CONTACT

Project Coordinator:
J Murray Roberts
murray.roberts@ed.ac.uk

Project Management Team:
eu-atlas@ed.ac.uk

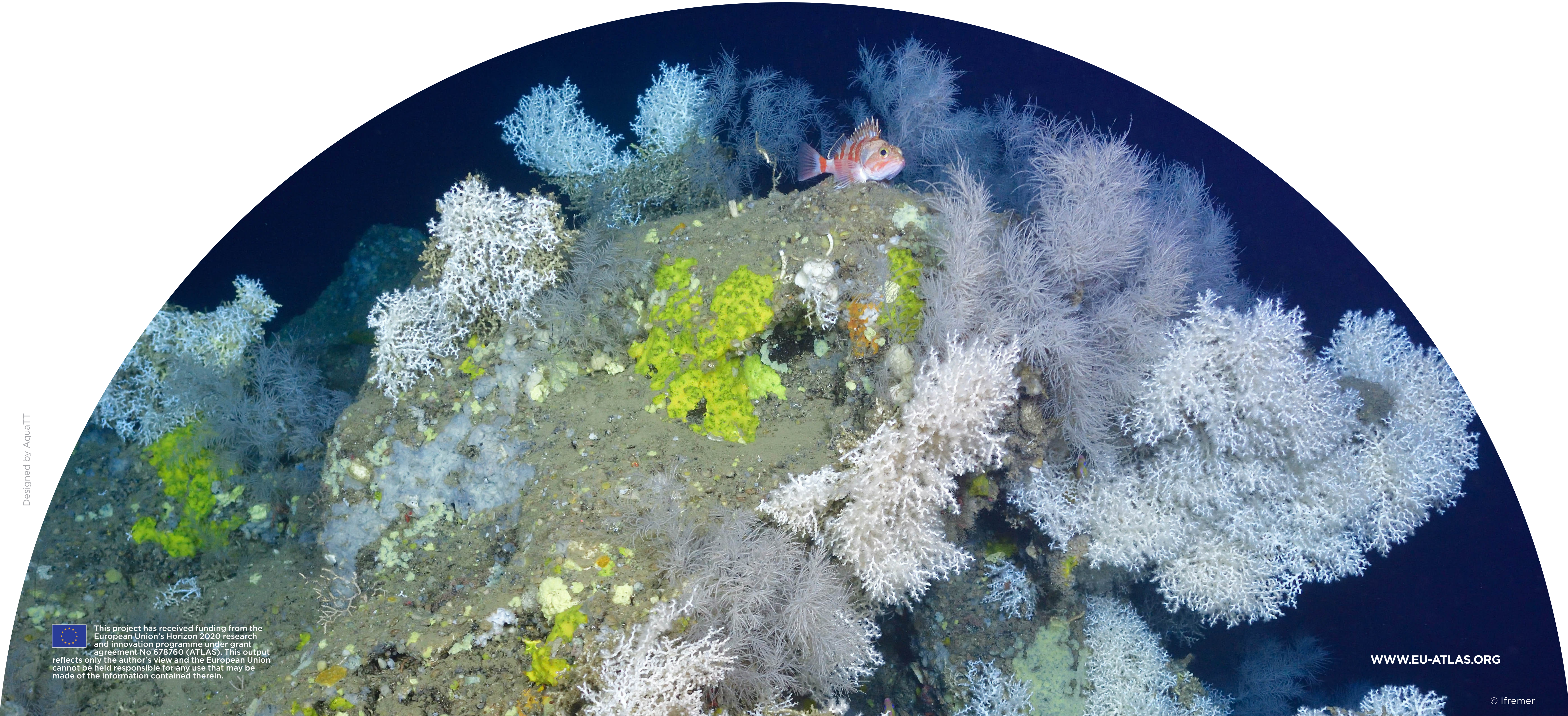
Communication:
Annette Wilson
annette@aquatt.ie

@eu_ATLAS @EuATLAS ATLAS-Deep Discoveries EU_ATLAS

atlas
UNDERSTANDING DEEP ATLANTIC ECOSYSTEMS

POLICY IMPLICATIONS OF THE ATLAS PROJECT

OCTOBER 2020



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 678760 (ATLAS). This output reflects only the author's view and the European Union cannot be held responsible for any use that may be made of the information contained therein.

WWW.EU-ATLAS.ORG

This document is a synthesis of the **ATLAS** report on "Policy implications on the governance regime for the North Atlantic and articulation with global and regional instruments resulting from changing deep-sea dynamics", **ATLAS** Deliverable 7.8: **DOI: 10.5281/zenodo.4064242**

Lead Authors: Phillip J. Turner, David E. Johnson, J. Murray Roberts

Contributing Authors: Claire Armstrong; Sophie Arnaud-Haond; Bich Xuân Bui; Jens Carlsson; Marina Carreiro-Silva; Hermione Cockburn; Stuart Cunningham; Pablo Durán Muñoz; Julia Eighteen; Alan Fox; Ana García-Alegre; Matthew Gianni; Ronnie Glud; Anthony Grehan; Lea-Anne Henry; Clare Johnson; Georgios Kazanidis; Ellen Kenchington; Godwin Kofi Vondolia; Christian Mohn; Telmo Morato; Katherine Needham; Covadonga Orejas; Stéphane Pesant; Patricia Puerta; Adriana Ressurreição; Marieke Reuver; Alex Rogers; Steve Ross; Lorenzo Rovelli; Mar Sacau; Peter Spooner; David Thornalley; Dick van Oevelen; Natalie Walls; Annette Wilson; George Wolff

For a high-level summary of all project results, please also refer to the **ATLAS** Compendium of Results: **DOI: 10.5281/zenodo.3925096**

This booklet was designed by AquaTT. The content was developed by Seascape Consultants Ltd with significant contributions from **ATLAS** partners and the **ATLAS** Project Office (University of Edinburgh). All of the results described were generated by the **ATLAS** Project.

