SUMMARY REPORT

NORTH ATLANTIC REGIONAL WORKSHOP

in support of the
UN Decade of Ocean Science for Sustainable Development (2021-2030)

Halifax, Canada, January 6 – 10, 2020

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BACKGROUND

The United Nations (UN) General Assembly proclaimed the UN Decade of Ocean Science for Sustainable Development (2021-2030) in December 2017. The UN Decade offers a once-in-a-lifetime opportunity for all ocean stakeholders to apply critical ocean science and knowledge to reverse the cycle of decline in ocean health and ensure ocean science can fully support countries in achieving the sustainable development of ocean. Under the framework of the UN Decade, scientists and stakeholders from all relevant sectors will convene to generate scientific knowledge, enhance infrastructure and partnerships, and bridge the science-policy interface to support a well-functioning, productive, safe, resilient and sustainable ocean - the Ocean We Need for the Future We Want.

The UN Decade Roadmap[1], by the Intergovernmental Oceanographic Commission (IOC), offers an initial guide for the steps and processes needed to develop the Implementation Plan for the UN Decade, and also formulates a preliminary set of globally defined objectives and research and development Priority Areas. Global and regional consultative workshops are essential mechanisms to achieve the objectives and to engage various communities through a multi-stakeholder process and structured dialogues. The first Global Planning Meeting (GPM) which took place May 13-15, 2019 (Copenhagen, Denmark), brought together key stakeholders to share information, to identify possible collaborations, to encourage them to take ownership of the Decade, and through the discussions, further developed the scope of the UN Decade.

Following the first GPM, a series of regional workshops commenced to provide an opportunity to engage and consult with ocean stakeholders across the globe, enriching the UN Decade conversation and influencing its design. These regional workshops aim to identify: knowledge gaps and regional science priorities for the 2030 Agenda, existing and potential partnerships/ networks/initiatives, priorities for capacity development and training, priority themes and topics the UN Decade will address, and other regional initiatives and meetings that align with the UN Decade.

North Atlantic Regional Workshop

Over 150 participants from 14 different countries and spanning the ocean community, met in Halifax, Canada (January 6-10, 2020) to discuss priorities and actions for the North Atlantic Ocean to support the Implementation Plan for the UN Decade on Ocean Science for Sustainable Development (2021-2030), as well as to discuss various domestic and regional initiatives that could support the Decade. Organizers achieved balanced participation across genders and engaged Indigenous and youth participants in all aspects of the workshop. All-Atlantic Ocean Youth Ambassadors were featured in a panel session where they presented several of the projects that they are leading around the North Atlantic Ocean.

The North Atlantic Regional Workshop culminated in the identification of a wide range of actions, potential initiatives, programs and partnerships that would advance ocean knowledge for sustainable development. This Summary Report covers major discussions and results structured around the workshop objectives (e.g. key North Atlantic Ocean science/knowledge gaps, and pathways for solving issues) and includes recommendations for potential initiatives/ programs/partnerships in support of the UN Decade.

[1] *Intergovernmental Oceanographic Commission, Revised Roadmap for the UN Decade of Ocean Science for Sustainable Development, 2018, https://unesdoc.unesco.org/ark:/48223/pf0000265141*

Opening Remarks and Plenary Session on Setting a Vision

The North Atlantic Regional Workshop commenced with a water ceremony and remarks from Dorene Bernard, a Mi'kmaq Grassroots Grandmother and Water Protector, who reminded participants of the importance of water and the need for meaningful engagement with Indigenous partners in science and in decision-making. Federal Minister of Fisheries and Oceans and the Canadian Coast Guard, the Honourable Bernadette Jordan, addressed the workshop participants, and encouraged participants to work together to achieve the actions our oceans need to be healthy and sustainable. Sieglinde Gruber, Office of the Director General Research and Innovation, European Commission stated that *cooperation, co-ownership,* and *co-creation* efforts form the heart of what will be achieved and that the European Commission will work over the next ten years to support the UN Decade. Other speakers in the opening session welcomed and encouraged the workshop participants to fully engage in the discussions at the workshop and in the UN Decade more broadly: Anya Waite, Ocean Frontier Institute (OFI); Craig McLean, National Oceanic and Atmospheric Administration (NOAA); Arran McPherson, Fisheries and Oceans Canada (DFO); and, Peter Thompson, UN Secretary-General's Special Envoy for the Ocean (by video).

The workshop then moved to plenary speakers who spoke to a vision for the UN Decade, and outlined supporting regional activities and partnerships, as well as highlighted ongoing planning and preparations. The Executive Secretary of the IOC, Vladimir Ryabinin opened this session by providing background and context on the evolution of the UN Decade, highlighting the associated timelines and milestones, and describing how this North Atlantic Regional Workshop fits into the global efforts. The UN Decade's Executive Planning Group representatives, Martin Visbeck (GEOMAR) and Craig McLean (NOAA), described the draft Science Action Plan that provides a framework to develop and deliver directed scientific knowledge contributing to the UN Decade. The emerging Science Action Plan will contribute, with other plans (e.g. governance, communication, business, capability development etc.), to the Implementation Plan for the UN Decade, and will build on its Revised Roadmap. They also reminded the audience of the strong scientific basis achieved to date through the efforts of the International Council for Exploration of the Sea (ICES) and the Atlantic Ocean Research Alliance (AORA), and the opportunity to build on this work over the UN Decade. The final speaker was Peter Haugan, Co-chair of the Expert Group supporting the High-Level Panel for a Sustainable Ocean Economy. He described this unique initiative, led by 14 world leaders who are committed to supporting the 2030 Agenda and its Sustainable Development Goals for a better future, creating a new relationship between humanity and the ocean that allows us to "Protect, Produce, and Prosper", and catalysing bold, pragmatic ocean solutions in governance, technology, and finance.

Unique Characteristics of the North Atlantic Ocean

The North Atlantic Ocean hosts globally unique physical features such as the meridional overturning circulation (MOC), and its poleward flow creates very strong connections to the Arctic Ocean. Changing climate across the world will be manifested in North Atlantic Ocean, including increasing temperatures, sea level, and storm surges, a weakening of the MOC, more frequent extreme weather events (e.g. hurricanes, storms, etc.), and an increasing number of toxic algal blooms, *Sargassum* seaweed outbreaks, and legacy pollution impacts. Further, given the strong linkages between the North Atlantic and Arctic Oceans, the dynamic changes occurring in the Arctic Ocean (e.g. warming temperatures, decreasing ice coverage, etc.) will be amplified in North Atlantic waters. The connections between the North Atlantic Ocean and the Arctic Ocean, the Tropical Atlantic Ocean (i.e. Caribbean) and the South Atlantic Ocean were not prominently discussed during the workshop as they were outside its scope.

The North Atlantic Ocean region is home to many Indigenous communities that hold a wealth of information on oceans which must be included in discussions regarding the future of oceans and in related decision-making processes. The many intensive and potentially overlapping ocean space uses – including fisheries, marine transportation and shipping, aquaculture, and offshore energy provide a historical experience and context, as well as vital lessons to inform future decisions. There is a history of anthropogenic use of the North Atlantic Ocean as a resource, coupled with emerging activities such as seabed mining and autonomous technologies. These strategically position the Region to examine marine spatial planning efforts in order to address their sustainability in the context of these multiple activities.

Further, there are strong existing collaborative science bodies within the North Atlantic Ocean community (e.g. AORA, ICES, AtlantOS, the regional bodies of GOOS and GEO, OSPAR, regional fisheries management organizations, etc.) as well as existing regional policy frameworks (e.g. Galway and Bélem Statements on Atlantic Ocean cooperation and various other trans-Atlantic cooperation mechanisms). These bodies position the North Atlantic region to move forward building on existing mechanisms and relationships in order to advance efforts contributing to the overall success of the UN Decade.

Workshop participants noted the lack of representation from the more southern and eastern reaches of the North Atlantic Ocean at the workshop. Participants were conscious of the geographic scope of the meeting and acknowledged that discussions relating to knowledge gaps, key priorities, and proposed actions might extend into the adjacent geographic regions of the Arctic, Mediterranean, Caribbean, and South Atlantic Ocean basins. They emphasized the importance of incorporating issues that might straddle the margins of the geographic region and acknowledged the need to consult with participants from other regions so they can provide thoughts and input on any such activities. It was noted that the series of ongoing regional workshops are not intended to provide full global coverage. They represent key forums to obtain input to the Science Action Plan and Implementation Plan for the UN Decade; however, they are not the sole forums to do so. It was confirmed that the geographic areas not included in the North Atlantic Regional Workshop would be captured in other regional workshops.

Societal Outcomes of the UN Decade of Ocean Science for Sustainable Development

There are six societal outcomes identified for the UN Decade:

1. **A clean ocean,** whereby sources of pollution are identified, quantified and reduced and pollutants removed from the ocean in an efficient manner.
2. **A healthy and resilient ocean**, whereby marine ecosystems are mapped and protected, multiple impacts on them, including climate change, are quantified and, where possible, reduced and provision of ocean ecosystem services is maintained.
3. **A predicted ocean**, whereby society has the capacity to understand current and predict future ocean conditions and their impact on human well-being and livelihoods.
4. **A safe ocean,** whereby human communities are much better protected from ocean hazards and where the safety of operations at sea and on the coast is ensured.
5. **A sustainably harvested and productive ocean,** ensuring the provision of food supply and alternative livelihoods.
6. **A transparent and accessible ocean,** whereby all nations, stakeholders and citizens have access to ocean data and information technologies and the capacities to inform their decisions.

All workshop discussions were framed around these six societal outcomes which, if achieved, aim to the reverse the cycle of decline in ocean health and ensure we have the scientific basis needed to fully support the sustainable development of ocean.

OUTCOMES OF THE CROSS-CUTTING THEME DISCUSSIONS

There are five cross-cutting themes that apply across all six societal outcomes of the UN Decade and thus to each of the corresponding Working Groups of the North Atlantic Regional Workshop. The five cross-cutting themes identified are:

1. Capacity building and technology transfer;
2. Partnerships and financing;
3. Access to information, data, and knowledge;
4. Awareness raising and inclusivity; and
5. Transdisciplinarity.

The following sections present highlights from the discussions associated with each of the cross-cutting themes, drawing particular attention to the importance of:

- Advancing **gender equality** across all disciplines as well as within and among sectors throughout the UN Decade;
- Engaging with **early career ocean professionals** to ensure that the ocean community hears different views and perspectives, and to build capacity among these future leaders;
- Establishing **meaningful partnerships across multiple sectors** including those considered somewhat under-represented at the North Atlantic Regional Workshop (e.g. industry, regional fisheries management organizations, etc.);
- Establishing **partnerships with Indigenous communities**, organizations, and Nations in order to learn from and respect each other's ways of knowing;
- Ensuring the balanced consideration and integration of **different knowledge systems;**
- Ensuring the **inclusion of social sciences and humanities, as well as policymakers and stakeholders** early in discussions and committing to building related insights and concerns into scientific activities to ensure the equal consideration and inclusion of (multi) disciplinary perspectives;
- Recognizing **ocean literacy's critical role** in supporting and facilitating active citizen engagement in the Decade; and
- Enhancing existing **governance approaches**, or developing new ones as required, that are fit-for-purpose for the complex social-ecological systems management decisions that we will face in the coming decade and for enhancing collaborations across the Atlantic basin.

Capacity Building and Technology Transfer

Discussions related to this cross-cutting theme highlighted an underlying and important observation that the more appropriate term “capacity exchange” should be used rather than “capacity building” in order to reflect that learning and the sharing of knowledge and information is not necessarily only one direction.

There is a need for inclusive and integrated knowledge and decision-making processes to strengthen communities-of-practice for inclusive ocean research, management, and governance activities. There should be an exchange of knowledge rather than assuming one-directional flow of information. Discussions recognized value in local Traditional Ecological Knowledge and Indigenous knowledge that must be integrated into science, policy, and decision-making. The challenge is how to best integrate these different

ways of thinking and knowing when we use different "languages", jargon, terminology, and have differing viewpoints between the two knowledge systems.

The Aha Honua, Coastal Indigenous People's Declaration presented at OceanObs '19 was tabled at the North Atlantic Regional Workshop to remind participants of the statement which reads: *"Establish meaningful partnerships with Indigenous communities, organisations, and Nations to learn and respect each other's ways of knowing; negotiate paths forward to design, develop, and carry out ocean observing initiatives; and share responsibility and resources."*

The UN Decade offers an opportunity to educate scientists on how to consider different kinds of information and to acknowledge that other forms of valuable information exist. The research community should develop best practice guidance on collaboration with stakeholders and citizens in relation to the UN Decade objectives (both regionally and globally).

Social science provides helpful insights by looking at various aspects of an issue and should be considered alongside natural science analyses. Social science can contribute more fully than it currently does to scientific studies to produce more robust outcomes; the Marine Social Science Network (http://www.marsocsci.net) exemplifies such an approach.

Community-based capacity development needs to be encouraged and more meaningful collaborations between research and practice must be fostered - we need to bring more communities-of-practice into the Decade. Community-based capacity building for coastal resilience has demonstrated success in addressing social vulnerability. One example of a successful partnership-building initiative is the Resilient-C platform - https://resilient-c.ubc.ca/ where communities discover other locations that face similar hazards and vulnerabilities, discover what actions these communities have undertaken to address coastal risks, and discover planning actions that have been taken to become more resilient.

