It contains the Celtic Seas, the Bay of Biscay, and the Iberian Coast. Located from the latitude of Gibraltar encompassing the coastal seas of the Iberian Peninsula and Bay of Biscay, shelf seas to the west of Ireland and Scotland the Celtic Sea and English Channel. The offshore area covers to approximately the latitude of 42 degrees west to the south if Greenland and Iceland and includes the seas surrounding the Azores islands, Maderia and The Canary Islands

2.2 The Arctic Basin

The Arctic covers the areas at the northernmost part of our planet. It is a vast area that includes the northern parts of eight Arctic states: Finland, Sweden, Iceland, Norway including Svalbard and Jan Mayen, Greenland, and Faroe Islands as part of Denmark, northwest Russia, and Alaska as part of the United States of America, and Northern Canada. Only Canada, the United States, Russia, Iceland, Norway, and Denmark via Greenland, border the Arctic Ocean. While only three of the Arctic countries are EU countries, the Arctic is still an important area for the EU, especially because of the area's

vast resource potential and the climate impact that severely affects the area as a result of global as well as European emissions. The Arctic is especially vulnerable due to the demand of the area's resources, which includes energy resources such as gas and oil as well as mineral resources excavated through mining, such as coal, iron ore, zinc, lead, nickel, precious metals, diamonds, and gemstones. The EU is a key market for these resources and the economic demand for oil, gas, the expansion of renewable energy, and the demand for sub-Arctic fisheries and shipping is prominent.

2.3 Danube River system

The Danube River Basin covers over 800,000 km^2 and 10% of continental Europe. It extends into the territories of 19 countries, making it the most international river basin in the world. Its major river is the Danube, which crosses nine countries from the Black Forest (Germany) to the Black Sea (Romania-Moldova-Ukraine). With a length of 2,857 km, the Danube River flows through varied landscapes, from high mountainous areas to lowlands and before entering the Black Sea, forming one of the world's largest wetlands with a size of 6,500 km^2. The marine part of this region includes the Black Sea coastal waters along the Romanian and partly Ukrainian coasts, directly affected by the Danube freshwater and sediment discharge.

2.4 Mediterranean Sea

The Mediterranean Sea, placed in the south of the European continent and occupying approximately 2.5 million square km, unites three continents, namely Europe, Africa and Asia. It is connected on the west to the Atlantic Ocean through the Gibraltar strait, just 13 km wide, forming an almost landlocked sea. To the east, it connects to the Black Sea through the Bosphorus strait and to the Red Sea through the artificial Suez Canal, through which about 26000 vessels transit each year. There are more than 500 million people from 21 different countries living on the shores of the Mediterranean Sea, about 200 in the north and 300 in the south and east. Aside of the north-south divide, the sea is often divided in east-west, the submarine ridge between Sicily and the African coast being the delimiter. The largest delta is that of the Nile River in Egypt while the river that provides the biggest discharge to the basin is the Rhone in France followed by the Po in Italy. These two rivers account for about 30% of the total discharge from all rivers to the sea, which amounts to 10000 m3/sec. The Mediterranean Sea, a vital marine ecosystem, faces significant pollution threats from industrial activities, maritime traffic, and tourism. Addressing these challenges requires a comprehensive approach encompassing prevention and elimination strategies.

2.5 Baltic and North Sea

The Baltic Sea is one of the largest bodies of brackish (mix of fresh and saline) water in the world with a surface area of 420,000 km^2. It is an important European region, as there are eight EU Member States that border it including Germany, Poland, the Baltic countries (Estonia, Latvia and Lithuania) and the Nordic countries (Denmark, Sweden and Finland). In addition, Russia borders to the Baltic Sea. The Baltic Sea is connected in its westernmost area to the North Sea, situated on the continental shelf of north-west Europe. The Baltic Sea can be divided into several sub-basins (e.g., Kattegat, the Danish Straits, Arkona Basin, Baltic Proper, Gulf of Riga, Gulf of Finland, Bothnian Sea, Bothnian Bay) with different environmental characteristics and challenges. The North Sea opens into the Atlantic Ocean to the north and, via the English Channel to the south-west. It is surrounded by densely populated, highly industrialized countries, such as the United Kingdom, Western European countries (Belgium, France, Germany and the Netherlands) and several Nordic countries (Denmark, Sweden and Norway). Together, the Baltic and North Sea form one of the most frequently traversed sea areas of the world, enduring therefore a lot of pressure from marine traffic and activities. The geographical lineation of Baltic Sea and

North Sea Lighthouse region is set out as based on Helsinki Commission (HELCOM[9]) and OSPAR[10] regional sea conventions.