Citation

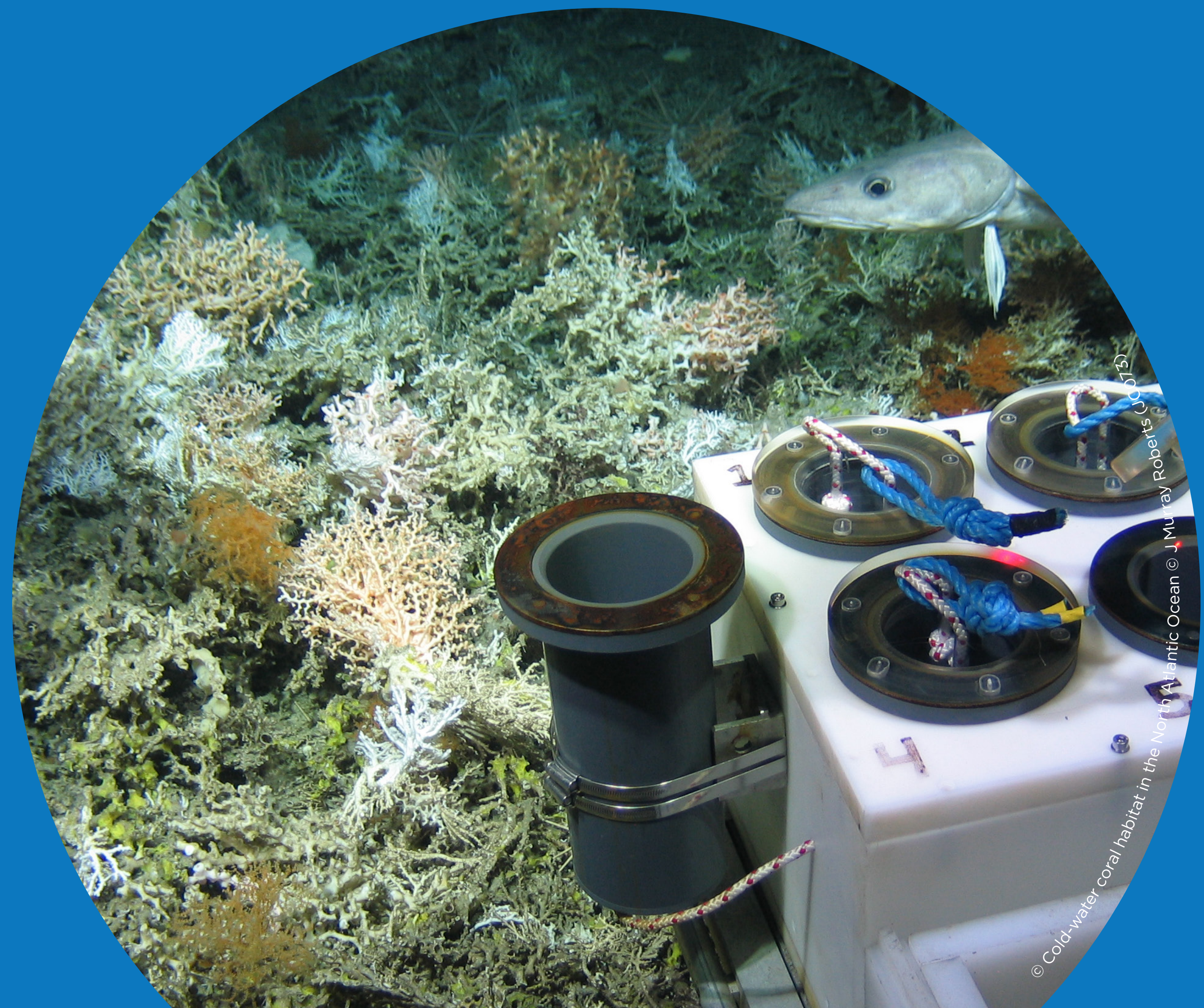
ATLAS Project Consortium. (2020) Policy implications of the **ATLAS** Project. Seascape Consultants Ltd, UK and AquaTT, Ireland. **DOI: 10.5281/zenodo.4063323**

POLICY IMPLICATIONS OF THE ATLAS PROJECT

PREFACE

This high-level summary brings together the key policy-relevant results of the four-year, European Union Horizon 2020 **ATLAS** Project: A trans-Atlantic assessment and deep-sea ecosystem-based spatial management plan for Europe (May 2016 – October 2020). The importance of these results to decision makers as well as their relevance to established policy objectives and on-going policy discussions is highlighted, with discussion focusing on five main themes:

1. Biodiversity, ecosystem functioning and the need for sustainable Blue Growth;
2. Climate change and Area Based Management Tools;
3. Connectivity and Area Based Management Tools;
4. **ATLAS** tools to inform ocean governance and sustainable Blue Growth; and
5. **ATLAS** contributions to the Galway Statement and research dissemination



© Cold-water coral habitat in the North Atlantic Ocean © J. Murray Roberts (2013)

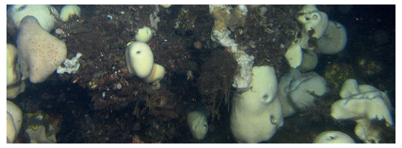
INTRODUCTION

The **ATLAS** Project was one of the first Galway Statement-linked projects funded under the European Union's Horizon 2020 research and innovation programme. The Galway Statement is a foundational policy statement that fosters collaboration between the European Union, Canada and the United States of America[1] and has enabled basin-scale research projects, such as **ATLAS**, to expand our understanding of North Atlantic ecosystems.