The availability of new learning opportunities creates potentially significant first-hand experiences and dialogues with other relevant actors that can lead to a more nuanced understanding of the context, problems, and decision implications over both the shorter and longer term. For example, a research chair in Oceans and Human Health – similar to the Universitat de Girona, Spain - http://www.oceanshealth.udg.edu/en/objectives-of-the-oceans-and-human-health-cha.html - can provide direct learning and trans-sectoral experience that helps break down silos and bridges the knowledge and communication gaps between research and practice.

It was noted that scientists must work with specific communities of practice and user groups to identify risks and needs, especially for the small-scale sector (e.g. fish harvesters) who are often the most vulnerable and at-risk. Finding effective ways to pass on important messages requires further research, helping increase public awareness of the risks and helping communities reduce negative incidents. Simply inviting people to attend meetings to participate in discussions is insufficient - it is also necessary to go to them and to engage them in their own communities and environments.

Creating an inventory of existing initiatives can highlight where we are, and where we are not, directing efforts. This inventory should build on the work of the Intergovernmental Oceanographic Data Exchange (IODE) capacity development activities that are currently underway.

The UN Decade offers an opportunity to build capacity for collaborative science and arts initiatives that visualize and communicate data/knowledge in novel and more accessible and engaging ways for diverse audiences (e.g. the TBA21-Academy who fund and run ocean science and arts collaboration projects in Europe and globally). This kind of strategy would help give new meaning and enhance and restore the emotional connection of citizens with our ocean.

Create greater opportunities to encourage and support Early Career Researchers and Ocean Professionals. More opportunities should be made available for equitable international twinning between ocean science and informatics (e.g. graduate school) and between ocean science and social science. Efforts under the UN Decade should also link with the recent Climate Action movement led by youth bringing the relevance of the ocean to their attention.

There is a need to build on what is already there using existing technology and tools. The IOC offers an existing capacity building framework to build on, however, capacity development requires a more holistic approach. Many tools already exist, and we need to determine how best to share these tools. There are some ongoing initiatives aiming to do this such as BBNJ (Biological Diversity of Areas Beyond National Jurisdiction) negotiations on how to share technology with less developed countries, crowd-sourced bathymetry efforts, the AtlantOS technology road map, etc.

The UN Decade offers opportunities to align with other Societal Risk Analysis (SRA)/policies (e.g. EU funded H2020 SOPHIE SRA on Ocean and Human Health research and funding for next decade in Europe – to be published in March 2020).

The ability to share and access knowledge, practices, low-cost technology, and tools should be democratized. We should transfer tools and current state-of-the-art technology and also that which may be "good enough" in capacity-limited environments from developed regions to those regions, environments, and communities that need it. The transfer of knowledge and technology goes both ways, with opportunities for "teaching vs. learning". Discussions noted not just North-South divides but persistence of within-country inequalities in the North Atlantic region too (e.g. rural-urban disparity, social deprivation of coastal areas, etc.).

The UN Decade should provide for equitable empowering of communities to make their own observations, increasing accessibility of technology creates a need and opportunity to consider novel ways of capacity building. For example, all-female ocean expeditions, citizen science initiatives, using mobile phone apps with readily available GPS and GIS technology to record data in real-time by fishers, fish harvesters, tourism operators, etc. The latter could help to provide early warning of potential issues in local areas and empower communities to become involved in their natural resource. Further, the UN Decade should explore and test similar approaches of providing tailored training and developing relationships in different relevant sectors, taking into consideration regional variability.

Partnerships and Financing

The *Roadmap for the Decade* identifies key stakeholders that should be engaged[2]. The North Atlantic Regional Workshop included representatives from most, but not all, of these sectors and participants noted that efforts must continue to be made during the UN Decade to capture the broadest input possible.

Partnerships

Many existing partnership programs exist and those already mentioned (e.g. ICES, AORA, Horizon Europe, AtlantOS, U.S. IOOS – Integrated Ocean Observing System, IOOS Regional Associations and others) effectively address regional and/or multi-national ocean issues. Participants strongly agreed that utilizing these existing programs was preferred over creating a new structure to address goals of the UN Decade. However, participants also acknowledged the need to amend or expand existing programs to focus on key priorities of the UN Decade.
The North Atlantic Regional Workshop would have benefited from stronger participation from important key sectors such as private sector/ industry, social scientists (including marketing, communication/outreach, economists), engineering,

[2]*Roadmap for the Decade – Final Version, Page 22*
Other key stakeholders : 93. The Planning Group will also develop strong collaboration with non-UN partners and invite inputs on the preparation and implementation of the Decade. For engagement, consultation and communication purposes, six main categories of stakeholders have been identified: (i) Ocean Science Community; (ii) Policy-makers and managers; (iii) Businesses and industries


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local and Indigenous communities, regional fisheries management organizations, Non-Government Organizations (NGOs), and the development finance community. Further, participants noted that connections need to be made across ocean basins and internationally. Participants strongly recommended the inclusion of other sectors in Decade programs in order for the Decade to achieve its goals. However, including these sectors will likely need new and/or different engagement strategies.

Financing

Participants identified the difficulty of funding multi-national programs as the single greatest challenge facing the UN Decade. Nonetheless, examples of intergovernmental agreements and multi-national programs that have enabled financing of multinational initiatives exist. The UN Decade should utilize these existing mechanisms and agreements to fund the research programs, as opposed to attempting to create a new financing mechanism.

The workshop identified examples of multi-national funding mechanisms that the UN Decade could utilize or leverage, including: Joint Program Initiatives (JPIs) that enable multiple nations to contribute to one funding pot of money; for example, the Belmont Forum facilities regional, collaborative projects and various Multinational Agreements such as the Arctic Council, OSPAR, Galway, HELCOM, Cartagena, and Belém all facilitate access to financial resources for various scientific projects.

The *Roadmap* describes general financing options that would likely include a campaign for a UN Decade fund that countries, NGOs and private foundations would contribute to thus creating a central budget with a secretariat to allocate funding. Workshop participants discussed these ideas but added no specific additional details.

The second theme to emerge was how to expand or adjust existing efforts to align with the UN Decade's societal benefits and goals. While simply identifying already planned work as UN Decade contributions is insufficient in and of itself, leveraging that work to include new scientists, communities, and/or collaborators from other geographic areas offers one tactic that program managers can use to contribute to the UN Decade. Similarly, participants discussed the idea of establishing 'virtual' projects that connect initiatives in different disciplines, sectors, or geographies to enable alignment with the broader scope of the UN Decade. Finally, in order to enable the alignment process to happen, participants discussed the need to identify relevant ongoing work so as to identify gaps and enable leveraging between projects.

Another overarching discussion point related to diversity of financing. As mentioned previously, the Roadmap notes the need for diverse funding sources. Workshop participants agreed with this recommendation and suggested the following potential funders specifically should be approached to contribute: NGOs (e.g. foundations, x-prizes), industry (e.g. shipping, energy, insurance), and crowd-sourcing initiatives. The latter potential funder merits consideration as much for revenue generation as for the engagement potential it provides.

The final point on financing concerned documenting the value of the ocean and its resources. Clear articulation of the value of the ocean and its economic contribution to nations, regions, and sectors might facilitate the effort of getting funders to support the UN Decade.

Access to Information, Data, and Knowledge

Three overarching questions were identified within this cross-cutting theme:

1. What is the current state of information and data;
2. How is information and data communicated; and
3. What needs to be done within the Decade?

(iv) Civil society; (v) Donors and foundations; (vi) Public

There was discussion regarding how to improve ocean science and decision-making with the information, data, and knowledge that is available. With this in mind, the discussion focused on: quality and precision, accuracy and resolution, appropriate collection, open access and FAIR (findable, accessible, interoperable, and reusable) principles, actionable data for a purpose, standardizing data, the sharing of best practices, and ensuring broad accessibility.

It was recognized that a lot of knowledge exists that cannot be easily accessed (e.g. local knowledge from fishermen). There is also non-traditional sources of information and data that are linked to industry and/or those that have possible restrictions (e.g. defense-related data). An underlying theme of increasing data access relates to the human dimension of trust. Trust between data/information providers and users is a necessary foundation. There needs to be a cultural and behavioural change to be inclusive in the communication of data and information, with the understanding that communication of knowledge is broader than knowledge transfer.

An opportunity exists to expand work on data visualization as the public wants to be able to see how doing something will tell them the answer to questions they are interested in. Case studies could be conducted to determine the most effective means of showing how data can be used (e.g. Google maps).

There was agreement that the UN Decade could make a real difference in increasing access to data, knowledge, and information. Possible features of this increased access could include: the design of a UN Decade data system, of increasing access to real-time data for decision-making, developing the use of Artificial Intelligence to search and analyze or communicate data, the potential removal of ownership of data, and increasing the number of information products to help the public engage more with the data.

Finally, all of the above challenges can only be addressed with partnerships and inclusion of many data and information providers and users.

Awareness Raising and Inclusivity (including consideration of Ocean Literacy, Indigenous Peoples, and Gender)

There was recognition that governance needs to be inclusive of social sciences – this expertise is needed to understand cultural sensitivities and knowledge systems, engagement activities, language and understanding, and also in evaluating the efficacy of different programs. There needs to be broader diversity in discussions as the diversity of society is not reflected within the scientific community. Further, the communities that will be most affected by the loss of, and changes to, ocean life are generally not present.

It is important, even critical, to have different types of thinking and perspectives considered in order to have successful transformative change and to reach the Sustainable Development Goals. The inclusion of youth at this workshop resonated across all discussions. The idea is that we may not be able to change the way of thinking for most, but we can alter our thinking by instilling new and innovative ways of sustainable practices by targeting youth at a young age and by giving great weight to our elders' stories; in many cultures and communities their way of knowing and thinking has always been transferred in this manner. Being inclusive also means that our notions of what needs to happen (and why it is necessary) might change with new perspectives.

It was raised that terms like “science” and “literacy” are exclusive to a world of academia, government, and policy makers. There is a need to mobilize knowledge systems and deepen public participation and this includes disseminating information, knowledge and data in a manner that will reach and be inclusive of the other 90% of the global population.

Participants felt that incremental progress on transforming partnerships and inclusiveness is no longer enough. There needs to be transformative change that is more inclusive of a larger percentage of the world's populations. Scientists need to take

what they know today, and take steps now to acquire partnerships and "buy-in" from those who can support action (e.g. Indigenous groups, policy makers, social scientists, economists, industry, etc.). Partnership and awareness of different approaches amongst industry needs to happen – all knowledge systems (western and traditional) need buy-in from industry to support research projects that can support change towards a sustainable and productive ocean. It is important to note that we must design transformative agendas that protect those who are negatively affected during the process of transformation.

Through improved ocean literacy the public will be better able to drive regional actions (through policies, business practices, regulation) across the North Atlantic for sustainable ecosystem management. In addition, citizens may undergo behavioural change (personal and collective) that will encourage them to become civic actors in their communities (e.g. contributing to/strengthening local ocean economies, engaging in community-based research and citizen science, organizing community events to strengthen ocean values, etc.).

The approach of integrating Indigenous knowledge into research solutions for a sustainable ocean must be inclusive of both land and water communities and must not be limited by coastal boundaries. This approach cannot be done through one lens but rather by using the "two-eyed seeing" approach whereby one is from the "Western science perspective" and the other is the "Traditional, local and Indigenous perspective". The UN Decade presents an opportunity to develop a framework to bring in and include other types of knowledge besides science, while recognizing the differences and sharing the responsibility to get it right. However, we must be mindful when we speak of the integration of knowledge systems; this is disheartening and distrust is only aggravated when communities feel that they have been studied/researched with no follow-up engagement or feedback on the studies.

Awareness can no longer be a process of simply speaking - we must also think of the outcome we want to achieve by bringing awareness to a particular research project, concern and/or solution through tangible actions.

We must be creative about communicating the importance of the UN Decade and the results of these regional workshops to those who are not present at the discussions. Messaging should be tailored to the language of the audience and, where appropriate, the arts can be used in creating visualizations that speak to the general population.

Transdisciplinarity

Transdisciplinarity is the notion that real world problems are agnostic to scientific disciplines and the best way to understand them is to incorporate all relevant disciplinary lenses needed to understand a problem. It is a problem-led style of investigation. With this in mind, the following six priority areas emerged within the cross-cutting theme of transdisciplinarity:

1. **Transdisciplinarity as a necessarily inclusive research design**

   Transdisciplinarity is more than inter-disciplinarity in that it attempts to expand on the notion of working across disciplines or exploring an issue across recognized disciplines. In order to effectively incorporate relevant perspectives, and in order to provide decision-relevant information in contexts of patchy scientific data, a very important aspect of transdisciplinary research is the inclusive notion of expertise. Transdisciplinary research recognizes that place-specific knowledge is often held by resource users, local communities, and Indigenous groups, and is generally not found in academic literature or government reports. So while the scientific community has much to offer local communities in terms of aiding decisions towards sustainable oceans, at the same time the scientific community has much to gain from the expertise of local

people. In this way it is recommended that research designs are based around "capacity exchange" and "expertise exchange" between the scientific community and local community knowledge holders.

2. **Pre-emptively plan for emerging challenges in transdisciplinary designs**

   While the incorporation of diverse sources of knowledge offers benefits to research (in terms of capitalizing on existing knowledge and filling in data gaps), the wide adoption of research designs that incorporate diverse knowledge sources face potential challenges that should be pre-empted where possible. In the context of working with Indigenous groups, a history of colonial effects and legacies has led to distrust and resistance to building working relationships. Building or rebuilding trust with Indigenous groups will require long-term consultation and partnerships, and indications that any research will have benefits for these groups. A more insidious challenge of engaging with divergent sources of knowledge is that there will be times when there will be fundamental disagreements between the scientific community and other knowledge holders. It is recommended that researchers engaging in transdisciplinary work should collaboratively and pre-emptively develop plans to resolve disagreements when they come up. Failing to develop these plans runs the risk of defaulting to trusting the input of the scientific community without input from the other knowledge groups. This result can lead to further distrust among other knowledge holders towards the scientific community. Developing these plans can follow best practices from Structured Decision Making and similar participatory discursive planning processes, but is also a potential area of focus for future research.