3 Priorities to be addressed in AQUARIUS TA calls

3.1 Protect and restore aquatic ecosystems – Atlantic-Arctic basin

3.1.1 Characteristics of Atlantic-Artic Lighthouse region

The **Atlantic** region faces several critical marine ecological challenges primarily driven by human activities and climate change. Overfishing and unsustainable fishing practices have caused the depletion of numerous fish stocks, disrupting marine food webs and threatening biodiversity. Additionally, climate change exacerbates these issues through rising sea temperatures and ocean acidification, altering marine ecosystems and species distributions. Coastal developments and shipping activities further contribute to habitat destruction and increase the level of contaminants entering the marine environment. Pollution, particularly from plastic waste, agricultural runoff, and chemical discharges, cause significant harm to water quality and marine life, leading to widespread habitat degradation.

In the **Arctic**, the main challenge is climate change, which is rapidly melting ice, leading to habitat loss for various species and changing global weather patterns. This environmental shift poses immense risks to biodiversity as well as threatening indigenous communities' ways of life. Furthermore, increased accessibility to the Arctic waters has raised geopolitical tensions and potential conflicts over natural resources. The Arctic is subject to increasing anthropogenic pressure from industrial activities, such as oil and gas exploration, mining, and increased shipping traffic which threaten the fragile ecosystem.

The Atlantic/Arctic Lighthouse specific objective is to protect and restore ecosystems and biodiversity (marine). The following three targets have been set under this mission:

1) Protect a minimum of 30 % of the EU's Sea area and integrate ecological corridors, as part of a true Trans-European Nature Network.

2) Strictly protect at least 10 % of the EU's Sea area.

3) Contribute to relevant upcoming marine nature restoration targets including degraded seabed habitats and coastal ecosystems.

The Atlantic/Arctic Lighthouse region, encompassing a vast maritime area, has established a specific baseline to guide its activities and initiatives. This baseline serves as a foundational framework aimed at promoting sustainable development, enhancing environmental protection, and fostering cooperation among the countries and stakeholders within the region. The key relevant elements of this baseline are (*the same elements are largely valid for all regions, with slight modifications, and they are not repeated for other regions*):

Environmental Conservation: At the core of the baseline lies a commitment to environmental conservation and protection. This involves measures to mitigate the impact of human activities on marine ecosystems, such as pollution, habitat destruction, and

[9] https://helcom.fi/about-us/
[10] https://www.ospar.org/about

climate change. Conservation efforts are aimed at preserving biodiversity, protecting endangered species, and maintaining the ecological balance of the region.

Sustainable Development: There is an emphasis on the importance of sustainable development practices that balance economic growth with environmental protection. This includes promoting renewable energy sources, sustainable fisheries management, and responsible tourism initiatives. The goal is to ensure that development activities contribute to the well-being of present and future generations without compromising the integrity of the natural environment.

Scientific Research and Innovation: To address emerging challenges in the Atlantic & Arctic region, it is important to recognize the role of scientific research and innovation. This includes supporting interdisciplinary research initiatives, fostering collaboration between scientists and policymakers, and leveraging technological advancements to enhance monitoring and data collection efforts.

Community Engagement and Indigenous Rights: Acknowledging the role of local communities and indigenous peoples in the sustainable management of the region, the baseline emphasizes the importance of community engagement and respect for indigenous rights. This involves consulting with local stakeholders, integrating traditional knowledge into decision-making processes, and ensuring that development projects benefit local communities while respecting their cultural heritage.

International Cooperation and Governance: Finally, the baseline underscores the need for international cooperation and effective governance mechanisms to address common challenges and achieve shared goals. This includes fostering dialogue, promoting multilateral agreements, and establishing institutions that facilitate cooperation and coordination among countries and stakeholders within the Atlantic/Arctic Lighthouse region.

In summary, the Atlantic/Arctic Lighthouse region has established a specific baseline that prioritizes environmental conservation, sustainable development, maritime safety and security, scientific research, community engagement, and international cooperation. By adhering to these principles and working together towards common objectives, countries and stakeholders within the region can build a more resilient and prosperous future for all.

Research and innovation play a crucial role in advancing our understanding of the Atlantic Arctic region and addressing the complex challenges it faces. Here are some expected research and innovation actions that could be undertaken within the framework of the Atlantic Arctic Lighthouse initiative and that are relevant to the AQUARIUS project:

- **Climate Change Impact Assessment:** Conducting comprehensive assessments to understand the impacts of climate change on the Atlantic & Arctic region, including changes in sea ice extent, ocean temperature, and ecosystem dynamics. Research efforts could focus on modelling future scenarios, identifying vulnerable areas, and developing adaptation strategies to mitigate the effects of climate change on both natural and human systems.
- **Biodiversity Monitoring and Conservation**: Implementing monitoring programs to assess the status of biodiversity in the Atlantic & Arctic region, including key species such as marine mammals, fish, and seabirds. Research initiatives could focus on identifying biodiversity hotspots, understanding migration patterns, and assessing the effectiveness of conservation measures. Innovation in monitoring technologies, such as satellite imagery and underwater drones, could enhance data collection efforts.
- **Sustainable Fisheries Management**: Conducting research to support the sustainable management of fisheries in the Atlantic Arctic region, including stock assessments, ecosystem modelling, and socio-economic analyses. Innovation in fishing gear technology, such as selective harvesting methods and

bycatch reduction devices, could help minimize the impact of fishing activities on non-target species and habitats.