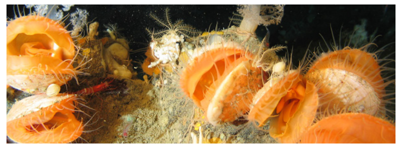
The **ATLAS** Project brought together over 70 researchers from diverse scientific fields (e.g., oceanographers, ecologists, social scientists), alongside experts in data management, science communication and marine policy, to provide new science and advice on how to ensure sustainable Blue Growth in the Atlantic Ocean. Structured around nine scientific work packages, the project team took a multidisciplinary approach to improve our understanding of ocean dynamics, ecosystem functioning, deep-sea biodiversity and ecosystem services, as well as the potential impact and implications of climate change on the deep ocean.

POLICY IMPACT OF ATLAS FIELDWORK AND DEEP-SEA DISCOVERIES

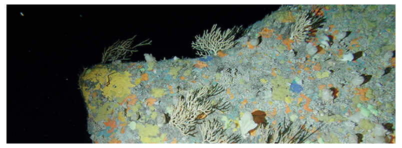
Forty-five research expeditions were conducted within the **ATLAS** framework (2016-2020), leading to numerous deep-sea discoveries that have helped to inform the development and management of Area Based Management Tools. Below are a few examples where **ATLAS** research has directly contributed to policy developments.



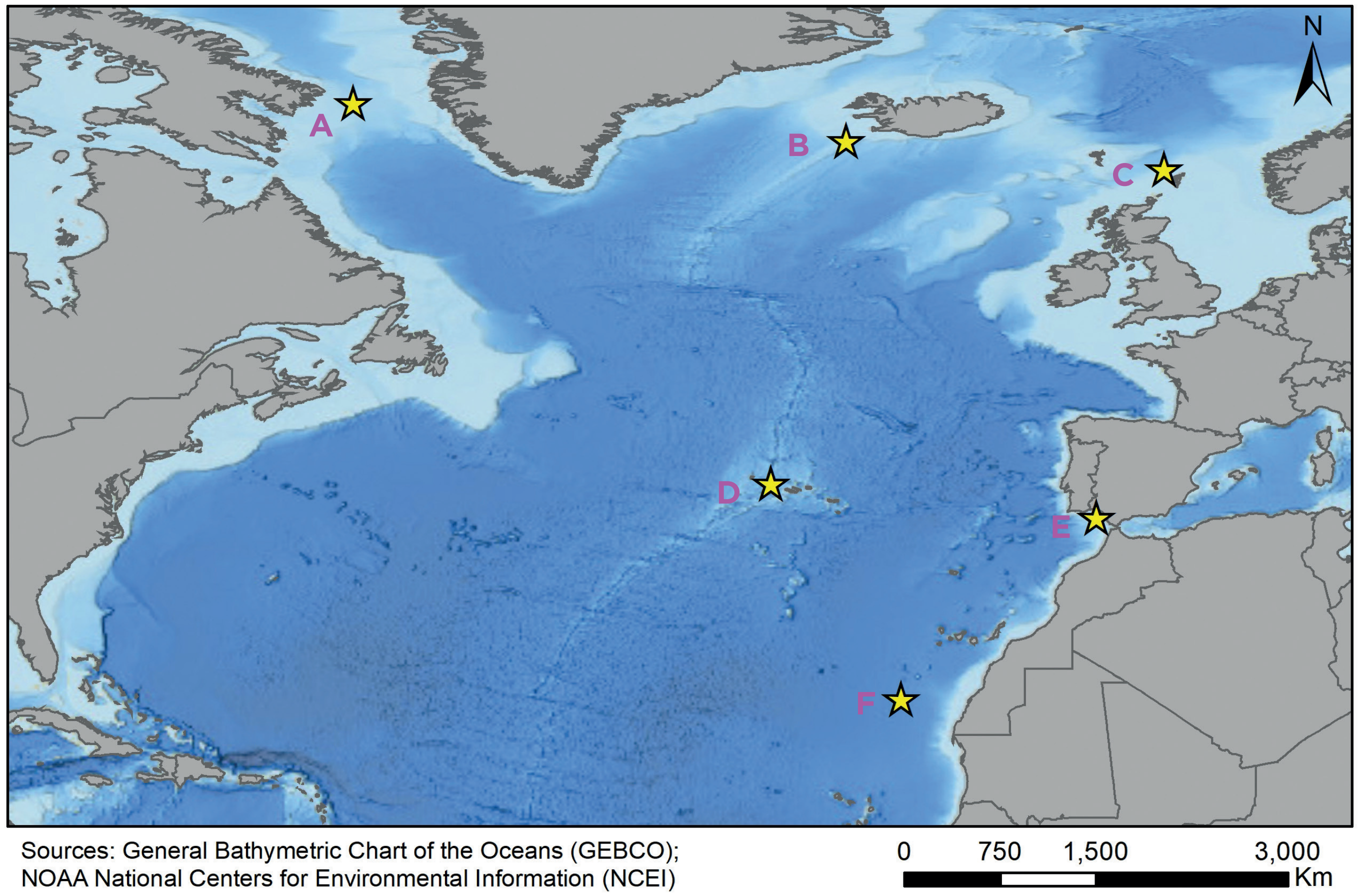
A. Eastern Canadian Arctic
Highly diverse sponge communities have been observed, with 93 species identified from the region. The data contributed to the establishment of three marine refuges, including the Davis Strait Conservation Area.