3. **The social sciences and humanities are not marketing and sales tools**

   The social sciences and humanities are fields that develop their own research topics, hypotheses, and investigations to explore issues of behaviour, institutional structure, perceptions, social groupings, cultural practices, economic decisions, artistic expression and more. There is a tendency for some natural and physical sciences to view the social sciences and humanities as tools to help "sell" or convince messages from the scientific community to the general public and policymakers. Incorporating the social sciences in transdisciplinary research is not a "fix" to be incorporated after the research is done but a design principle to first understand the decision context and priorities before and alongside the work of natural and physical science.

4. **Prioritize research through the use of models/ theories of change**

   Not all ocean research is useful to advance ocean sustainability. Similarly, increasing the volume or availability of ocean information and science may not necessarily promote ocean sustainable development. Instead of assuming that any and all developments of ocean knowledge will contribute to ocean sustainability, a useful exercise will be to explicitly model how research programs and topics will contribute to achieving the UN Decade societal outcomes and further, how they link the societal outcomes to the Sustainable Development Goals. These models act as a current understanding of a theory of change. The formulation of these explicit theories of change serves two purposes: first, it forces the research community to consider how (or even if) research programs connect with sustainable development goals, and therefore helps to ensure policy relevance of their work. Some of the biggest potential uncertainties in these theories of change are how the "societal outcomes" of the UN Decade actually connect to human well-being (that is, how we can ensure they increase human well-being). Second, this exercise helps determine the other variables needed to ensure that research is contributing to sustainable development, and what links are more or less certain. Determining which linkages are more or less certain can help prioritize research plans, as it can direct what topics require additional research. With more research the theories of change should be updated. This iterative process can aid in

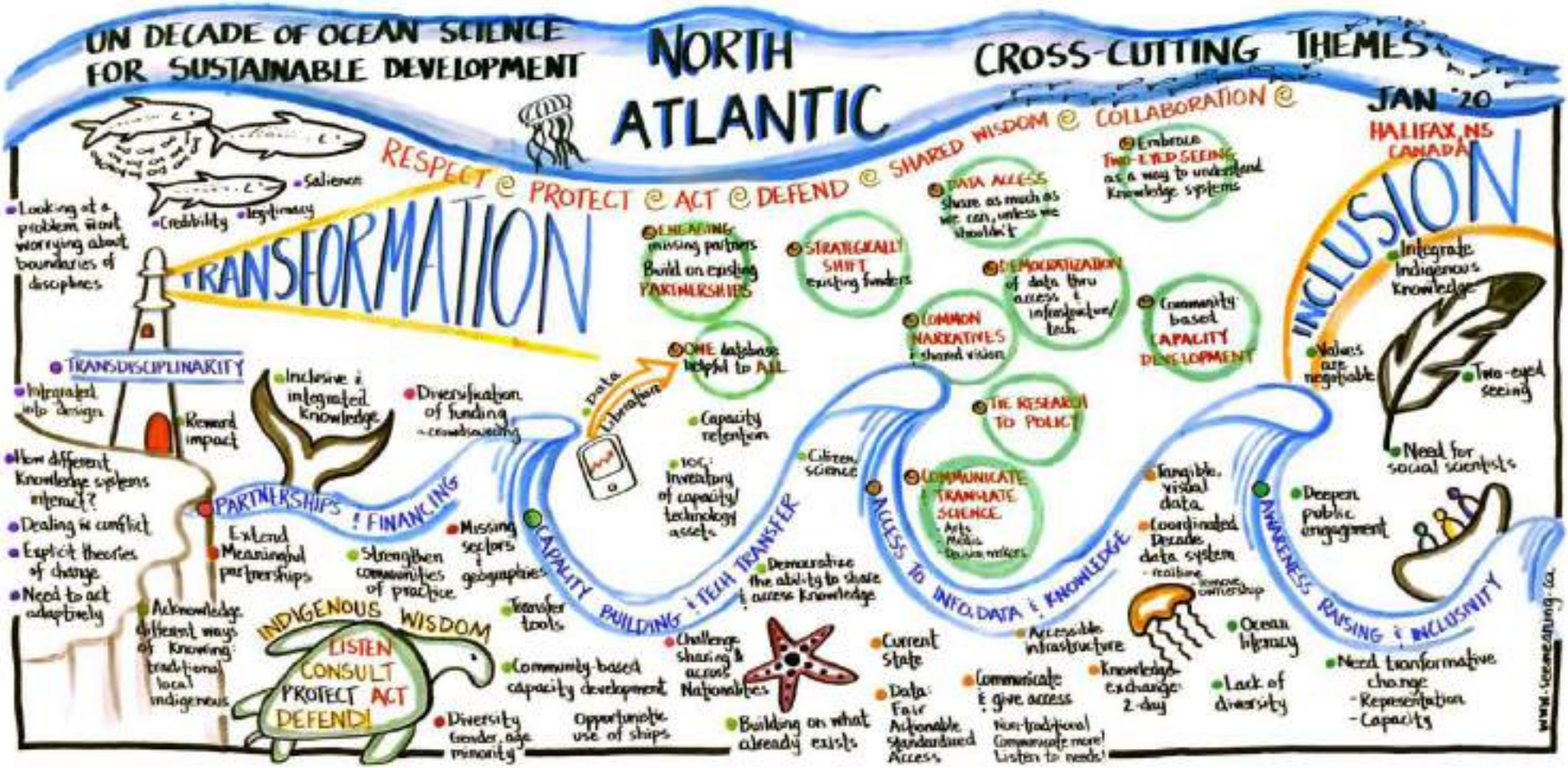
developing the transition plan from where our global society is to where it wants to go meet the transformational sustainable development goals.

5. **Transdisciplinarity for transformations through learning by doing**

   Science is an investigative and diagnostic process. The simultaneous urgency of addressing sustainable development with the uncertainty behind a lack of clear direction in terms of planning has led a sense of crisis and the development of a diversity of initiatives around the world to address ocean sustainability. Proposed and ongoing initiatives include funding mechanisms, education programs, partnership-building institutions, and other initiatives to promote sustainable oceans, based on different models and philosophies. While the intention behind these ongoing and existing initiatives is admirable, it is likely that there will be discrepancies among these initiatives in terms of their effectiveness towards their intended goals, and potential unintended consequences. The existence of a diversity of initiatives creates opportunities for ongoing research into the effectiveness of real-world initiatives to build on. Taking on an adaptive management approach to research, where the scientific community learns by the real-world trials of ongoing and emerging initiatives, ensures that both the successes and failures of initiatives are informative in a real-world context, and can help understand what works and why. To capture the successes, failures, and unintended side-effects means that diverse researchers from the natural sciences, social sciences, health research, engineering, humanities, and interdisciplinary fields are engaged early. This "learning by doing" approach to transdisciplinary research benefits from the chance-successes of diverse actions while simultaneously refining and planning initiatives to ensure the benefit of any individual initiative.

6. **Ensuring that research translates to action**

   Research on science for sustainable development recognizes three broad dimensions that contribute to the policy uptake of research. They are perceptions of the credibility of research (the scientific adequacy of research), perceptions of the legitimacy of research (the perception that the production of knowledge is unbiased and fair), and the salience of the research (the relevance of the work to meet the needs of decision-makers). The science community almost exclusively focuses on ensuring the credibility of their work without considering the perceived legitimacy or salience of their work outside of the scientific community (and often only within their own fields). Research during the UN Decade should ensure that all three dimensions are considered in relation to the perceptions of the groups that will make decisions that affect ocean sustainable development. The recommendations here – that research is inclusive, evaluative of initiatives, and follows or develops effective theories of change – are meant to contribute to these dimensions, especially to ensure that legitimacy and salience are considered as well as credibility.



Credit: Corrie Melanson, See Meaning Graphic Facilitators

OUTCOMES OF THE SIX WORKING GROUPS ALIGNED WITH THE SOCIETAL OUTCOMES OF THE UN DECADE

Working Group 1: A clean ocean whereby sources of pollution are identified, quantified and reduced and pollutants removed from the ocean

A list of pollution issues for the North Atlantic Ocean and related natural and social science research needs was produced and prioritized using a matrix approach (Table 1) and much of the discussion centered on the need to better target resources to solve issues rather than generating additional knowledge. It was recognized that priorities under 'A Clean Ocean' outcome will vary according to location (i.e. within and between geographic regions), and that existing initiatives such as the World Oceans Assessment - https://www.un.org/regularprocess/content/first-world-ocean-assessment - should be used to better define priorities for the UN Decade, as there were both regional and topic-specific limitations of expertise within the working group (as is likely to be the case across all working groups).

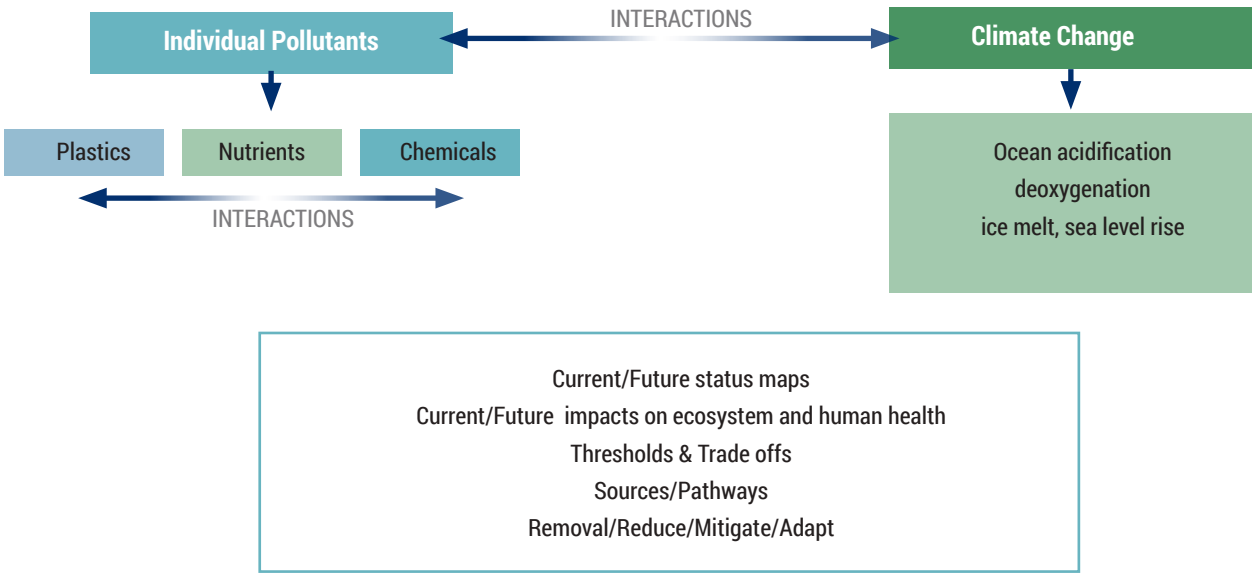
Key science priorities pertaining to 'A Clean Ocean' for the North Atlantic region were identified as:

- **carbon dioxide** increase and the associated impacts of ocean acidification, heating, and inundation or flooding;
- **chemical pollution** including endocrine disruptors, Persistent Organic Pollutants (POPs), Persistent, Bioaccumulative and Toxic (PBTs), Per- and Polyfluoroalkyl Substances (PFAS), pharmaceuticals, and biocides;
- **nutrient enrichment** and the associated impacts of eutrophication, deoxygenation, harmful algal blooms (HABs), and *Sargassum* seaweed;
- **plastics** (from nano to mega);
- **species transfer** (including pathogens and disease) associated with shipping and fisheries activities as well as associated multiple vectors; and
- **underwater noise and light.**

An early product of the UN Decade could be to complete a more formal, structured expert opinion survey to further inform prioritization of issues within and between regions, as well as within the pollution categories.

Many of the pollution issues identified are already well documented and sufficient evidence exists to warrant reduction of inputs. It was agreed that the UN Decade should, in most cases, conduct research to generate/implement solutions or to motivate political action and behavioral change to see improvements in ocean pollution, rather than generating additional knowledge. It was recognized, however, that key information gaps may be related to interactive or cumulative effects of pollutants under climate and sea level changes (Figure 1).

Figure 1. Key information gaps for 'A Clean Ocean': Interactions and Cumulative Effects



Key North Atlantic Ocean Regional Science/ Information Gaps for 'A Clean Ocean'

In consideration of the stressors and contaminants identified above, key knowledge gaps were identified relating to the need for:

- Understanding individual impacts on biota and human health to identify acceptable level thresholds;
- Risk assessment methods for understanding impacts on biota and human health under climate change and interactive/multiple stressors;
- Quantifying risks/benefits of interventions and replacement substances;
- Evaluation of interventions/replacement substances – quantifying benefits and risks;
- Evaluation of trade-offs (Management Action A vs. Management Action B);
- Developing methods to capture and incorporate non-science information (e.g. traditional, generational knowledge, sectoral, local); and, characterizing structure of different knowledge systems;
- Developing methods for effective transboundary governance/management systems (mechanisms to reduce land-based inputs reaching the ocean – integrations of political, geographical, social, sectoral);

- Emerging pollutants (e.g. light pollution);
- Effective monitoring that informs knowledge gaps AND development of solutions;
- Monitoring effects from contamination levels;
- Evaluation of trade-offs for different management actions; and
- Full assessment of socio-economic costs of degraded ecosystems.