- **Renewable Energy Development**: Investigating the potential for renewable energy sources, such as wind, wave, and tidal energy, to meet the energy needs of remote communities in the Atlantic Arctic region. Research efforts could focus on assessing resource availability, optimizing technology performance, and evaluating the socio-economic feasibility of renewable energy projects. Innovation in energy storage systems and grid integration could help overcome the challenges of intermittency and remote locations.
- **Maritime Safety and Navigation**: Advancing research and innovation in maritime safety and navigation to reduce the risk of accidents and environmental spills in the Atlantic & Arctic region. Research initiatives could include the development of improved navigational charts, risk assessment models, and real-time monitoring systems for vessel traffic. Innovation in autonomous vessels and unmanned aerial vehicles could enhance surveillance and response capabilities in remote and ice-covered waters.

By prioritizing research and innovation actions in these key areas, the Atlantic/Arctic Lighthouse initiative can contribute to the sustainable development and resilience of the region while fostering collaboration and knowledge exchange among countries and stakeholders.

3.1.2 Research priorities identified for the Atlantic-Artic Lighthouse region

Knowledge Gaps

There are significant gaps in data collection efforts necessary to support informed decision-making in the Atlantic & Arctic. These include:

- Mapping of marine biodiversity and supporting ocean variables to understand species distribution and abundance
- Mapping of marine microbiomes to explore microbial diversity and its ecological roles
- Improving understanding of ecological processes to predict changes and manage ecosystems effectively
- Integrating basin-scale observations (physics, chemistry, biology), remote sensing and modelling to understand connectivity and the status of ocean health
- Studying historical trajectories of ecological change and exploring restoration possibilities to enhance resilience
- Filling the gaps in the detailed seabed map of the North Atlantic from a Geological and habitat perspective

Additionally, there are insufficient studies of human activities' impact and threshold values on seabed integrity. Detailed research gaps exist on how human activities, such as fishing, shipping, and resource extraction, affect the seabed integrity of the Atlantic & Arctic. These include:

- Comparing benthic habitats with the aid of technologies (new and proven) through space and time at anthropogenically impacted sites and protected sites to improve understanding of human impact on seabed integrity.
- Identifying the threshold values beyond which these activities cause irreversible damage is essential for sustainable management practices.
- Assessing the impact of aquatic activities in protected areas is vital for designing more effective conservation responses.

Scientific Challenges

Challenges in monitoring and forecasting biodiversity changes due to climate change or anthropogenic pressures include a lack of:

- Robust monitoring systems and forecasting models to accurately track and predict biodiversity changes in the Atlantic & Arctic due to climate change and human activities. Developing advanced monitoring technologies and predictive models is essential for proactive conservation and management.
- High-quality ocean observing data (physics, BGC, BioEco) for assimilation into and validation of numerical models.
- Prioritisation of efforts to protect and restore key marine and river ecosystems.

There is an urgent need to identify land-ocean continuum for protection and restoration of key marine and river ecosystems in the Atlantic & Arctic. In particular, designing and implementing cost-effective methods for monitoring Marine Protected Areas (MPAs) to support conservation measures, and ensuring these efforts are efficient and impactful in preserving biodiversity and ecosystem health.

Our understanding of the interactions between species is limited. Gaining deeper insights into predator-prey dynamics, symbiotic relationships, and competition for resources is crucial. By enhancing our knowledge in these areas, we can significantly improve ecosystem management and inform more effective conservation efforts.

Societal Challenges and Opportunities

- Insufficient engagement and awareness among local communities and stakeholders:
  A significant challenge exists in effectively engaging local communities and stakeholders in the Atlantic/Arctic regarding environmental and conservation issues. Enhancing awareness and involvement is crucial for the success of sustainable management practices and conservation initiatives.

- Limited access to education and resources for sustainable practices:
  Many communities in the Atlantic/Arctic face challenges due to limited access to education and resources needed to implement sustainable practices. Addressing this gap is vital for empowering local populations to contribute to environmental conservation and sustainable development.

- Economic dependence on activities harmful to the environment:
  The economic dependence of local communities on activities that harm the environment, such as overfishing, oil and gas extraction, and unsustainable tourism, presents a major societal challenge. Finding alternative, sustainable economic opportunities is essential for reducing environmental impact while supporting local livelihoods.