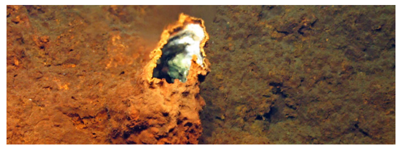
B. Reykjanes Ridge
ATLAS research around Steinhóll hydrothermal vent documented *Lophelia pertusa* reefs and a diverse sponge community. The data contributed to its consideration at the CBD NE Atlantic EBSA workshop.



C. Faroe-Shetland Channel
ATLAS described sponge communities located between 450 and 530 m water depth. These data have contributed to the management of the Faroe-Shetland Channel Nature Conservation Marine Protected Area.



Sources: General Bathymetric Chart of the Oceans (GEBCO); NOAA National Centers for Environmental Information (NCEI)



D. Azores
The Luso hydrothermal vent field was discovered on the Gigante Seamount during the Blue Azores Expedition in 2018. The Regional Government of the Azores has since declared the vent field a Marine Protected Area that is fully protected from fishing impacts.

E. Gulf of Cádiz
Sponge aggregations dominated by *Leiodermatium* sp., and coral gardens were discovered at Gazul mud volcano during the MEDWAVES cruise (2016). The data were used in the ICES workshop on EU regulatory area options for VME protection.

F. Tropic Seamount
ATLAS documented diverse communities, including octocoral gardens, crinoid fields and sponge grounds formed by the glass sponge *Poliopogon amadou*. The data contributed to its consideration at the CBD Regional EBSA Workshop for the North-East Atlantic in 2019.

Image credits: A) Fisheries and Oceans Canada; B) MFRI, Iceland; C) Kazanidis *et al.* 2019, DOI: 10.3389/fmars.2019.00163[2]; D) Oceano Azul Expedition ROV Luso EMEPC, IMAR-UAz;[3] E) IEO-MEDWAVES/ATLAS [4]; F) Ramiro-Sanchez *et al.* 2019, DOI 10.3389/fmars.2019.00278 – image from the NERC-funded MarineTech project (NE/MO1151/1) and crew of cruise JC142.[5]

1. BIODIVERSITY, ECOSYSTEM FUNCTIONING AND THE NEED FOR SUSTAINABLE BLUE GROWTH

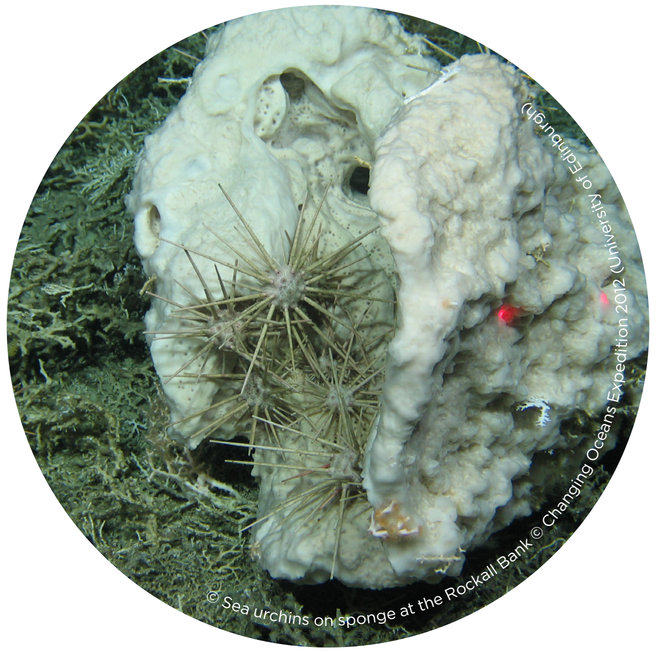
Importance of deep-sea sponge and coral ecosystems

Deep-water sponge grounds, cold-water coral reefs and coral gardens were focal ecosystems within **ATLAS** due to their importance as a habitat for deep-sea species, their role in global biogeochemical cycles and the vulnerability of cold-water coral habitats to climate change.

Using a new and highly innovative methodology for measuring *in situ* respiration rates, **ATLAS** showed that sponge grounds, cold-water coral reefs and coral gardens trap and process large quantities of organic matter, with benthic respiration rates between two and ten times that of surrounding deep-sea sediment[6,7]. New models combining hydrodynamics and animal physiology suggest that even in regions where biomass is low, cold-water corals can have a significant impact on biogeochemical cycles, altering the concentration of suspended organic matter over large areas of the seafloor[8,9]. At the Mingulay Reef Complex off western Scotland, a new modelling approach that predicts and maps cold-water coral biomass by integrating biological, environmental and ecosystem function data, estimates that this reef complex turns over 241 tonnes of carbon each year; over four times more than equivalent soft-sediment habitats[10]. Overall, the biodiversity and ecosystem services (e.g., carbon cycling and habitat provision) provided by sponge grounds, cold-water coral reefs and coral gardens are highly significant and confirm these as important habitats to safeguard against unsustainable human activities.