There are various ways to convey the message that different stressors and contaminants have various levels of knowledge associated with them. In some cases, knowledge of extent and impacts was quite high, thus regulatory action is, or could be, taken. In other cases, knowledge may be lower but enough evidence exists to start adaptive management (Figure 2). The UN Decade should focus on limiting factors inhibiting action, whether they be at the knowledge-building or communication stages.

Pathways for Solving Issues of 'A Clean Ocean'

The following actions were identified as possible pathways to solving the identified key science/ knowledge gaps:

- Risk assessment methods for multiple/ cumulative stressors;
- Cost-effective sampling and analysis, including sensor development (e.g. low-cost, real-time);
- Maps of impacts or loss presented in a manner that is understandable and using meaningful metrics for end-users (e.g. depreciation in gross domestic product, GDP);
- Focus on solutions with multiple benefits; and
- More strategic funding to target priorities with a focus on finding solutions and evaluating trade-offs.

Figure 2. Providing guidance for regulatory response

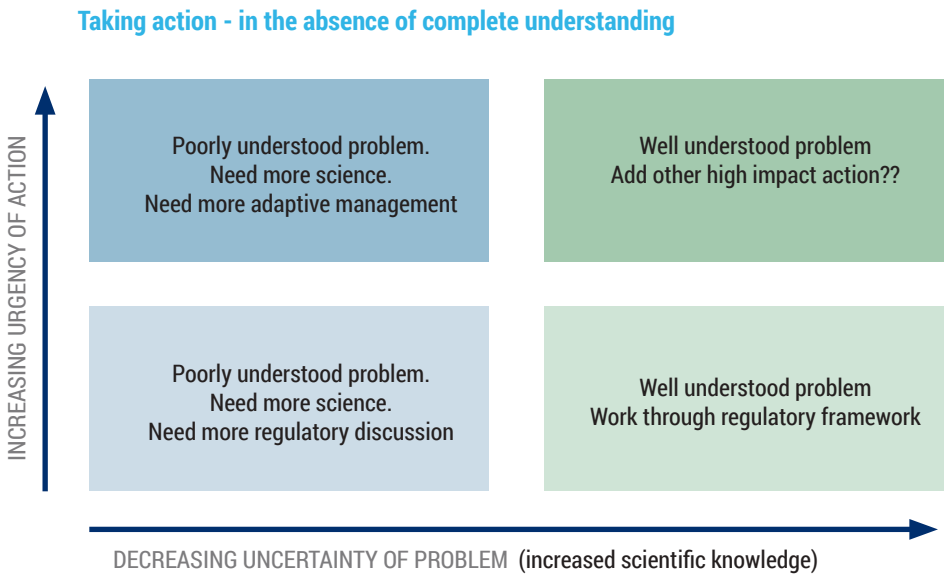


Table 1. Relative importance and current trends in key pollution issues across activities/sectors

Activities/Sectors	Key pollution issues: CO2	Chemical pollution	Nutrient enrichment	Plastics	Species transfer	Underwater noise/light
Fossil fuel use (e.g., transport, industry, heating, power production ...)	H-1					
Agriculture	M-2	M-3	M-3			
Aquaculture		M-2 *(localised; fed, open-pen mariculture)*	L-4	L-3	L-4	
Shipping	L-2	M-3		L-3	H-3	H-2
Extraction (e.g., oil, gas, sand, gravel, metals)		L-3				H-3 *(localized)*
Wastewater and run-off (e.g. industrial, domestic)		H-2	L-3	H-2	M-2	
Wet renewables (e.g. offshore wind, tidal)						M-2
Fisheries				H-3		L-3
Recreation and tourism		L-3 *(Caribbean?)*		M-3		L-3

Relative importance of Activities:

- H – High
- M – Medium
- L – Low

Current Trend:

- **1** – strong increase
- **2** – medium increase
- **3** – no change
- **4** – medium decrease
- **5** – strong decrease

Discussion regarding Cross-Cutting Themes in the context of 'A Clean Ocean'

Capacity building should be seen as a two-way exchange of information, and that 'capacity exchange' may be a better terminology. The North Atlantic region has a unique opportunity to build on existing dialogue and bring in Indigenous communities and organizations, scientists, and managers.

The key capacity exchange pathways relating to 'A Clean Ocean' were identified and included the following recommendations:

- Meaningful activities should be undertaken by all members of the ocean community (e.g. scientists, Indigenous, fisherman, youth), rather than only discussions at meetings;
- Indigenous and generational knowledge must be preserved;
- Communication needs to occur without scientific jargon;
- Consultation at the location and the time that is convenient for the community (rather than expecting others to show up at science meetings);
- Bridges must be built across scientific disciplines as well as sectoral disciplines; and
- More community/sectoral involvement is needed at all steps of research (rather than just sharing results at the end).

Participants emphasized that all sectors should be involved in UN Decade activities, with input/interaction at the early stages of science rather than just recipients of information at the end. Social science should be given equal importance as natural science, as it comprises society, politics, cultural issues and policy perspectives, and is essential for developing effective actions and behavioural change.

Further, actions to improve collaboration with marketing and public relations sectors to better communicate science as well as develop training opportunities for early-career community members (broader than scientists) in effective science communication and outreach skills will improve access to information, data, and knowledge.

In conclusion, the following broad actions under the UN Decade are proposed to achieve the societal benefit of 'A Clean Ocean'. There is a need to:

- Build on existing expertise (e.g. International Panel on Climate Change reports and the World Oceans Assessment Report) to identify pollution-related priorities;
- Focus on action-oriented efforts to support the UN Decade now;
- Seek transformative change in resource use including circular economy initiatives and improving resource efficiency;
- Change the structure for the scientific reward/evaluation system (i.e. not just publications are considered a metric of success, but also engagement) and to make "engagement" a requirement for any funding related to the Decade; and,
- Change existing funding expenditures, to create more focus on solutions/action vs. monitoring/knowledge (although there will also need to be some research to close knowledge gaps).

Working Group 2: A healthy and resilient ocean whereby marine ecosystems are mapped and protected, multiple impacts, including climate change, are measured and reduced, and provision of ocean ecosystem services is maintained

Consideration should be given to these future-looking societal outcome goals for 'A Healthy and Resilient Ocean' for the end of the UN Decade in 2030:

- Governments will have implemented science-based, effective Marine Spatial Planning and Ecosystem-Based Management systems to maintain/restore/strengthen ecosystem resilience in the face of competing ocean uses;
- The science community will have gained an understanding of the mechanisms that drive marine ecosystem structure and function in order to maintain (or restore) a healthy and resilient ocean; and
- Society will have gained significantly enhanced institutional capacity for sustainable ocean use by encouraging broad participation in understanding and resolving tradeoffs among ocean uses.

To achieve this future, the following science priorities were identified:

- **Evaluate ecosystem resilience to ecological regime shifts,** and therefore improve projections of site-specific costs of impacts and benefits of adaptation to climate change. This priority reinforces the need to model ecosystems effectively in order to forecast changes, determined by human or natural activities.
- **Understand ocean structure and function** (and loss) to maintain or restore a healthy and resilient ocean. This includes an understanding of global marine processes, and the role of species, including poorly-sampled environments such as the mesopelagic, and marine micro-organisms that form the basis of most marine food webs. This priority encompasses basic knowledge needs for key species, including auto-ecology, life history traits, connectivity patterns, migratory pathways and food web linkages as well as linking to nutrient and carbon cycling/sinks.
- **Quantify socio-ecological trade-offs of human activities** through enhanced institutional capacity for sustainable ocean use by encouraging broad participation in understanding and resolving trade-offs among ocean users. These effects on biodiversity, ecosystem structure, and function include climate change, plastic and other pollutants including noise and light pollution, and links to ocean acidification and deoxygenation. The interactions between stressors and degradation also require examination in order to develop effective and comprehensive risk assessments to understand the spatial and temporal risks to marine ecosystems.
- E**xplore the need for effective governance, policy, and engagement considerations** including what types of transformative governance, at local/regional/global scales, will society require to assimilate the evidence from the UN Decade into local management needs, legitimacy, and policy action? This priority noted that the variance in human systems and the effectiveness of responses can complicate these considerations.

Key North Atlantic Ocean Regional Science/ Information Gaps for 'A Healthy and Resilient Ocean'

The following key regional science and information gaps were identified in support of the aforementioned science priorities:

- Temperature changes and their impact on physical and biological ecosystems;
- Ecosystem changes associated with aquaculture operations as an increasingly important protein source and ocean space use;

- Understanding of multi-stressor/user environment (e.g. climate change, invasive species, etc.) with unknown cumulative effects on ecosystem function;
- Better understanding of "Blue Growth" and associated economic opportunities; and
- Effective Area-Based Management schemes, including Marine Spatial Planning, Environmental Impact Assessments (EIA) and Strategic Environmental Assessments (SEA).

An additional and extensive range of potentially important variables that are considered regional science and information gaps exist but time constraints precluded detailed discussion of these variables at the North Atlantic Regional Workshop (i.e. eutrophication, oil and gas, anoxia, invasive species, terrestrial inputs, shipping, noise, and light).

For each of the science/information gaps discussed, more detailed questions, knowledge gaps, and possible pathways for solving these challenges were identified (Table 2).

Table 2. Science and information gaps corresponding to 'A Healthy and Resilient Ocean' coupled with potential questions and possible pathways to solving these challenges.

Science / Information Gap	Proposed knowledge gaps and pathways for solving
Temperature changes and their impact on physical and biological ecosystems	• Understanding heat budgets and heat distribution in the ocean • Understanding animal range shifts in response to changing temperatures • The need for nearshore downscaling of predictive models • Examination of animal tolerances and adaptability to change (and the critical boundaries/thresholds that species cannot cross) • Improving adaptive management with the new knowledge • Incorporating temperature impacts into Marine Spatial Planning and adaptive ecosystem-based management
Ecosystem changes associated with aquaculture operations	• Improved understanding of fish health (e.g. impacts on wild fish, new diseases) • Development of feed formulations to replace fish meal and oils • Development of methods and approaches for improved environmental remediation • Mitigate susceptibility to environmental variability in a changing ocean • Consideration of and better understanding of land based aquaculture options (e.g. reducing energy footprints of land based options) • New knowledge is needed on veterinary and feed science of aquaculture operations • Explore lower trophic level aquaculture • Expand systematic real-time monitoring of environment and aquaculture sites • Examine the social facilitators for land- based and sea cage approaches
Understanding of multi-stressor/user environment (e.g. climate change, invasive species. etc.) with unknown cumulative effects on ecosystem function	• Understanding North Atlantic Ocean ecosystem stressors, structure and function links • Valuation of ecosystem structures and functions • Understanding "microbiomes" and ecosystem health and resilience • Research on sources and impacts of ecosystem stress and function • Understanding of microbiomes including relationships with hosts • Understanding communication across all life forms in ecosystems including signals that are picked up from the environment • Understanding the different rates of adaptation to different rates of change • Understanding how ocean sectors and human patterns will adapt to changing environments

Science / Information Gap	Proposed knowledge gaps and pathways for solving
Better understanding of "Blue Growth" and associated economic opportunities	• Understanding how ocean sectors and human patterns of use will develop in the future • Compile data on patterns of human uses; examine the historical, current • Identify potential Blue Growth opportunities • Understanding cumulative impacts and development of strategic environmental assessments
Effective Area Based Management schemes, including Marine Spatial Planning, Environmental Impact Assessments (EIA), and Strategic Environmental Assessments (SEA)	• Examine ecosystem service values (e.g. weighting, market and non-market values) • Identification of stakeholders and understanding their needs • Determining how to make equitable decisions amongst users • Developing spatial and temporal information integration across sectors • Providing open data and science

Discussion regarding Cross-Cutting Themes in the context of ' A Healthy and Resilient Ocean'

A suite of key capacity exchange pathways were identified to achieve 'A Healthy and Resilient Ocean' including encouraging transdisciplinary graduate programs and networks that will develop transdisciplinary ocean professionals. Existing institutions that enable participatory governance (e.g. for public, science, industry, policy participation - for example in marine spatial planning) should be supported; the European Union's Marine Strategy Framework Directive (EU-MSFD; https://ec.europa.eu/info/research-and-innovation/research-area/oceans-and-seas/eu-marine-strategy-framework-directive_en) could be considered an appropriate framework. Ocean literacy initiatives (especially those focused on ocean-land interactions) that can inform public debate and shape policy should be further developed. Common platforms, standards, and methods (e.g. monitoring) should also be developed in order to make it easier to reach and maintain agreements on required actions. The role of science in supporting these efforts and in providing the underpinning evidence (especially cause and effect relationships) upon which to make decisions should be strengthened.

Regarding partnerships, it was suggested that existing initiatives that link science, industry, policymakers and decision makers, educators, youth organizations, philanthropists should be built upon to advance the UN Decade. Further, there should be increased collaboration amongst national, regional and international funding agencies and cultural and demographic partnerships should be expanded.

Opportunities for increased collaboration between national monitoring programs and the development of joint ship-time programs should be explored. The adoption of transformative technologies (e.g. digital, sensor, artificial intelligence, etc.) and the forming of partnerships with industry sectors is needed.