- Insufficient policy support and governance for environmental protection:
  There is a need for stronger policy support and governance frameworks to effectively protect the Atlantic & Arctic environment. This includes the development and enforcement of regulations that balance economic development with environmental sustainability.

- Vulnerability to climate change and its societal impacts:
  The communities in the Atlantic & Arctic are highly vulnerable to the impacts of climate change, which can lead to displacement, loss of traditional livelihoods, and health risks. Addressing these vulnerabilities through adaptive strategies and resilience-building measures is a significant societal challenge.

- Challenges in integrating traditional knowledge with scientific research:
  There is a gap in effectively integrating traditional knowledge of indigenous and local communities with scientific research. Bridging this gap can enhance understanding and management of the Atlantic-Arctic environment, ensuring

that traditional practices are respected and incorporated into modern conservation efforts.

- Equity and inclusion in environmental decision-making:
  Ensuring equity and inclusion in environmental decision-making processes remains a challenge. Efforts must be made to include diverse voices and perspectives, particularly those of marginalized and indigenous communities, in shaping policies and actions that affect the Atlantic & Arctic.

By addressing these societal challenges, efforts to conserve and manage the Atlantic & Arctic can be more inclusive, equitable, and effective.

3.2 Protect and restore aquatic ecosystems – Danube River system

3.2.1 Characteristics of Danube Lighthouse region

The **Danube region** encompasses both EU and non-EU countries, with diverse political systems and different socio-economic backgrounds. Common challenges across the region are climate change, ageing/migrating populations and, currently, the war triggered by the Russian invasion of Ukraine affecting especially the Lower Danube regions, but certain challenges vary by geography and socioeconomics: the type of region (rural-urban), the position of a country (upstream/downstream), Gross Domestic Product (GDP) level, status of EU membership, structure (centralized or decentralized).

In line with the Mission Implementation Plan, the lighthouse in the Danube River basin focuses on Mission "Restore our ocean and water by 2030" objective 1 - Protect and restore marine and freshwater ecosystems and biodiversity, in line with the EU Biodiversity Strategy 2030. For the Danube basin lighthouse area, the following two Mission targets have been set:

1. Restore at least 25,000 km of free-flowing rivers in Europe
2. Restore certain coastal and freshwater ecosystems habitats

The Danube as well as its major tributaries (Inn, Morava, Drava, Sava, Tisza, Prut, etc.) are very important both economically and ecologically. They provide important resources to the basin's communities such as freshwater (both for human consumption and agriculture purposes), food (mainly fish), hydropower, naval transportation (both goods and persons) and resources for tourism with its picturesque landscapes in mountainous, hilly and flat areas with forests, national parks, urban and rural regions. Besides the provisioning and cultural ecosystem services, the Danube basin also provides regulatory services of immense significance. The Danube River Basin is characterized by a large variety of biodiversity, hosting diverse and dynamic ecological territories with many unique plant and animal species. Its habitats, hosting around 2000 vascular plants and more than 5000 animal species, include fast flowing mountain streams, wide and slowly flowing lowland rivers, large sand and gravel banks, wetlands and floodplains, wet meadows, oxbows, small and large lakes, and the dynamic Danube Delta. The Danube Delta is one of the world's largest wetlands, featuring 30 different types of ecosystems. With over 5500 flora and fauna species, spreading on over 5050 km^2 of marshes, canals, reed islets, and lakes, Danube Delta is third place in the world regarding biodiversity.

Changes to the river profile and width, water depth and flow velocity following the construction of dams, dikes, weirs and canals can significantly disturb the aquatic environment by disconnecting animals from their spawning grounds or otherwise degrading their habitats. Hydro morphological alterations are significantly impacting water bodies in the Danube River Basin and often hindering the achievement of environmental objectives.

The Danube Basin Area is covered by the Danube Region Strategy (EUSDR), agreed by the European Commission and partner states. It has objectives that are in synergy with the Mission Objective 1 (*Protect and restore marine and freshwater ecosystems and biodiversity, in line with the EU Biodiversity Strategy 2030*) and can be considered as supportive framework that legitimize the implementation of the Mission. At the same time, its foreseen interventions take the shape of actions that work at the level of framework conditions from an innovation ecosystem perspective (regulation, policy, markets, education, etc.). They aim to improve the policy frameworks of the signatory countries related to the diverse fields of environment, marine and freshwater ecosystems and habitats, biodiversity protection, etc. Another transnational body active in the Danube region is the International Commission for the Protection of the Danube River (ICPDR), which has 14 countries as signatories and the European Union and aims to facilitate multilateral cooperation and implement the Danube River Protection Convention. The recently published 2021 Update of the Danube River Basin Management Plan (DRBMP) of ICPDR includes several analyses that are relevant for the Danube lighthouse area (e.g. hydro-morphological alterations, effects of climate change (drought, water scarcity, extreme hydrological phenomena and other impacts).