Societal support for Good Environmental Status in the deep sea

The need to safeguard deep-sea habitats and the ecosystem services they provide appears to be widely recognised by society. **ATLAS** research shows that members of the public in Scotland, Norway, mainland Portugal and Canada have low-to-moderate knowledge regarding deep-sea ecosystems but nevertheless believe that changes in the deep sea would have some effect on them personally. Between 60% and 85% of survey participants in each country considered changes in the deep sea to have a 'personal effect on them' [11]. The public surveys also showed that members of the public are willing to pay to support new management plans that address deep-sea environmental health and quality, with preference given to management plans that aim to reduce the density of marine litter and improve the health of commercial fish stocks[11]. These environmental attributes align with Descriptor 10 (marine litter) and Descriptor 3 (commercial fish and shellfish) in the assessment of Good Environmental Status (GES) for European Seas[12,13]. Results highlight societal support for the conservation of unfamiliar deep-sea ecosystems, and for further collective action under the European Commission's Marine Strategy Framework Directive (MSFD) to achieve GES in the deep sea[11]. As the European Union moves beyond the 2020 MSFD target, Member States can build on societal support for marine strategies that improve environmental health and, in particular, address environmental issues relating to marine litter (GES Descriptor 10) and commercial fish and shellfish (GES Descriptor 3).



© Sea urchins on sponge at the Rockall Bank © Changing Oceans Expedition 2012 (University of Edinburgh)

Sponge ground on the Flemish Cap © DFO

Box 1. The assessment of Good Environmental Status in the deep sea is challenging and requires deep-sea specific indicators

ATLAS conducted an initial assessment of Good Environmental Status (GES) in European case study areas for five GES Descriptors (biodiversity, commercial fish and shellfish, food webs, seafloor integrity and marine litter), using the Nested Environmental status Assessment Tool (NEAT) that was developed by the EU-funded FP7 project DEVOTES[60,61].

NEAT includes a database of more than 600 indicators[62]; however, most indicators have been developed for coastal and shallow-water ecosystems[61]. **ATLAS** reviewed a shortlist of 305 indicators to identify those that are appropriate for assessing deep-sea environmental status, and had the opportunity to suggest new indicators specifically for the deep sea[60,61]. In total, 24 indicators were agreed upon by **ATLAS** case study leaders, 10 of which were new indicators specific to the deep sea[60].

Within the assessment, case study leaders agreed that data availability and data standardisation need to be improved before NEAT can be used to monitor environmental status in the deep sea[61].

At present, data are only available for localised areas, representing specific habitats and (or) ecosystem components. Therefore, the number of habitats and ecosystem components that can be included in an assessment of GES is limited for the deep sea and the data collected within a Spatial Assessment Unit are not always representative of the unit as a whole[61]. Improvements are specifically needed in:

i. The quantity and quality of data on the spatial distribution of habitat-forming species and the sensitivity of species to multiple stressors;

ii. The availability of long-term datasets to understand ecosystem natural variability; and

iii. Our understanding of connectivity among cold-water ecosystems in order to identify priority areas for environmental assessments[60].

This additional research effort must also be met with standardised methodologies (in terms of the sampling units, sampling approach and the time frame of observations) in order for local assessments to be combined and GES to be evaluated at a regional scale[61]. Overall, GES in the deep sea may have to be assessed at the habitat and ecosystem level, with simplified indicators and larger spatial and temporal scales than those used in shallow-water assessments[61].

Once indicators relevant to the deep sea are refined and assessment methodologies are standardised, the EU framework for assessing GES could serve as a useful assessment approach to support policy objectives relating to Areas Beyond National Jurisdiction (ABNJ)[63]. The EU Marine Strategy Framework Directive (MSFD) shares overarching objectives with other international frameworks such as the ecosystem assessments developed by OSPAR, the Convention on Biological Diversity's evaluation of Safe Ecological Limits, and the process for assessing significant adverse impacts of fishing on vulnerable marine ecosystems developed by the United Nations General Assembly and the Food and Agricultural Organization of the UN[63]. Due to this commonality, the MSFD framework could be applied to ABNJ and would help to establish a common approach to assess environmental status of deep-sea ecosystems[63].

2. CLIMATE CHANGE AND AREA BASED MANAGEMENT TOOLS (ABMTs)

Climate change and its impact on deep-sea ecosystems was a crosscutting theme throughout the **ATLAS** Project, requiring a project-wide, pan-disciplinary approach to help improve our understanding of climate change impacts (i.e., ocean warming, deoxygenation, ocean acidification and decreased food availability) and to improve our capacity to predict future shifts in deep-sea ecosystems.

Changes in North Atlantic circulation and environmental conditions

Palaeoceanographic research conducted by **ATLAS** suggests that greenhouse gas emissions and subsequent climate forcing is linked to changes in North Atlantic circulation. Changing circulation patterns include a weakening of the Atlantic Meridional Overturning Circulation (AMOC) during the last ~150 years that is unlike any conditions experienced in the last 1,500 years[14,15]. Changing circulation patterns also include a shift in subpolar gyre circulation during the 20th century that is unlike any conditions experienced in the past 10,000 years[16]. The shift in subpolar gyre circulation has led to a north-westward expansion of warmer, less-productive water that may also be connected to a northward migration of Atlantic mackerel[16]. Changing subpolar gyre circulation may also result in reduced coral growth rates within the Mingulay Reef Complex, highlighting the sensitivity of deep-sea ecosystems to hydrological changes associated with climatic change[17].