Transdisciplinary work at the whole Atlantic scale is important (e.g. should not always consider North and South Atlantic separately), including a better understanding of the linkages between the Southern and Northern Atlantic Ocean in order to achieve improved collaboration. Stakeholder and "rights holder" engagement and communication should be encouraged, together with academics, government, and non-government organizations. The establishment of a secretariat that would bring people together via focused workshops to multiply effort may be useful (e.g. Census of Marine Life "glue" model).

United Nations bodies with an ocean focus (e.g. IOC, ISA - International Seabed Authority, ILO - International Labour Organization, IMO - International Maritime Organization, UNESCO, BBNJ, etc.), individual countries, UNESCO National Commissions, the European Union, AORA, ICES, and regional fisheries management organizations, all have a role to play in advancing partnerships in support of the UN Decade.

In order to improve access to information, data, and knowledge, best practices are needed in relation to adaptive management, in participatory governance across society, and on the high seas whereby information sharing would be done from domestic jurisdictions. New digital technology should be adopted, recognizing that big data are powerful tools that have the potential to transform governance and science. Taxonomic and functional information (e.g. environmental, genomic and morphological) need to be easier to access and it would be very useful to have data compiled on patterns of human uses and on historical ocean uses so changes can be understood and forecasted, and also to conduct interviews with ocean users to identify potential ocean use change. Further, maps that incorporate the location of habitats, ecological features and incorporate Traditional Knowledge should be created.

In conclusion, immediate focus to achieve the societal benefit of 'A Healthy and Resilient Ocean' should be on solution-based activities, using a risk-based approach to allow for urgent action. The actions must engage social scientists, industry and the public – those who can instigate the needed change.

Working Group 3: A predicted ocean whereby society has the capacity to understand current and future ocean conditions, and forecast their change and impact on human well-being and livelihoods.

Key North Atlantic Ocean Regional Science / Information Gaps for 'A Predicted Ocean'

Four major issue/research areas were identified for 'A Predicted Ocean':

1. Observe, in order to characterize, the state of the ocean now, its use, and human interactions, and initialize models as the basis for mechanistic understanding;
2. Understand ocean processes to improve models for robust predictions, including risk assessment and uncertainty analysis;
3. Predict how to provide information to users about future conditions, as adequate models need to be initialised by adequate observations; and
4. Provide data and generate information and provide it to people that need it, when they need it.

Transformational objectives were developed for the UN Decade for each of the four issue/research areas identified for 'A Predicted Ocean' (Table 3). These transformational objectives could serve as aspirational guideposts for the four major issue/research areas, each describing a future state that is different than what we have today, and that we aspire to achieve by 2030. In addition, gaps and barriers that need to be addressed, along with proposed actions, so as to attain those objectives were also defined for each issue/research area.

In conclusion, while many of the above results and recommendations for achieving the societal benefit of 'A Predicted Ocean' in the North Atlantic region are consistent with other regions, there is an opportunity and a need for the North Atlantic to begin taking steps toward some of these actions as soon as possible. It is recommended that North Atlantic Ocean experts further identify near-term actions amongst players to "hit the ground running" when the UN Decade starts. Additionally, as the northern North Atlantic agrees on actions to be taken, it would be ideal to engage with other parts of the world that did not participate at this workshop.

Table 3. Transformational objectives for four issue/research areas identified for 'A Predicted Ocean', including gaps and barriers and the actions that need to be addressed to attain them.

Issue / Research Area: Predicted Ocean *(Table 3)*

1 **Observe in order to characterize the state of the ocean now, its use, and human interactions, and initialize models as the basis for mechanistic understanding**[1]

Transformational Objectives

- An infrastructure approach is taken to Atlantic ocean observing as it is fundamental for sustainable development. Efforts are coordinated globally and funded by nations, rich and poor, with benefits for all; see Argo success and AtlantOS vision.
- Principles are defined that all ocean data should be openly accessible and available.
- New technology is widely available for under-sampled locations, at reduced costs, enabling new parameters.
- Local communities make affordable observations that are relevant to them through the full engagement of all partners around the Atlantic Basin, enabling citizen science.

Gaps and Barriers to be addressed

- Current ocean observation systems poorly address many key issues, from physics to ecology to societal dimensions, with many geographic gaps (e.g. coastal areas, the deep basin) and are not presently sustainably funded.
- North Atlantic observations are loosely-coordinated and not rationalized (see AtlantOS strategy paper https://www.atlantos-h2020.eu/atlantos-achievements/atlantos-high-level-strategy-atlantos-blueprint-process/).
- Most observations are still funded through short-term research programs.
- Support for sustained ocean observing infrastructure is lacking.
- Challenges exist in extending observations to cover biology and biogeochemistry.
- Limited data exists in the deep ocean – particularly long-time series.
- There is a lack of integration of networks, data sets, data types (including social dimension data).

[1]A number of additional barriers were identified for Research Area #1, including: timely and open distribution of data, consistency of standards and best practice, the need for better coordination and engagement internationally, limited communication between various groups, limited partnerships, lack of funding, technical limitations, and organizational challenges (e.g. cross-border, international); however these barriers were not discussed in detail.

Actions to be addressed

Short-term (1-3 years)

- Support an AtlantOS – or similar - program to build a basin-scale coordinated observing system based on existing networks (e.g. open ocean such as Argo, Tropical Atmosphere Ocean project, drifters, XBTs - eXpendable BathyThermograph, AMOC - Atlantic meridional overturning circulation, GO-SHIP, Atlantic Seabed mapping programs, MBON - Marine Biodiversity Observation Network, Animal Tracking Networks / Ocean Tracking Network etc.) as well as also coastal observations (e.g. JERICO NEXT, U.S. IOOS, etc.).
- Adopt effective open data policies.
- Work to develop private-public-partnerships (e.g. working with fish harvesters, industry associations).
- Expand ocean observations on existing programs such as ship transects, moorings, drifters, floats and other automated platforms (e.g. biology, bathymetry mapping).
- Coordinate with the International Hydrographic Organization (IHO) to leverage crowd-sourced bathymetry data.
- Tell stories through ocean literacy programs and citizen science initiatives to excite interest and awareness of the oceans leading to behavior change (e.g. ocean plastics, deep sea exploration).

Medium-term (3-5 years)

- Work to minimize international limitations to coordinated ocean observing activities to encourage sharing and to enable wider use of autonomous vehicles.
- Interface with the IOC's Ocean Best Practices initiative https://www.oceanbestpractices.org/ to ensure best information (including system design, other) is available to the international community.
- Expand the existing AtlantOS program to build towards the basin-scale level.

Long-term (5+ years)

- Deploy sustained and coordinated ocean observing infrastructure throughout the basin, including in the deep ocean basins.

Issue / Research Area: Predicted Ocean *(Table 3)*

2 Understand ocean processes to improve models for robust predictions, including risk assessment and uncertainty analysis

Transformational Objectives

- International "partnerships" across disciplines and domains are in place to improve understanding of key processes with a more effective and integrative approach.
- Partnerships and capacity building efforts are led by local and Indigenous communities - citizen science to meet their needs.

Gaps and Barriers to be addressed

- Gaps exist in understanding key disciplinary (e.g. biological, ecological, as well as chemical and physical) processes and interactions across domains (e.g. climate, biodiversity, coastal, benthic, societal use, impacts and changes).
- There is a lack of connection between climate, biodiversity, impact, societal change, coastal modeling communities.
- There is a lack of partnerships between developed and less-developed countries, as well as a lack of trust and lack of cultural understanding and inclusivity for science engagement.
- Underutilization of alternative forms of information exists.
- There is a lack of meaningful time series across domains.
- There is a lack of public literacy around ocean predictions.

Actions to be addressed

- Coordinate internationally to enable more ambitious co-conceived process studies (e.g. an Atlantic "forum" or more fora, where such international activities can be discussed and initiated).
  This could be something like the ICES or CLIVAR Atlantic panel but more integrative in disciplines and objectives and including observations and models.
- Build adaptive frameworks for predicting (e.g. sea level rise and infrastructure and planning decisions need scenarios and tools).
- Create model intercomparison activities to improve ecological, and biogeochemical modeling (e.g. Ocean Model Intercomparison Project OMIP, Coupled Model Intercomparison Project - CMIP, Ice Sheet Model Intercomparison Project – ISMIP, Fisheries and Marine Ecosystem Model Intercomparison Project – Fish-MIP).

Issue / Research Area: Predicted Ocean *(Table 3)*

3 **Predict ocean conditions in order to provide information to users about future conditions. Adequate models need to be initialized by adequate observations.**

Transformational Objectives

- Observation infrastructure provides the appropriate data for the most accurate and effective predictions.
- Prediction models and tools are available to people via their mobile devices and more channels of ocean prediction information products are part of everyday life for society.
- Build a community to develop fully integrated whole ecosystem models (e.g. geological, biological, chemical, physical, and human dimensions) in support of policy and decision-makers.
- Establish modelling systems that are capable of predicting across multiple temporal and spatial scales.
- The modeling community adopts open source principles and methodologies similar to the FAIR data principles.

Gaps and Barriers to be addressed

- Coupled models, across disciplines and domains, are still developing and the use and communication of model results remains a challenge.
- It is a challenge for all communities to make use of current prediction models and tools.
- We are still working to develop coupled model systems that include physical models and biological, biogeochemical and socioeconomic components.
- Gaps exist in prediction and alternatives to prediction/ forecasting, prediction of unknown unknowns, and cumulative human interactions.
- There is a lack of prediction community and infrastructure coordination.
- There are challenges in developing models that can predict emergent properties.

Actions to be addressed

- Develop and improve science-based frameworks for adaptive risk mitigation.
- Develop an ensemble approach across the international community to improve coupled models and to assess societal risk.
- Share best practices for developing communities of practice around involving decision-makers, policymakers, and stakeholders in establishing model products and services towards societal goals.
- Improve whole ecosystem modelling frameworks (e.g. geological, biological, chemical, physical, and human dimensions).
- Support OceanPredict (a grassroots effort currently supported through in-kind national contributions - http://oceanpredict19.org/) as a way to foster intelligent combinations of ocean models with observations is a viable strategy to deliver requisite ocean information.

Issue / Research Area: Predicted Ocean *(Table 3)*

4 **Provide data and generate information and provide it to people that need it, when they need it. Current examples include Copernicus, Argo, and ocean literacy initiatives.**

Transformational Objectives

- Users and the information they need are identified (now and future) and that information is accessible to them.
- Infrastructure includes an adaptable data system with a framework for sharing and best practices.
- Generate and communicate the return on investment in infrastructure (e.g. economic, health, biodiversity, etc.).

Gaps and Barriers to be addressed

- Our ability to transform data to information and knowledge is limited by the absence of linkages across data sets and the need for new approaches to communicate the information and knowledge.
- The research environment can be a major barrier.
- There is a lack of access to integrated data sets.
- It is challenging to translate data to information.
- It is challenging to communicate complex model information in an easily understood graphical form.
- Collection and archiving of requirements to feed data collection and information products is lacking.

Actions to be addressed

- Convene consultation workshops and meetings at local/regional levels to define user data and information needs and to help design products at an appropriate level of processing and abstraction.
- Develop trust and acceptance through engagement activities to enable provision of accurate, fit-for-purpose and understandable information.
- Support and promote international data standardization and identify what further standards need to be developed.
- Support the integration of existing data portals (e.g. EMODnet – European Marine Observation and Data Network, CIOOS – Canadian Integrated Ocean Observing System, U.S. IOOS) to facilitate accessing of data and enable the development of user-friendly and easily accessible products (e.g. apps for mobile devices).
- Implement and expand policies that support open science and open data (public and private) and offer the appropriate infrastructure to where the data can be provided (e.g. an integrated or connected data system).
- Develop a fit-for-purpose observation system that satisfies user and societal needs justifies the return on investment in infrastructures.
- Fund professional communication and exciting stories about the ocean.

Working Group 4: A safe ocean whereby human communities are protected from ocean hazards and where the safety of operations at sea and on the coast is ensured

Risk profiles of activities in the ocean and offshore are changing rapidly, and the associated governance and activities may not be adapting quickly enough. The changing risk profile is driven by the following factors: a rapidly changing environment; increasing interconnectedness (e.g. communications, trade), intensity and changing patterns of activities (e.g. shipping, offshore oil and gas and renewable energy, growth in coastal tourism); locations and timing of activities changing in response to environmental change (e.g. fishing); new technology-enabled activities (e.g. autonomous technologies, seafloor mining); changing patterns of vulnerability (e.g. coastal population rise and concentration); possibility of cascading risks, where one risk triggers another with knock-on impacts (e.g. changing climate relocates marine traffic or marine mammals, such as North Atlantic Right Whales, and puts them in conflict).

Risk has traditionally been considered locally and within sectors, and participants indicated that there has been inadequate effort conducted at the ocean basin scale to conduct an integrated examination of existing and changing hazards and interlinked risks with a view to understanding differences and similarities in hazard clusters and risks, sharing of best practices, connecting similarly vulnerable communities to support shared learning.

A broader scope to define 'A Safe Ocean' was used by participants of this working group than what was included in the Roadmap for the Decade to avoid issues being overlooked that may not be covered by other working groups. In addition, the definition of "safety" was expanded to include:

- health and human well-being (e.g. not only risks of death or of injury);
- both the safety of individuals and of communities;
- infrastructures, property, and agricultural production (e.g. which have knock on effects to human health and wellbeing); and
- animal safety and health because animal health can impact human health through the food chain.