3.2.2 Research priorities identified for the Danube Lighthouse region

Knowledge Gaps

- Lack of a common agreed definition of free-flowing rivers and harmonization of the scale of evaluating the condition of river morphology, as well as the parameters that are considered in the evaluation, among the Danube basin countries. Consequently, there is no dataset currently available on free-flowing rivers in the Danube basin.
- Gaps in the field of assessment of hydro-morphological alterations.
- Assessment of the sediment balance on rivers is still less developed part of hydro-morphological assessment in most Danube River Basin countries.
- Although there are national biodiversity plans that provide valuable information on freshwater and coastal habitats, there is no Danube-wide assessment available.
- Gaps in assessing the effectiveness of current measures provided in the Danube Basin River Management Plan.

Scientific Challenges

- Increase the research-development and innovation capabilities in the Lower Danube regions (knowledge transfer from the Upper Danube region where there are some on the most important European RDI hubs).
- Developing, testing and implementing at river basin scale active, passive and nature-based solutions for freshwater and marine ecosystems restoration.
- Developing, testing and implementing nature based solutions for mitigating the effects of extreme phenomena (drought, floods, heavy storms, etc.).
- Better assessment of the cumulative effects of natural and anthropogenic pressures on the freshwater and marine ecosystems, as well as the local communities welfare.
- Harmonization of methods for assessing significant pressures related to disconnected wetlands/floodplains and further implementation of monitoring for identification of negative impacts of disconnected wetlands/floodplains on biological quality elements.

Societal Challenges and Opportunities

- Increased public understanding and awareness of the actions needed to protect and restore the degraded habitats/ecosystems within the Danube River Basin.
- Reducing the disparities in development occurring in the Danube River basin.
- Input and basis for further European, regional and/or national/local legal and policy, documents (in particular for the upcoming EU nature restoration targets, reviews of the Marine Framework Strategy Directive, Water Framework Directive,

Marine Spatial Planning (MSP), updates of the Danube River Management Plan, etc.).

3.3 Prevent and eliminate pollution – Mediterranean Sea

3.3.1 Characteristics of the Mediterranean Lighthouse

The **Mediterranean Sea** stands as a crucial region in the context of marine biodiversity and ecosystem health, facing a high number of challenges that necessitate urgent attention and concerted efforts for restoration and conservation. It is a region characterized by a diverse range of environmental conditions and threats, including pollution, overfishing, habitat degradation, and the impacts of climate change, all of which are significantly impacting on marine ecosystems.

The identified lighthouse area for the Mediterranean Sea, "Prevent and eliminate pollution," underscores the critical need to address pollution in its various forms to safeguard the marine environment. The specific targets for Mediterranean are:

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

The Mission has initiated targeted efforts in the region to streamline existing activities, disseminate innovative solutions, and engage relevant stakeholders in combating pollution. Initially focusing on plastic pollution, the Mission will subsequently address agricultural pollution (nutrients), urban/industrial pollution (chemicals), pharmaceuticals, and noise pollution, following a zero-pollution hierarchy approach. The Mission's approach to pollution prevention encompasses several key strategies:

1. **Prevent**: By focusing on upstream prevention and reducing the generation of pollution, initiatives will include the design and implementation of renewable, bio-based, and marine bio-degradable materials and processes.
2. **Minimise**: Efforts will be made to minimize and ultimately eliminate (micro-)plastic waste, chemical, and nutrient pollution entering aquatic environments through improved waste collection, sorting, recycling, and wastewater treatment.
3. **Eliminate and Remediate**: Strategies will focus on collecting and reusing waste in an environmentally sustainable and economically feasible manner, particularly in areas where litter poses environmental or socioeconomic risks.
4. **Monitor and Control**: The Mission will establish and maintain reliable baseline data on pollutants in different environmental compartments, aligning with existing processes like the Marine Strategy Framework Directive in the EU.

Furthermore, in the white paper "The Mediterranean We Want" written under the framework of the UN Ocean Decade Programme "SciNMEet: the Science we need for the Mediterranean we want" (Cappelletto et al. 2021), it is emphasized that there is a need for enhanced governance mechanisms and stronger enforcement of environmental regulations to combat pollution effectively in the Mediterranean Sea.

The comprehensive research conducted on the current state of pollution in the Mediterranean lighthouse area has identified key pollutants and their concentration levels, emphasizing the need for coordinated efforts to address these environmental challenges. The analysis, which short-listed 43 key pollutants associated with MSFD Descriptors, highlights the complexity of managing pollutants with varying legal thresholds and regulatory frameworks. Notably, while some pollutants have established legal thresholds referenced by legislative texts like the Water Framework Directive (WFD) and Environmental Quality Standards (EQS), others lack agreed-upon thresholds at the EU level, necessitating ongoing collaboration between the European Commission and Member

States for defining threshold values, particularly for pollutants such as underwater pollution and plastic litter.