Threat of climate change to deep-sea biodiversity

ATLAS results show that food supply was a key environmental factor in determining the persistence of cold-water coral reefs over the past ~20,000 years and that the unprecedented changes in temperature and pH expected by the end of the century are of high conservation concern[18]. Ocean acidification is a particular threat to cold-water coral reefs because reductions in pH may impact the structural integrity of the reef-building coral *Lophelia pertusa*, and the ability of the reef to provide habitat for a variety of deep-sea species[19,20]. By 2100, some areas of the deep North Atlantic Ocean are expected to experience a decrease in pH by >0.3 units (e.g., the Mingulay Reef Complex and Davis Strait [21]), with shallow cold-water coral reefs (e.g., the Mingulay Reef Complex) expected to experience more extreme seasonal variation in pH due to changes in local hydrodynamic conditions[22]. **ATLAS** research shows that ocean acidification and decreased food supply can have interactive effects on the octocoral *Viminella flagellum* and potentially impact long-term growth and reproduction[23]. These results emphasise the importance of additional research to better understand the interactive effects of all climate change impacts (i.e., ocean warming, deoxygenation, ocean acidification and decreased food availability) as well as the need to incorporate climate change into management decisions.

To better understand the potential impact of climate change at a basin scale, **ATLAS** used habitat suitability models to predict changes in the distribution of commercially important deep-sea fishes and cold-water coral species between now and 2100, under the “business-as-usual” (RCP8.5) climate scenario[3,24]. For deep-sea fishes, **ATLAS** models predict a northward shift in suitable habitat between 2.0° and 9.9°[24]. Whilst some species may experience an expansion of suitable habitat (e.g., blackbelly rosefish [*Helicolenus dactylopterus*] and deep-water redfish [*Sebastes mentella*]), others are predicted to lose suitable habitat, including a 30% to 50% reduction in Atlantic cod (*Gadus morhua*) and American plaice (*Hippoglossoides platessoides*) habitat that may impact commercial fisheries[24]. For cold-water corals, models predict a decrease in suitable habitat ranging from 30% to more than 80% depending on the focal species[24]. A large (> 80%) reduction in range is predicted for the reef-forming cold-water coral *Lophelia pertusa* as well as the octocorals *Acanella arbuscula*, *Acanthogorgia armata* and *Paragorgia arborea*[24]. The loss of coral taxa will likely impact the ecosystem services provided by coral habitats, with subsequent impacts on the GES of the deep North Atlantic[3,24]. Similarly, the impact of climate change on the deep ocean is likely to limit the effectiveness of current management efforts as areas become unsuitable for species that are conservation targets[25].

Need for ABMTs that are resilient to climate change

To safeguard deep-sea biodiversity and ecosystem services, management decisions need to account for the cumulative impact of human activities, including climate change[26,27]. For populations that are already threatened by climate change, efforts are needed to reduce any additional stressors; this may require heightened application of the precautionary principle, such as more stringent

mitigation measures within environmental impact assessments or a restriction on activities that may adversely impact populations.

ATLAS predicts that within the next 20 to 50 years, current area-based measures in the North Atlantic will become less fit for purpose, unless efforts are made to establish a network of ABMTs that are resilient to climate change and include climate change refugia[25,28,29]. High-resolution climate change predictions are needed for the coming decades in order to increase our level of confidence in selecting areas that are resilient to climate change impacts and to make effective decisions under current policy targets[28]. Until such information is available, a pragmatic starting point may be to use current Marine Protected Areas (MPAs), other effective conservation measures (e.g., Vulnerable Marine Ecosystems [VMEs]) and Ecologically or Biologically Significant Marine Areas (EBSAs) as an initial starting point to inform network design[28,29]. These areas can then be assessed for redundancies, expanded upon to address key gaps and periodically reviewed to ensure management effectiveness and to reflect advances in understanding[29].

Blackbelly rosefish © Changing Oceans Expedition 2012 (University of Edinburgh)

3. CONNECTIVITY AND AREA BASED MANAGEMENT TOOLS (ABMTs)

Importance of understanding ocean circulation and larval behaviour in order to understand connectivity

Another important consideration in network design is how biological populations are connected within a network of ABMTs[29]. **ATLAS** results show that both larval behaviour and atmospheric-driven changes in ocean circulation (e.g., phase shifts in North Atlantic Oscillation) can impact connectivity within a network of MPAs[30]. Specifically, when connectivity models included parameters that mimic the behaviour of *Lophelia pertusa* larvae, **ATLAS** found that wind-driven northward transport of Atlantic water during a positive North Atlantic Oscillation (NAO) phase increased MPA connectivity, whereas clusters of MPAs became more isolated during a negative NAO phase[30]. The differences observed between positive and negative NAO phases highlight the importance of considering atmospheric-driven changes in ocean circulation in protected area network design, as well as the potential importance of seamounts, offshore banks and anthropogenic structures[30,31] in maintaining connectivity across a protected area network. The potential for anthropogenic structures (e.g., oil and gas installations) to facilitate connectivity between populations of the reef-forming cold-water coral *Lophelia pertusa*[31] has possible implications for management decisions relating to national decommissioning policies as well as any revision of OSPAR Decision 98/3 on the Disposal of Disused Offshore Installations.