Key North Atlantic Ocean Regional Science/ Information Gaps for a 'A Safe Ocean'

Environmental and social-economic-institutional changes are interacting to influence hazard type, scale, clusters and thus risks, uncertainty in risk assessment and actual and potential impacts. Some hazards are emerging and changing and are poorly understood with uneven research, monitoring, prediction, organizational and other capacities. Uneven, often sector-specific, knowledge of hazards and risk assessment tends to focus on some hazards (natural/ social) independently of others and links between hazards and safety are often assumed versus fully developed and evaluated.

There is a **lack of a basin-wide, multi-scale understanding of hazard vulnerabilities** (physical and social), sources of resilience, and previous and potential impacts. Hazard-related knowledge and risk assessment is sector/issue specific and tends to focus on single or specific hazards. Improved understanding of risk profiles across the region is needed in order to prioritize research and actions related to anticipating and reducing risk - starting with the highest/most complex risk situations and encompassing diverse profiles and groups to ensure key groups and contexts are not left out. Those most at risk of injury/illness are not necessarily those who demand attention or receive the most resources (e.g. small scale fish harvesters/Indigenous groups versus other groups). A particular gap is social vulnerability mapping – exists in some areas but not others – across diverse contexts and groups and encompassing multiple hazards including social/organizational hazards. It is recommended that projects should identify similar risk profiles,

communities and sector groups with similar profiles to share learning and identify, design, implement and evaluate best practices.

The **lack of knowledge** about sea level rise is especially important as it will amplify risk associated with other hazards such as extreme weather, poorly managed coastal developments, and erosion. The focus should not only be on the coastline itself but also on how sea level rise may affect storm-related impacts (both offshore and inland) including impacts on key infrastructure. In addition, the migration of human population may result in threats to safety.

Improvements are needed in climate models and marine-coastal weather forecasting, including prediction of the intensity and pathways of storms. The public loses confidence in forecasting capabilities when there are inaccurate predictions (e.g. with over-evacuation or under-response/preparedness). Appropriate time and space scales need to be made available in the modelling efforts to provide the public with accurate and relevant information.

Better understanding of risk associated with increased and changing ocean traffic (e.g. shipping, recreational fishing and boating) and uses on the ocean. There are multiple hazards associated with increasing cruise ship traffic, particularly in the northern areas of the North Atlantic, with the high density of passengers and crew, navigation and SAR (Search and Rescue) challenges, and pollution risks. The emergence of autonomous shipping introduces Machine Learning and Artificial Intelligence hazards that require high level and standardized navigation resources and information across voyages that are not currently available.

New technology development opportunities should be explored (e.g. personal locator beacons that could be used to focus Search and Rescue efforts, reduce costs and improve effectiveness; or construction of "smart" submarine cables to replace aging cable networks).

Sectoral and regional 'unevenness' and gaps in identifying and managing ocean-related risk should be addressed, including through engineering, training and other initiatives. Subsistence fisheries and traditional fisheries are a key way to include Indigenous concerns and safety issues in research. There is a need to design, test, evaluate and extend training opportunities in collaboration with key stakeholder groups. Further, **research and monitoring gaps exist on public and occupational health effects** associated with *Sargassum*, algae blooms, and shellfish toxins.

Pathways for Solving Issues of 'A Safe Ocean'

A suite of priorities were identified that are necessary for solving the issues associated with achieving 'A Safe Ocean':

A risk map for the North Atlantic Ocean Basin should be generated that includes coastal and offshore areas (including hazards, and physical and social vulnerabilities), provides the framework for action, and informs the design of multi-hazard warning systems. This risk map should underpin and provide the organizational framework for other proposed actions to attain 'A Safe Ocean' and it needs to inform the design of multi-hazard warning systems (see associated pathway for solutions). The following key features were identified for the risk map:

- a "roundtable" discussion forum should be created that would enable discussions where we can learn from others, learn what works and share best-practices (e.g. what is necessary and sufficient to protect and enhance safety) in differing environments;
- inclusive of both physical and social vulnerabilities;
- have the capacity for both down – and up-scaling in space and time;
- the basis for setting priorities; and
- used to connect regions with similar risk profiles.

Specific hazards should be linked to risk and resilience concerns in order to guide the design of mitigation strategies (e.g. sea-level rise and coastal resilience, extreme North Atlantic weather, autonomous shipping, and seabed mapping/safety perspectives).

A robust ocean safety evaluation system should be established that includes the development of an inventory of initiatives and networks that aim to improve ocean safety, and metrics of success. A "roundtable" discussion forum should be created where we can learn from others and learn what works (e.g. what is necessary and sufficient to protect/enhance safety) in differing environments. It is important that metrics be established for a robust evaluation system that include information and data on financial costs, insured and uninsured losses, lives lost, asset value at risk, and direct and downstream costs. Finally, the evaluation system needs to determine a baseline of what a "safe ocean" looks like - a sound description of this must be identified and agreed upon, and metrics determined so that measurements can be made on progress towards achieving this safe ocean state.

The governance structures that are needed to foresee, adapt and respond to change/events must be identified to achieve a safer ocean for all groups including the most vulnerable. An inventory should be conducted of existing activities engaged in ocean safety-relevant work, and to map the distribution, resources, and networks associated with these activities. This inventory could be used as a baseline for multi-hazard mapping, science safety impact evaluation, and monitoring impacts of decade safe ocean programs and activities.

A multi-hazard warning system should be developed that incorporates physical, biological and social data as well as new technologies. There needs to be a shift from traditional systems to those under a new paradigm that include low cost and distributed technologies, crowd-sourcing, ships of opportunity for multi-parameters, and increasing citizen science. The system needs to incorporate multi-users and not be project-based. It needs to include physical, biological, and social data (e.g. merge health data with Harmful Algal Bloom- HAB- mapping) and finally the system needs to embrace new technologies (e.g. HAB detection, observation, and warning).

A template and a sample risk map has been developed for the North Atlantic Ocean (Table 4) that identifies a series of potential risks and assesses the knowledge / predictability associated with each risk. This mapping exercise can be scaled up or down across geographic basins and serve to inform other possible actions. The proposed mapping also provides a unifying framework for other proposed actions. In particular, it brings the human dimension of 'A Safe Ocean' to the forefront to inform and identify key gaps in hazard identification and risk assessments, helps ensure operational multi-hazard warning systems are designed with community input and community needs, and provides an appreciation of risks including cascading risks. Vulnerabilities are shaped by the way information is used and actioned - and not simply technology or natural science led. Finally, it is important to note that the map and warning systems need to be living documents and infrastructures that are regularly updated and adapted based on lessons learned.

It is recommended that current efforts need to continue and that these activities need to be better connected. With improved connections, additional gaps in knowledge areas will be identified and can be addressed as regional priorities. Finally, there may be threats to 'A Safe Ocean' that could be re-considered as opportunities.

Table 4: North Atlantic – 'A Safe Ocean' Basis for Risk and Resilience Assessment Map of North Atlantic Basin

Features include: locally developed, shared regionally, covers coastal and offshore spaces, enhanced by sharing best-practices, includes physical and social vulnerabilities, capacity for down- and up-scaling (space, time), basis for priorities and connecting regions with similar risk profiles and the work to improve safety. This underpins and provides organization framework for other proposed actions. It should be noted that prioritization took place without participants from tropical or polar regions.

Template of Hazard Map, and Risk and Resilience Tables:

	Location – down-scalable further to regional, national, provincial, local scales						
Hazard Map	Tropical West N Atlantic	Sub-Tropical West N Atlantic	Sub Polar West N Atlantic	Tropical East N Atlantic	Sub -Tropical East N Atlantic	Sub-Polar East N Atlantic	Knowledge/ Predictability
Natural Hydro-Meteorological							
Natural Geo-hazards							
Natural Bio-hazards							
Anthropogenic: Waste							
Anthropogenic: Maritime Operations							

	Who/What							
Risk and Resilience	Coastal Communities & Infrastructure	Offshore People Infrastructure Shipping	Coast & Inland Human Health	Coast & Inland Economy	Animals	Vulnerability	Perception[3]	Impact
Natural Hydro-Meteorological								
Natural Geo-hazards								
Natural Bio-hazards								
Anthropogenic: Waste								
Anthropogenic: Maritime Operations								

[3]*Perception: Understanding risk perceptions is a key part of risk research, as well as understanding differences between perceptions of different groups, or differences between perceptions and formal treatments of risk.*

Sample Hazard Map – North Atlantic Region

Hazard Map	Location – down-scalable further to regional, national, provincial, local scales						Knowledge/ Predictability
	Tropical West N Atlantic	Sub-Tropical West N Atlantic	Sub Polar West N Atlantic	Tropical East N Atlantic	Sub -Tropical East N Atlantic	Sub-Polar East N Atlantic	
Natural Hydro-Meteorological							
Hurricanes							M
Storms							M
Squalls							M
Cold spells							M
Heatwaves							M
Fog (visibility)							M
Dust (visibility)							L
Sea level rise							M
Tides							H
Storm surges							M
Meteo-tsunami							L
Waves							M
Freak waves							L
Extreme currents							M
Sea-ice							M
Icebergs							L
Polar depressions							
Freezing spray							

Hazard Map	Location – down-scalable further to regional, national, provincial, local scales						Knowledge/ Predictability
	Tropical West N Atlantic	Sub-Tropical West N Atlantic	Sub Polar West N Atlantic	Tropical East N Atlantic	Sub -Tropical East N Atlantic	Sub-Polar East N Atlantic	
Natural Geo/Geo-chemical -hazards							
Coastal /Island Volcano				■	■	■	L
Subsea Volcano	■	■	■	■	■	■	L
Seabed Gas release	■	■	■	■	■	■	L
Submarine Landslides	■	■	■	■	■	■	L
Submarine Earthquake	■	■	■	■	■	■	L
Hydrate-destabilisation			■			■	L
Islands flank collapse	■	■	■	■	■	■	L
Tsunami	■	■	■	■	■	■	M
Shoreline stability	■	■	■	■	■	■	M
Coastal erosion	■	■	■	■	■	■	M
Seabed topography	■	■	■	■	■	■	M
Corrosion	■	■	■	■	■	■	M
Oxygen depletion	■	■	■	■	■	■	M
Natural Bio-hazards							
Toxic micro-algae	■	■	■	■	■	■	L
Macro-algae (e.g. sargassum)	■	■	■	■	■	■	L
Jellyfish (blooms)	■	■	■	■	■	■	L
Dangerous predators	■	■	■	■	■	■	M

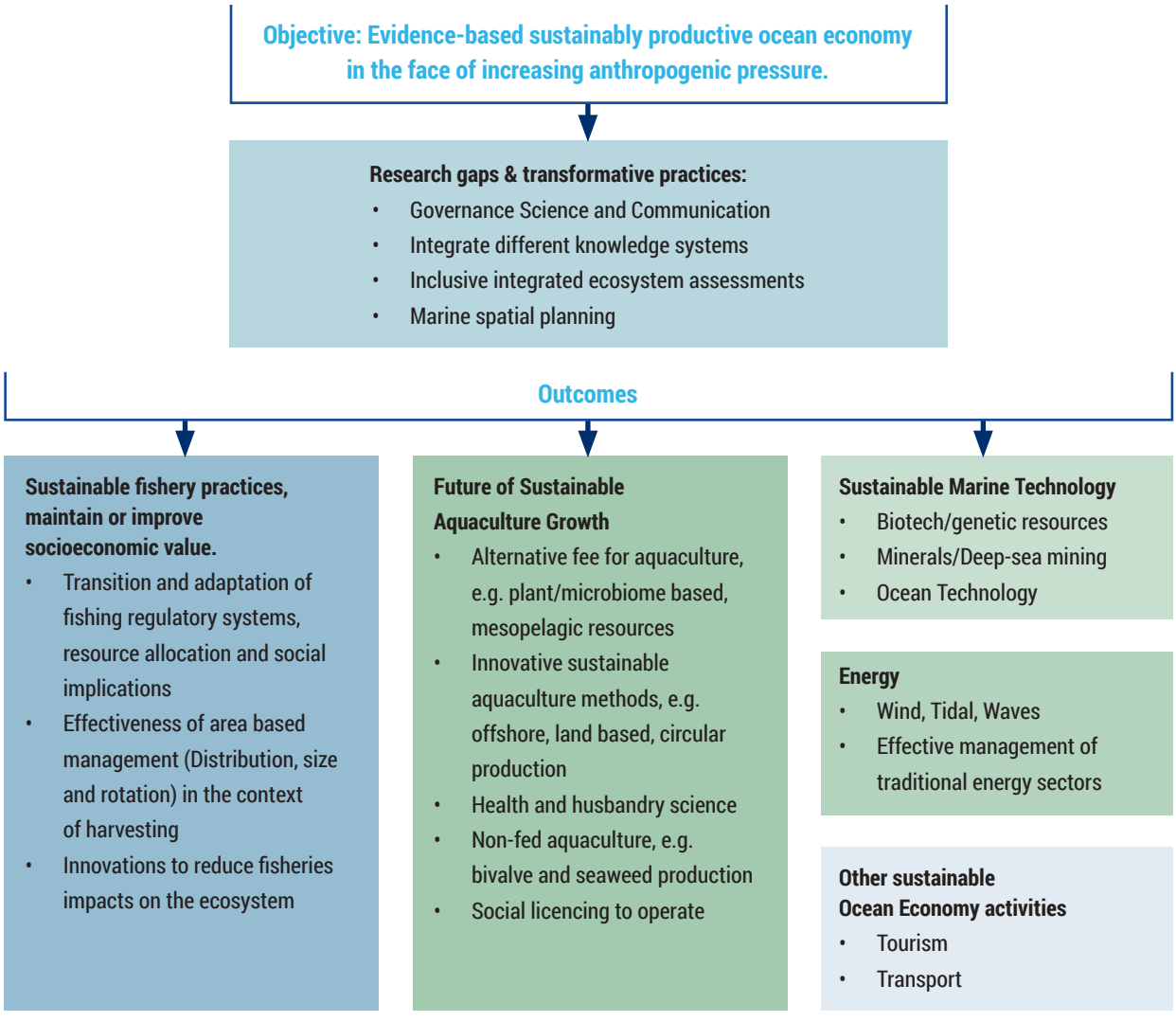
Hazard Map	Location – down-scalable further to regional, national, provincial, local scales						Knowledge/ Predictability
	Tropical West N Atlantic	Sub-Tropical West N Atlantic	Sub Polar West N Atlantic	Tropical East N Atlantic	Sub -Tropical East N Atlantic	Sub-Polar East N Atlantic	
Anthropogenic: Waste							
Chemical waste (organic/inorganic)							M
Chemical waste (emerging)							L
Radio-active waste							M
Legacy contaminants (sediments)							L
Micro plastic							L
Macro-plastic							M
Oil spills							M
Munitions							M
Wrecks							M
Flotsam/Jetsam							L