In this context, the utilization of data sources such as the European Marine Observation and Data Network (EMODnet) and the WISE databases has been prioritized for their accessibility and coverage of key pollutants across multiple countries in the Mediterranean region. By integrating data from EMODnet Chemistry, which offers visualization and extraction of chemical data related to marine environments, researchers can access valuable information on contaminants and eutrophication trends.

A pollution hotspot is characterized as a location where at least one descriptor fails to achieve good status, indicating a persistent source of pollution that requires targeted remediation efforts. The distribution of pollution hotspots among EU member states highlights varying levels of environmental non-compliance, with countries like Spain, Croatia, and Greece showing notable challenges in achieving good environmental status across multiple indicators. The analysis of pollution hotspots in the Mediterranean lighthouse area reveals that 77% of hotspots exhibit more than two descriptors under noncompliance, showing that the area faces complex pollution issues that require targeted interventions. The prevalence of metals, litter floating, and litter seabed as key non-compliant descriptors showcases the diverse nature of pollutants affecting these hotspots. Heavy metals, particularly mercury, emerge as significant contributors to the failure to reach good environmental status in 75% of identified hotspots.

Furthermore, the preliminary analysis of pollutant patterns based on location characteristics reveals a nuanced understanding of pollution sources. While certain pollutants like nitrogen and phosphorus are ubiquitous, others show specific associations with rivers or urban areas, emphasizing the need for tailored mitigation strategies. The identification of pollutant-specific patterns informs targeted interventions to address pollution sources effectively.

3.3.2 Research priorities identified for the Mediterranean Lighthouse region

In the Mediterranean region, a comprehensive analysis of priorities has revealed several key areas where knowledge gaps exist, along with scientific and societal challenges and opportunities. These priorities are crucial for addressing environmental concerns and promoting sustainable development in the region.

Knowledge Gaps

- Understanding the long-term impacts of pollution from land-based sources on marine ecosystems.
- Assessing the effectiveness of current measures in reducing hazardous waste generation and transboundary movement.
- Monitoring and mitigating pollution from offshore oil and gas activities to protect marine biodiversity.
- Evaluating the implementation and impact of integrated coastal zone management practices on coastal ecosystems.

Scientific Challenges

- Developing innovative technologies for early detection and response to oil and hazardous substances pollution incidents.
- Enhancing biodiversity monitoring and conservation efforts to safeguard unique marine species and habitats.
- Integrating data from various sources to improve understanding of ecosystem dynamics and resilience in the face of environmental stressors.
- Advancing research on the interactions between human activities and marine environments to inform sustainable management practices.

Societal Challenges and Opportunities

- Promoting public awareness and engagement in marine conservation efforts to foster a sense of stewardship among local communities.
- Enhancing collaboration among Mediterranean countries to address shared environmental challenges and achieve common conservation goals.
- Leveraging the Barcelona Convention[11] and its protocols to strengthen regional cooperation and governance for sustainable marine resource management.
- Creating economic opportunities through sustainable blue economy initiatives that balance environmental protection with socio-economic development.

3.4 Make the Blue Economy climate-neutral and circular – Baltic & North Sea

3.4.1 Characteristics of Baltic and North Sea Lighthouse region

Due to the specific environmental configuration of the **Baltic Sea** (e.g., its enclosed nature, salinity gradient, low biodiversity, high level of eutrophication, large drainage area) and the **North Sea** (diversity of marine landscapes, relatively shallow waters, strong water exchange, strong tides, dense population and high level of industrialization), they are especially vulnerable to environmental pressures. They are among the most heavily used sea basins in the world supporting fishing, shipping, trade, energy, aquaculture, recreation, defense and dredging. The marine ecosystems are affected by eutrophication (excessive richness of nutrients in a water body), chemical and plastic pollution, introduction and spread of non-indigenous species, underwater noise pollution, fishing and hunting, as well as habitat loss and disturbance.

The third objective of Mission Implementation Plan, "Make the sustainable blue economy carbon-neutral and circular", is a target for the Baltic and North Sea Lighthouse. The lighthouse works for reduction of greenhouse gas and other emissions in main maritime sectors, with the following key targets.