Limited information on larval behaviour requires decision makers to consider low-connectivity assumptions

ATLAS teams showed that the larval biology of cold-water corals can be highly variable, with different larval species spending different amounts of time in the water column and being dispersed by ocean currents. For example, the octocoral *Viminella flagellum* appears to have a pelagic larval duration of 7 to 12 days[32], whereas *Lophelia pertusa* has a pelagic larval duration of 3 to 5 weeks[33]. Larval biology can also be different between corals with seemingly similar ecological roles, geographic distributions and environmental tolerances (e.g., the reef building corals *Lophelia pertusa* and *Madrepora oculata*), resulting in different dispersal abilities. This variability may partly explain the different population structures and different responses to past climate change and current modifications reported for *Lophelia pertusa* and *Madrepora oculata*[32,34].

How larval behaviour is modelled has a considerable impact on connectivity predictions. Therefore, information on species-specific larval behaviour is needed before connectivity models can provide accurate predictions to help inform decision making[35,36]. High-resolution genetics data based on genome-wide scans are also needed to estimate connectivity and to test predictions from larval models. Until such information is available, managers should consider low-connectivity assumptions when designing a network of ABMTs, likely requiring the designation of large portions of habitat that are closely spaced together[37,38]. The additional benefit of this precautionary approach is that a network of ABMTs designed under low-connectivity assumptions will automatically be more resilient to climate change because the uncertainties in larval biology have a much greater impact on connectivity than changes in circulation[35,39]. Protected area networks developed under low-connectivity assumptions will help to provide routes for shifting species ranges as well as increase the potential habitat available for colonisation and the persistence of populations threatened by climate change.


Reef building coral *Lophelia pertusa* © Solvin Zankl GEOMAR

POLICY IMPLICATIONS OF THE ATLAS PROJECT

4. ATLAS TOOLS TO INFORM OCEAN GOVERNANCE AND SUSTAINABLE BLUE GROWTH

The **ATLAS** Project's engagement with maritime industries has shown that many Blue Economy sectors expect to expand their activities or areas of operation in the North Atlantic before 2030[40]. Therefore, transparency and an understanding of trade-offs is important for effective maritime spatial planning that considers the needs of industry as well as the marine environment. To assist with management decisions, **ATLAS** has developed a number of tools that may help to balance environmental protection and Blue Growth.

VME Index: A tool to help locate and consider Vulnerable Marine Ecosystems (VMEs) in management decisions

In collaboration with the International Council for the Exploration of the Sea (ICES) Working Group on Deep-water Ecology (WGDEC), **ATLAS** has developed an assessment method that combines VME indicator records into a single VME index, and can help to identify areas where VMEs are known or are likely to occur[41,42]. Areas are assigned a VME index score of high, medium or low depending on the species present and their abundance[41]. Since 2018, ICES has been using the VME index to provide advice to the North East Atlantic Fisheries Commission (NEAFC) and the European Union concerning the protection of VMEs and the location of potential fishing closures[43-45]. The VME index can be updated as new data become available, providing a repeatable, defensible and transparent evaluation tool through which the best available scientific information can be used to inform decisions[41].

Genotyping-By-Sequencing: A tool to help consider population structure in management decisions

ATLAS developed new protocols to extract high-quality DNA from archived tissue samples (particularly cold-water corals) and to conduct high density genome scans for several deep-sea coral and fish species[32,37]. **ATLAS** also refined a Genotyping-By-Sequencing (GBS) technique to provide a rapid, cost-effective methodology that is capable of assessing population structure even if the target species has little or no previous genomic information[32,37]. **ATLAS** researchers applied the technique to samples of Norway lobster (*Nephrops norvegicus*)[46], boarfish (*Capros aper*)[47] and Atlantic horse mackerel (*Trachurus trachurus*)[32,37,48], highlighting differences between population structure and the boundaries of fisheries management units[32,37]. The mismatch between population structure and fisheries management is concerning because a change in one functional unit may have a knock-on effect in the remaining units, causing the population to be more susceptible to overfishing[32]. Ideally, genetically differentiated populations should be treated as distinct management entities because they will respond independently to exploitation and management[37]. Overall, this research highlights the benefit of incorporating molecular studies into fisheries management, with GBS offering a potentially valuable, cost-effective tool to help align fisheries biology and management[32]. The protocols and GBS technique could also be applied to other deep-sea species that are a conservation priority (e.g., VME indicator taxa, OSPAR threatened and/or declining species) so that management measures can be applied that protect genetic diversity at relevant spatial scales.


Chasing coral - ATLAS expedition to Rockall Bank © Edda Heinsman

Maritime Spatial Planning (MSP) decision-support tool: A tool to help test different Blue Growth scenarios

ATLAS researchers have developed a Maritime Spatial Planning (MSP) decision-support tool that will allow for the rapid testing of different Blue Growth scenarios in marine areas, including the potential impact of different scenarios on the provision of ecosystem services[49]. The potential impact of an activity on the provision of ecosystem services is poorly assessed in current environmental impact assessments and is an issue that has been highlighted by **ATLAS** industry partners[50], emphasising the future utility of the **ATLAS** MSP support tool. The tool uses open-source software (i.e., pre-packaged R scripts and QGIS) and an automated workflow, allowing MSP practitioners with little programming knowledge to perform the scenario testing in an open, transparent and easily reproducible way. The tool can compile data from different sources, with different resolutions and spatial scales, and identify areas of potential conflict relative to how sensitive a habitat is to a specific activity. The resulting sensitivity maps can help to inform cumulative environmental assessments that take into account economic, environmental and social considerations - a key consideration for sustainable decision-making, as emphasised by the European Union's MSP Directive[51].