Hazard Map	Location – down-scalable further to regional, national, provincial, local scales						Knowledge/ Predictability
	Tropical West N Atlantic	Sub-Tropical West N Atlantic	Sub Polar West N Atlantic	Tropical East N Atlantic	Sub -Tropical East N Atlantic	Sub-Polar East N Atlantic	
Anthropogenic: Maritime Operations							
Fishing							M
Aquaculture							M
Navigation							
Shipping							M
Aviation							M
Security, piracy, illegal, unregulated activity							
Autonomous Shipping							L
Offshore Structures/Infrastructures							H
Offshore Leisure							L
Coastal tourism/leisure							M
Coastal transportation							M
Coastal construction							M
Emergency Response							M
Social governance							L
Communication							L
Physical Security							M
Cyber Security							L
Seaborne Hunan migration/trafficking							L
Offshore mining, dredging							M

Working Group 5: A sustainably harvested ocean ensuring the provision of food supply and ocean resources

An overarching objective was developed for 'A Sustainably Harvested Ocean' in which "an evidence-based sustainably productive ocean economy in the face of increasing anthropogenic pressure should be achieved". To attain this objective, outcomes were identified relating to: sustainable fishery practices that maintain or improve socioeconomic value; sustainable aquaculture growth; sustainable marine technologies (e.g. biotech/genetic, minerals, deep-sea mining); new and emerging energy sources; and, other sustainable ocean economy activities (e.g. tourism and transport); see Figure 4.

Figure 4. Research gaps and transformative practices that will achieve the outcomes necessary to attain an evidence-based, sustainably productive, ocean economy in the face of increasing anthropogenic pressure



Key North Atlantic Ocean Regional Science /Information Gaps for 'A Sustainably Harvested Ocean'

The following were identified as key regional science and information gaps for the North Atlantic related to 'A Sustainably Harvested Ocean':

- **The need for better integration of social science** and natural science to co-design management frameworks.
- **An increased understanding of anthropogenic pressures** on a sustainably harvested ocean, including global and regional climate change, species movement, range shifts, tolerance, changes in productivity, ocean warming, and eutrophication.
- **The need for an ecosystem approach and inclusive integrated ecosystem assessments** or cumulative impacts to sustainably harvest the ocean, including marine spatial planning and effectiveness of area based management (e.g. distribution, size and rotation) in the harvest context.
- **An increased understanding of sustainable fishery practices** that maintain or improve socioeconomic value and reduce fisheries impacts.
- **An understanding of the future of aquaculture growth** and the social licensing associated with it, including feed for aquaculture, connection to mesopelagic resources offshore aquaculture, low trophic aquaculture and seaweed production, and circular sustainable food production.
- **An understanding of sustainable marine technology,** marine renewable energies, and other sustainable ocean economy activities.
- **A better understanding of the socio-economic value of ocean products and services, i**ncluding of the strategic role of fisheries and aquaculture on food security (e.g. considering whether something should be a priority in the North Atlantic and how will it affect the region).
- **The creation of social science and transformative governance structures** to enable Integrated Economic Assessments (IEA) for resolving interactions and conflicts between different economic activities, including governance, science, and communication, the integration of different knowledge systems, and also the effective communication of science to policy makers and communities.

Pathways for Solving Issues of 'A Sustainably Harvested Ocean'

Pathways and actions to support the proposed vision statement for 'A Sustainably Harvest Ocean' and to address the noted associated knowledge gaps were highlighted as:

- The need to link inclusive integrated ecosystem assessments with marine spatial planning to manage the diverse and changing demands on ocean space.
- The need for a comprehensive social science approach to:
  - more effectively implement scientific advice into policy action;
  - address the issues of human impacts, equity and social justice; and
  - identify the best governance approach in order to achieve a sustainably harvested and productive ocean.
- Innovations to reduce fisheries impacts on the ecosystem to support sustainable fisheries.
- A new generation of methods to model fisheries in the face of the rapidly changing marine environment. The traditional methods are based on a stable history and won't necessarily be applicable to new issues (e.g. when we don't know what the future will look like, how do we prepare?).
- Shift from species specific management to ecosystem based management.
- Identification of those indicators and governance structures that are working now (and those that are not) to deliver a sustainably harvested and productive ocean.

- Additional research to support sustainable aquaculture, including:
  - alternative feeds and the role of mesopelagic fisheries as feed for aquaculture and the consequences for carbon budget;
  - non-fed aquaculture species (e.g. bivalve and seaweed production);
  - aquaculture health and husbandry science;
  - the study of societal acceptance for sustainable aquaculture; and
  - innovative aquaculture management methodologies.
- Advance the development of sustainable or low-impact marine technologies relating to biotechnology and genetic resources, minerals and deep sea mining, alternative energy, transport, and tourism.
- Better understanding of the impacts of new energy technologies (e.g. wind, tidal and waves).

Discussion regarding Cross-Cutting Themes in the context of ' A Sustainably Harvested Ocean'

Key capacity exchange pathways were identified relating to 'A Sustainably Harvested Ocean' that included the need to incorporate non-traditional knowledge systems into existing ones. The importance was noted of the need to learn what it is that you value in your knowledge system and what other knowledge systems value, and to be able to respond to the question of "Why do you value what you value?" to help determine where there are common values. Another capacity exchange pathway that was identified was the need to develop low-cost stock assessment technologies and tools that are transferable and that could enable developing countries to develop science-based fisheries management. In addition, create exciting, experience-building, and transformative opportunities for early career scientists from all disciplines and at all scales by encouraging them to share their new knowledge and experience with their peers.

In regards to the cross cutting theme of partnerships, the need to strengthen and enable existing networks, rather than focusing on the establishment of new ones is emphasized. Examples of existing partnerships and networks that are in place, and that could be built upon, include: regional fisheries management organizations; ICES, PICES (North Pacific Marine Science Organization), assembly of Indigenous communities, Oceantech (e.g. acoustics, underwater cameras, flume tanks, gliders, etc.), social science networks, and many more. Another area to be addressed under partnerships is a proposal to recruit the great minds from all disciplines and communicate how they can contribute to ocean science, innovation, and transformative change, for the earlier we can connect all disciplines and communities, the more perspectives and knowledge we have to design strategies and solutions to address ocean problems. And finally, interdisciplinary programs should be promoted that recruit students from all disciplines, nationalities and backgrounds with a focus on solving oceanic issues in a transdisciplinary approach.

In improving access to *information, data, knowledge,* the following actions are recommended:

- Sharing and communicating science via pathways that are in addition to scientific publications, in order to create a network and community that is freely accessible to all (e.g. social media, podcasting, video, and more).
- Engaging with scientific networks outside the natural sciences (e.g. social, engineering, technology, etc.).
- Providing open access to ocean education that empowers people to contribute towards improving the status of the ocean with their own unique skill set, not only the natural sciences (e.g. sociology, psychology, business, IT, etc.).

- Linking research networks to enable data and knowledge exchange between all disciplines, for example:
  - Linking research networks can ease the identification of knowledge gaps that require expertise from all disciplines;
  - Creating these connections can also aid in creating new learning and collaboration opportunities for professionals at all stages of their career, and with a global reach; and
  - Combining networks will strengthen existing partnerships, create trust among communities, and form new relationships that can address existing gaps.
- Creating opportunities for exchanges to acquire data, knowledge, and information through lived experiences with local, Indigenous, and professional communities that can foster a complementary way of understanding ocean related problems.
- Creating incentives to share data, rather than keeping it locked away.

Working Group 6: A transparent ocean whereby all nations, stakeholders and citizens have access to ocean data and information technologies and have the capacities to inform their decisions

A vision statement for 'A Transparent and Accessible Ocean', described as the Atlantic version of "Ocean5D" (in short Atlantic5D), was developed that would see rapid, standardised, and credited sharing of data, information, and knowledge through a distributed digital commons where material is findable, accessible, interoperable, and reusable (FAIR). Ocean5D is a vision where a digital-twin ocean would be produced that allows all actors to interact with ocean information in a 5D manner. In an Ocean5D, the first dimension is time - from the past, to the near real-time present, to predictions day to months ahead, including scenarios of the future.

Three further dimensions cover the Atlantic Ocean basin, from pole-to-pole, its coasts, and the 'hinterland' to the deep abyss. The 5th dimension represents societal issues including: fish abundance, ocean heat wave, storm surge risk exposure, fishing potential, acidity, surface waves, currents, deep sea habitat, and sites for ocean extraction, protection and tourism. Ocean5D would be based on harvesting all the data and visualize and query the information but also engage all actors to contribute new information as citizens (e.g. app based), governments, scientists and the private sector. Services would be generated and custom tailored (e.g. the Windy-APP for weather, Google Ocean, etc.). An Ocean5D digital twin ocean would provide a tremendous opportunity to advance ocean literacy, ocean education and engagement.

Two issues were raised and discussed in relation to this vision. It was noted that there is a current lack of consistent access to data and their interoperability, as well as there is a lack of coordination and inter-operation (at all scales) amongst existing capacities across the region. Actions to attain this Atlantic/ Ocean5D vision statement for 'A Transparent and Accessible Ocean' were divided into the following sub-themes: ocean literacy; data accessibility and technology transfer; and best practices, shared facilities and capacity exchange.

Key North Atlantic Ocean Regional Science/ Information Gaps for ' A Transparent Ocean'

Ocean literacy

The following points were identified as key regional science and information gaps in ocean literacy:

- There is limited international coordination amongst ocean literacy activities;
- Governments should mandate the integration of ocean knowledge and ocean learning experiences into provincial/territorial and national school curricula;

- Establish an ocean literacy research program that includes measuring, monitoring ocean literacy, including both baselines and impacts;
- Strengthen regional and international ocean literacy community collaboration; and,
- Key ocean science findings should have an integrated team including a social scientist, marine educator, and/or communicator working with scientists.

Data accessibility and technology transfer
Noting that all ocean data, information, and knowledge should be open and accessible and that the UN Decade should support groups working to realize these principles, the following were identified as key regional science and information gaps in data accessibility and technology transfer:

- There is a current lack of consistent access to data and data may be non-existent, in varying formats, have legal restrictions, commercial sensitivity, and/or there is a lack of awareness;
- Differences need to be identified between collecting and sharing data;
- Good and best practices should be registered and shared (e.g. oceanbestpractices.org);
- Too much attention has been given to the "science perspective"- we should begin balancing the value chain and integrating societal perspectives; and
- Defining goals for a North Atlantic Basin Scale Sustained Ocean Observing System such as those promoted by AtlantOS.

Best practices, shared facilities and capacity exchange
The following points were identified as key regional science and information gaps relating to the sub-theme on best practices, shared facilities and capacity exchange:

- Entwining disciplines and interdisciplinarity and building equitable twins (between disciplines, nations, and institutions);
- Show the way by example and register good practices (e.g. oceanbestpractices.org);
- Creating a digital twin (Ocean5D or the Atlantic version Atlantic5D);
- Equitable empowering of communities to observe their own environments;
- Developing UN instruments to contribute to the digital twin (Ocean5D); and
- Official development assistance contributions.

Pathways for Solving Issues of 'A Transparent Ocean'

The following actions are necessary to address the knowledge gaps and to support the vision and sub-themes:

- Grow capacity and capability by twinning between communities across dimensions such as technical capability, disciplines or societal actors (e.g. small island states, marine and informatics communities, scientist and policy makers, research and education).
- Build an inclusive digital ecosystem, linking digital resources including social media streams and the knowledge of local experts (e.g. fish harvesters) and Indigenous communities.
- Use data and information stored in accessible data systems to visualise many aspects of the ocean to support ocean literacy and education initiatives.
- Create at minimum, a set of standards (e.g. metadata) for data of all types that will also facilitate and optimize machine-to-machine readability (as advanced by Global Ocean Observing System (GOOS), the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (JCOMMOPS), and EMODnet).
- Use frameworks such as GOOS, Group on Earth Observations (GEO) and AtlantOS to share equipment, implementation plans, and join-up strategies to grow and sustain observing systems.
- Building on what already exists, develop easy-to-use tools to contribute and access data which

would greatly democratize sharing and accessing (e.g. Copernicus Marine Environment Monitoring Service, EMODnet).