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

The key sectors identified for this objective include maritime transport, maritime ports & facilities, renewable energy and its offshore facilities, offshore renewable energy storage facilities, multipurpose platforms and aquaculture. Other sectors (like waste, circular economy, fisheries, integrated coastal zone management, coastal tourism, blue bioeconomy) may be also considered as relevant for Mission objectives. While utilising marine resources, several laws and agreements governing the sea need to be considered (e.g. those from United Nations Environment Programme (UNEP)/ Regional Seas Programme (RSP), Intergovernmental Oceanographic Commission (IOC), International Maritime Organisation (IMO), International Seabed Authority (ISA) and Food and Agriculture Organisation (FAO)) and also the governance at EU level (e.g., MSP, MSFD, WFD) and regional level (e.g., HELCOM, OSPAR, EU Strategy for the Baltic Sea Region, The North Sea Region 2020 and 2030 strategy) needs to be followed.

[11] https://www.unep.org/unepmap/who-we-are/barcelona-convention-and-protocols

Specifically, the Mission will capitalise on results and experience from Horizon 2020 Green Deal and projects of Horizon Europe Cluster 5 and Connecting Europe Facility, to approach offshore renewable energy technologies, green ports and waterborne transport. It looks forward in supporting technical solutions for use of renewables, actions for multi-use of marine space and supporting transition towards zero emissions and a circular economy. Support for sustainable and circular aquaculture is also in the agenda. Finally, it includes topics for climate change mitigation and solutions to mitigate pressures from increased tourism.

The Baltic and North Sea Lighthouse will facilitate technological solutions for sustainable use of various marine resources. The solutions may also include coexistence of various activities and multi-use of marine space. Multi-use concept is also valid for different platforms, that may support different aims at the same time, improving cost efficiency. Such multi-use may also include marine monitoring and research.

When supporting activities related to the Blue Economy, different environmental and anthropogenic pressures, with all possible combinations, must be considered. While Marine Spatial Planning provides some tools for it, modelling scenarios also provide insight on the potential future risks. This emphasises the role of Digital Twin of Ocean[12] for future marine applications and the need for reliable data for model build-up and validation.

Interconnection of regions and domains (e.g., freshwater–marine, air–sea) and related fluxes of materials and organisms (e.g., nutrients, organic matter, volatile compounds, non-indigenous species, fish diseases/parasites) and their potential trajectories along with development of new applications needs to be considered as well. Interconnecting regions and nations in planning of the use of marine space is another concern, as well as regulation of harmful activities (like waste dumping) in international waters. The basic principle should be that the effects of the operation are not outsourced to other areas.

3.4.2 Research priorities identified for the Baltic and North Sea Lighthouse region

Knowledge Gaps

- Lack of harmonised practices in data collection and processing for various blue economy sectors, like wind farms.
- Environmental impacts of aquaculture, especially for eutrophication, still exists despite recent technology developments and their monitoring and modelling requires further support. Impacts of potentially emerging low trophic level aquaculture (sometimes done for animal feed or energy feedstocks) are still largely unknown.
- Reasons for the occurrence of toxic or harmful algae blooms are not fully resolved, and they may compromise aquaculture production and location of their sites.
- Despite regulated, amount and effects of spills of oil, hazardous noxious substances, litter, emissions from scrubbers, or noise for ships or marine constructions to the marine environment are not well known.
- Impacts of mineral and sand excavation and physical disturbances due to constructions (e.g., wind parks) on the sea bed integrity, fish stocks, spawning areas and habitats in generally can be significantly negative. The knowledge on seabed geomorphology and related habitats in the outer pelagic areas is still poor.

[12] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/restore-our-ocean-and-waters/european-digital-twin-ocean-european-dto_en#what-is-the-european-digital-twin-of-the-ocean

- Despite being studied signicantly, all areas with sea-dumped munitions, wrecks and other potentially harmful seabed objects are not yet known, challenging the constructions of platforms, pipelines and cables.
- Though environmental impacts of singular new sites for Blue Economy may be considered negligible, as they may concentrate in same marine area, their interacting and cumulative impacts need to be assessed.

Scientific Challenges

- Cumulative impacts of multistressors (e.g. high nutrients, low oxygen, increase of temperature, contaminants, acidification, noise, dissolved organic matter) on marine biodiversity and ecosystem functioning are poorly studied and the effects of increasing use of marine space on environmental conditions may strengthen these.
- Side effects of fisheries and aquaculture on marine food-webs and habitats require attention to avoid unwanted feedbacks on marine productivity.
- To support aquaculture, reliable warning systems for biological (harmful algae), chemical (oxygen depletion) or physical (heat waves, storms) hazards are required. Similar services may support fisheries, recreation and tourism industry.
- Methods and consequences of using exhausted gas fields as sites for CO^2 storage are under scrutiny.
- Understanding how the shift in ship fuels, e.g., from diesel to LNG, or reduction of sulphur in fuels, affects their real emissions and which are the impacts on marine ecosystem.
- Can the Blue Economy platforms and related constructions be built up in such a way they promote biodiversity hot spots?
- Collecting biomaterials (specimen, eDNA) to search for new potentially cultivated marine organisms or for new biotechnology components.