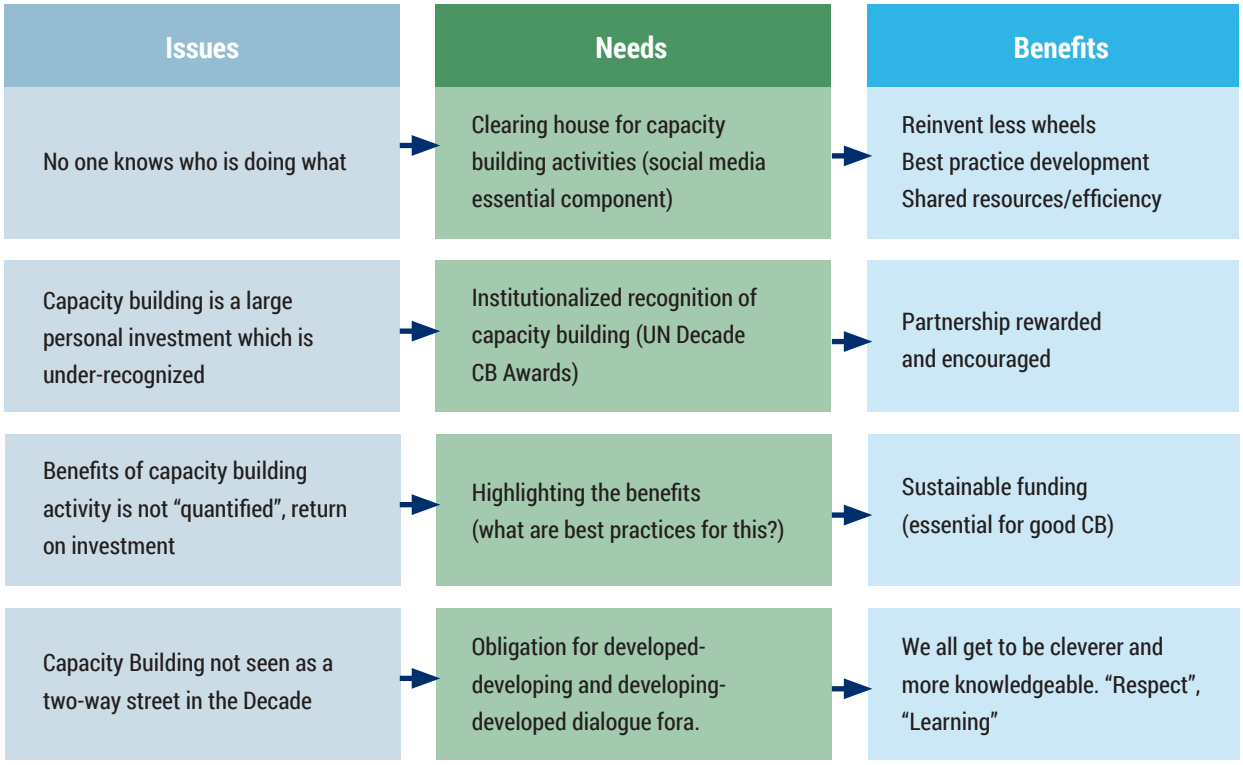
- Fully implement the FAIR (Findable, Accessible, Interoperable, and Reusable) principle and recognize the CARE (Collective benefit, Authority to control, Responsibility and Ethics) principles applying to Indigenous sourced data.
- Through the existing AORA and AANChOR (All AtlaNtic Cooperation for Ocean Research and Innovation) ocean literacy working groups, establish an ocean literacy research program to better understand the different dimensions of ocean literacy (i.e. knowledge, values, and actions), to identify baseline levels of ocean literacy at the start of the Decade, and how those levels change (or not) over the 10 years.

Discussion regarding Cross-Cutting Themes in the context of ' A Transparent Ocean'

The Atlantic5D Ideal Capacity Building Vehicle (Figure 5) presents a visual of issues, needs and benefits that can be gained from investing in capacity building within the UN Ocean Decade.

Two categories of participants were identified in capacity building and exchange: actors and enablers. First, the funding category described as "actors" include States (e.g. Official Development Assistance-ODA), programs (e.g. SCOR - Scientific Committee on Oceanic Research, SCAR - Scientific Committee on Antarctic Research, ISA, IOC, UNESCO, etc.) and philanthropic organizations. The second funding

Figure 5: Atlantic5D ideal capacity building vehicle that presents issues, needs, and benefits that can be gained from investing in capacity building during the UN Decade of Ocean Science for Sustainable Development.



category was described as the "enablers" and include regional organizations such as OECS (Organization of East Caribbean States), WIOMSA (Western Indian Ocean Marine Science Association), SPC Pacific Ocean Portal, GOOS, IOC, WMO, GEO, and local communities (e.g. local Indigenous communities such as the Mi'kmaq).

To address the current lack of consistent access to data and to improve access to *information, data, and knowledge,* we need to build an inclusive digital ecosystem, linking digital resources including social media streams, knowledge of locals and Indigenous communities. In addition, we need to create a minimal set of standards (e.g. metadata) for data of all types which will also facilitate and optimize machine-to-machine readability.

To address the lack of *coordination and interoperation* (at all scales) between existing capacities across the North Atlantic, coupled with notable disparities, the following actions are proposed:

- Build easy-to-use tools to contribute and access data which would greatly democratize sharing and accessing;
- Assess what already exists and what can be built on;
- Data/information collectors and providers must take responsibility for ensuring their contributions are consistent with the FAIR principle; and
- Address issues of legal restrictions as well as commercial and academic sensitivities.

Current initiatives and potential partnerships in the category of networking and coordination of digital resources include AtlantOs, AORA, Copernicus Marine Environment Monitoring Service, GOOS, IOC, IHO, and others. In the category of funding and resourcing, examples of initiatives focus on philanthropic organizations, awards, and challenges (e.g. X-prizes). Finally, in the digital category, examples of initiatives and potential partnerships include online companies (e.g. Google, Microsoft), gaming, technology and computing companies.

MAIN CONCLUSIONS FROM THE NORTH ATLANTIC REGIONAL WORKSHOP

The North Atlantic Regional Workshop presented an opportunity for participants from across the region to come together to discuss priorities and actions to support the Implementation Plan for the UN Decade on Ocean Science for Sustainable Development (2021-2030), as well as to discuss various related domestic and regional initiatives that could support it.

The workshop culminated in the identification of a wide range of actions, potential initiatives, programs, and partnerships that would advance ocean knowledge for sustainable development. The need to include social science considerations in discussions and decision-making, as well as the importance of including traditional and local knowledge, was reinforced in many of the recommended actions. A particular focus on youth engagement was recommended as these individuals are the future scientists and policymakers. There were also recommendations to build on regional programs and activities that are already in place and that could form solid foundations for actions under the UN Decade. Opportunities exist to strengthen and enable existing networks, rather than focusing on the establishment of new ones. Those existing under ICES and AORA are examples of coordinated and partnership-based approaches to deliver the science needs for the ocean we want in the future.

Finally, participants at the North Atlantic Regional Workshop see the UN Decade as a significant opportunity to advance ocean knowledge to achieve sustainable development goals at the global and regional level. Participants and organizations across the region are ready to further engage and act on activities to advance the Decade's societal outcomes and goals.

ACKNOWLEDGEMENTS

A very special thank you to our co-conveners and cross-cutting champions (Annex 1) - without their knowledge, expertise, and substantial effort this workshop would not have been possible. Thank you also to the Youth Ambassadors, Master's students and other notetakers who supported the co-conveners and cross-cutting theme champions and worked hard to capture the discussions at the workshop.

Thank you to the members of the workshop Steering Committee whose contributions and guidance were essential in the planning phase of the workshop. The Steering Committee was comprised of representatives from: Brazil, Fisheries and Oceans Canada (Canada), the European Commission, the Intergovernmental Oceanographic Commission, the International Council for Exploration of the Sea (ICES), the Marine Institute of Ireland, the National Oceanography Centre (United Kingdom), the National Oceanographic and Atmospheric Administration (United States), and the Ocean Frontier Institute.

Financial support for the North Atlantic Regional Workshop was kindly provided by Fisheries and Oceans Canada, Ocean Technology Council of Nova Scotia (OTCNS), International Council for the Exploration of the Sea (ICES), Marine Institute – Ireland, Dalhousie University, Cooke Aquaculture, Nova Scotia Business Inc. (NSBI), Centre for Ocean Ventures and Entrepreneurship (COVE), and the European Commission.

Photo credit: Bruce Bottomley, Bruce Bottomley Multimedia

ANNEX 1: WORKING GROUP CO-CONVENERS AND CROSS CUTTING THEME CHAMPIONS

Working Group Co-Conveners

1: A Clean Ocean

Peter Kershaw, Chair, GESAMP, U.K.
Sarah Bailey, Chair, ICES Human Activities, Pressures and Impacts Steering Group, Canada

2: A Healthy and Resilient Ocean

Isabel Sousa-Pinto, Director, Coastal Biodiversity Laboratory, Portugal
Paul Snelgrove, Memorial University, Canada

3: A Predicted Ocean

Carl Gouldman, Director, IOOS Office, NOAA, U.S.A.
Sabrina Speich, Co-Chair CLIVAR Atlantic Regional Panel, France

4: A Safe Ocean

Barb Neis, Professor, Memorial University, Canada
Ed Hill, Chief Executive, National Oceanography Centre, U.K.

5: A Sustainably Harvested and Productive Ocean

Martina Stiasny, PostDoctoral Researcher, Norway
Francis Neat, Professor of Sustainable Fisheries, Ocean Biodiversity and Marine Spatial Planning, World Maritime University, Sweden

6: A Transparent and Accessible Ocean

Martin Visbeck, GEOMAR and Kiel University, Germany
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Cross Cutting Theme Champions

Capacity Building and Technology Transfer

Easkey Britton, National University of Ireland, Galway, Ireland
Glenn Nolan, EuroGOOS, EU

Partnerships and Financing

Debra Hernandez, Executive Director, SECOORA, U.S.A.

Access to Information, Data and Knowledge

Angela Hatton, Director, Science and Technology, National Oceanography Centre, U.K.

Awareness Raising and Inclusivity (Ocean Literacy, Indigenous, Gender)

Angeline Gillis, Associate Executive Director, The Confederacy of Main and Mi'kmaq, Canada

Transdisciplinarity

Gerald Singh, Professor, Memorial University, Canada

ANNEX 2: LISTING OF ACRONYMS

AANChOR	All AtlaNtic Cooperation for Ocean Research and Innovation
AMOC	Atlantic Meridional Overturning Circulation
AORA	Atlantic Oceans Research Alliance
AtlantOS	Atlantic Ocean Observing system
BBNJ	Biological Diversity of Areas Beyond National Jurisdiction
CARE	Collective benefit, Authority to control, Responsibility and Ethics
CIMP	Coupled Model Intercomparison Project
CIOOS	Canadian Integrated Ocean Observing System
CLIVAR	Climate and Ocean: Variability, Predictability and Change
COVE	Centre for Ocean Ventures and Entrepreneurship
DFO	Fisheries and Oceans Canada
EIA	Environmental Impact Assessments
EMODNet	European Marine Observation and Data Network
EU-MSFD	European Union's Marine Strategy Framework Directive
EuroGOOS	European Global Ocean Observing System
FAIR	Findable, Accessible, Interoperable, and Reusable
Fish-MIP	Fisheries and Marine Ecosystem Model Intercomparison Project
GEO	Group on Earth Observations
GEOMAR	Helmholtz Centre for Ocean Research Kiel
GESAMP	Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIS	Geographic Information Systems
GOOS	Global Ocean Observing System
GO-SHIP	Global Ocean Ship-based Hydrographic Investigations Program
GPM	Global Planning Meeting
GPS	Global Positioning System
H2020	Horizon 2020
HABs	Harmful Algal Blooms
HELCOM	Helsinki Commission, Protection of Baltic Marine Environment
ICES	International Council for Exploration of the Sea
IEA	Integrated Economic Assessment
ILO	International Labour Organization
IMO	International Maritime Organization
IOC	Intergovernmental Oceanographic Commission
IODE	Intergovernmental Oceanographic Data Exchange
IOOS	Integrated Ocean Observing System

IPPC	International Panel on Climate Change
ISA	International Seabed Authority
ISMIP	Ice Sheet Model Intercomparison Project
IT	Information Technology
JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
JERICO NEXT	Joint European Research Initiative (European Commission Initiative)
MBON	Marine Biodiversity Observation Network
MI	Marine Institute (Ireland)
NGO	Non-Government Organizations
NOAA	National Oceanic and Atmospheric Administration
NSBI	Nova Scotia Business Inc.
OceanObs '19	Ocean Observing conference 2019
OECS	Organization of East Caribbean States
ODA	Official Development Assistance
OFI	Ocean Frontier Institute
OMIP	Ocean Model Intercomparison Project
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic
OTCNS	Ocean Technology Council of Nova Scotia
PBTs	Persistent, Bioaccumulative and Toxic Substances
PFAS	Per- and Polyfluoroalkyl Substances
PICES	North Pacific Marine Science Organization
POPs	Persistent Organic Pollutants
Resilient-C	Resilient Coasts Canada platform
SAR	Search and Rescue
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Oceanic Research
SEA	Strategic Environmental Assessments
SECOORA	Southeast Coastal Ocean Observing Regional Association of IOOS
SOPHIE SRA	Seas, Oceans and Public Health in Europe Strategic Research Agenda
SPC Pacific Ocean Portal	Geoscience, Energy and Maritime Division, Pacific Community Ocean Portal
SRA	Societal Risk Analysis
TBA21 Academy	Thyssen-Bornemisza Art Contemporary Academy
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WIOMSA	Western Indian Ocean Marine Science Association
WMO	World Meteorological Organization
XBTs	eXpendable BathyThermograph