Societal Challenges and Opportunities

- Finding suitable offshore spaces that combine different activities and uses of the marine space, and to avoid conflicts between different uses.
- Testing multipurpose platforms, also for marine monitoring and research purposes, could be one element supported by AQUARIUS TA calls, including ships, aquaculture sites and wind parks, to name some.
- Marine measurements may be better utilised in creating products and solutions for maritime traffic, e.g., for finding cost-efficient routes (avoiding ice or counter current),
- Increase of uses in marine space may cause habitat loss and disturbance
- Societal and economic pressures to have a fast lane for permissions to build-up solutions for green transition may compromise thorough environmental impact assessment. Therefore, it is vital to facilitate opening all so-far hidden data, use up-to-date model tools and use all additional opportunities to perform baseline studies at key sites of interest.

3.5 Cross-cutting enablers for the Mission

In the EU Mission "Restore our Ocean and Waters by 2030", knowledge gaps must be filled by implementing a comprehensive digital ocean and water knowledge system and environmental monitoring system, jointly with other initiatives. The Mission will enhance our ability to monitor, forecast, evaluate the health, and manage the aquatic system comprehensively. Building on existing structures and capacities, the Mission will support the development of a fit-for-purpose observation, monitoring, and forecasting system, including climate predictions, which will provide crucial insights for implementing the Green Deal.

Addressing knowledge gaps is essential for tracking the main sources and pathways of pollution and assessing the impact of oceanic changes within ecosystems of high ecological and societal value that require protection and restoration. By supporting the Blue Economy sector, marine science creates a societal impact and will achieve further recognition and resourcing. Expanding our understanding of ocean and water life, including sequencing DNA and studying microbiomes of marine and coastal ecosystems, is a key focus. Combining acquired ecosystem data sets, such as biological, genetic, and molecular data, will support a more comprehensive understanding of the land-water interface.

Integrating and increasing the capacity of existing knowledge sources like Copernicus[13] (CMEMS, space observation) and the European Marine Observation and Data Network (EMODnet) is crucial. The development and use of technology and protocols for monitoring and forecasting marine species abundance, diversity, movements of aquatic life, and developing dynamic marine biodiversity maps are vital. This includes mapping and classifying habitats such as wetlands, seagrass, kelp, coral, and deep sea, as well as studying the impact of pollution and human activities. Finally, we must focus on developing and deploying next-generation ocean observation sensors and platforms to enhance our monitoring capabilities.

[13] https://marine.copernicus.eu/

4. Summary: Key messages for TA calls

European seas and waters present a unique and diverse environment that faces significant challenges related to pollution, biodiversity conservation, and sustainable resource management. To address these challenges effectively and promote scientific cooperation and innovation, potential key messages for Transnational Access (TA) calls are outlined below:

- **Collaborative Research Opportunities**: TA calls should emphasize the importance of collaborative research initiatives that bring together scientists, stakeholders, and policymakers from various countries and regions, and from various disciplines, to address common environmental concerns. Encouraging transnational research projects that focus on cross-cutting issues such as pollution, biodiversity conservation, and sustainable blue economy practices will foster regional cooperation and knowledge exchange.
- **Capacity Building and Knowledge Transfe**r: TA projects should include capacity building activities that enhance the scientific expertise and technical skills of researchers. Facilitating knowledge transfer through TA programs will enable researchers to leverage best practices, methodologies, and technologies from international partners to address local and regional environmental challenges effectively.
- **Innovation and Technology Development**: Promoting innovation and technology development through TA calls will support the implementation of cutting-edge solutions for monitoring, mitigating, and managing our aquatic environments. Encouraging the use of remote sensing, autonomous monitoring systems, new technologies, and data analytics tools will enhance the region's capacity to address emerging environmental threats and improve decision-making processes.
- **Stakeholder Engagement and Policy Impact**: TA projects should engage with stakeholders, including local communities, industry representatives, and policymakers, to ensure that research outcomes have practical applications and policy relevance. Demonstrating the policy impact of TA-funded projects by translating scientific findings into actionable recommendations and policy measures will contribute to evidence-based decision-making and sustainable marine governance in the region.

For each Lighthouse region, we have listed a comprehensive number of priorities under categories of "Knowledge Gaps", "Scientific Challenges" and "Societal Challenges and Opportunities". These listings are derived and interpreted from the Mission documentation, and they form front-line topics, for the implementation of which the AQUARIUS research infrastructures can offer support via TA calls.

We recommend that TA calls contain a clear reference to the priorities identified in this work, but also enable the implementation of projects whose research topic has not been prioritized in here, but which are nevertheless in line with the Mission's goals.

5. References

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