Box 2. eDNA assays offer a powerful tool to assess species distributions but are currently limited by genetic data availability

ATLAS has developed and tested species-specific environmental DNA (eDNA) assays that may be used to detect species presence on a large spatial scale[64]. eDNA assays have been developed and field-tested for the Chilean devil ray (*Mobula tarapacana*[65]), tope shark (*Galeorhinus galeus*) and blackbelly rosefish (*Helicolenus dactylopterus*[64]). Additional assays for orange roughy (*Hoplostethus atlanticus*) and the hydrothermal vent shrimp *Mirocaris fortunata* are awaiting field testing[64].

This research has shown that eDNA methods can be developed for detecting the presence of target species within pelagic and deep-water environments, as well as discrete habitats such as hydrothermal vents. The successful field deployment of assays for pelagic and deep-sea fish demonstrate that eDNA assays have the capacity to detect target deep-sea species and to assess species distributions over space and time, despite large sampling depths and a low concentration of DNA[64].

Unfortunately, the limited availability of genetic data within public repositories means that eDNA assays cannot always be developed to assess the presence of key deep-sea taxa.

In the case of *Lophelia pertusa*, the limited availability of genetic data prevented identification of a species-specific region of the DNA and therefore prevented development of an eDNA assay. *Lophelia pertusa* is an ecologically important, abundant species that has received considerable research attention. The fact that an eDNA assay could not be developed for *L. pertusa* suggests that insufficient quantities of genetic data is likely to be a widespread problem across many deep-sea species[64]. In fact, a review of deep-sea population genetic studies showed that only 115 species have been studied from non-chemosynthetic ecosystems and less than 4% of the 77 studies were conducted at an ocean basin-scale[66].

Overall, where species-specific assays can be developed, eDNA assays offer a powerful and low-cost tool for detecting and assessing the spatial and temporal distribution of target species. However, there are situations where eDNA methods cannot be used to assist with current deep-sea management decisions[64]. To increase the future utility of eDNA methods, significant efforts are needed to sample, sequence and archive deep-sea genetic data[64]. At present, because eDNA methods cannot be broadly applied across deep-sea taxa, species-specific eDNA assays should be seen as complimentary (rather than a replacement) to traditional sampling methodologies for environmental assessments.

5. ATLAS CONTRIBUTIONS TO THE GALWAY STATEMENT AND RESEARCH DISSEMINATION

As an international basin-scale research project, **ATLAS** has increased our knowledge of deep-sea ecosystems in the North Atlantic, improved our understanding of climate change impacts and developed new tools to help inform sustainable management – three key objectives of the 2013 Galway Statement[1].

ATLAS policy engagement

ATLAS research outputs have informed on-going policy discussions through a series of presentations, side events, stakeholder engagement activities (e.g., science-policy panels) and policy briefs (Box 3 and 4). **ATLAS** research has already helped to inform the development of ICES management advice[43–45], the description of features in the North-East Atlantic that meet the EBSA criteria[52] and the negotiation of an international legally binding instrument on the conservation and sustainable use of marine biological diversity of Areas Beyond National Jurisdiction (BBNJ Negotiations). **ATLAS** has also submitted formal commentary on the deep-sea mining exploitation regulations being developed by the International Seabed Authority[53], the UK Government's Sustainable Seas Inquiry[54] and the Scottish Government's Deep-Sea Marine Reserve consultation[55], highlighting key results for consideration by decision makers. **ATLAS**' response to the Scottish consultation was positively received, with **ATLAS** research being used by the Joint Nature Conservation Committee (JNCC) to enhance the content of the supporting documentation[56]. These examples of policy engagement during the **ATLAS** Project emphasise the relevance of **ATLAS** research and highlight the continued impact that **ATLAS** research will have as policy discussions continue beyond the lifetime of the project.

Lander recovery on the CCGS *Amundsen* (c) Alex Ingle

ATLAS joined the Arctic Net expeditions onboard the CCGS Amundsen in a transatlantic collaborative effort to explore the Davis Strait. © Alex Ingle

Box 3. Key International Policy Engagement Activities

ATLAS Science-Policy Panels

ATLAS organised three science-policy panels to provide a face-to-face opportunity to inform and interact with policy makers. The first panel was hosted by Professor Ricardo Serrao Santos, a member of the European Parliament, in March 2017 and served as an opportunity to get feedback on where **ATLAS** results would be most beneficial. The second panel was hosted by the Department of Fisheries and Oceans Canada in May 2018 and discussions emphasised commitments to the 2013 Galway Statement, including the need for transatlantic collaborations in both the science and policy arenas, as well as involvement of local communities. The third panel was hosted by the Brussels Museum of Natural Sciences in May 2019 and discussions emphasised the importance of science in management decisions, specifically the need for both **ATLAS** data to be included in the ICES VME database and climate change impacts to be considered in the designation of protected area networks.

Convention on Biological Diversity (CBD)

ATLAS provided input to the Convention on Biological Diversity's North-East Atlantic EBSA workshop (September 2019, Stockholm[52]), contributing data from **ATLAS** case study areas to support the description of features that meet the EBSA criteria. In a letter from the CBD Secretariat, the **ATLAS** Project was said to have "*significantly strengthened the scientific basis for the workshop's considerations of areas meeting the EBSA criteria*". In total, **ATLAS** contributed to the description of six significant features: the Gulf of Cádiz, Tropic Seamount, North Azores Plateau, Charlie-Gibbs Fracture Zone, the Southern Reykjanes Ridge, as well as the Hatton and Rockall Banks and Basin. The results of the workshop will be considered by the Conference of the Parties (COP) during its 15th meeting in 2021.

BBNJ Negotiations

ATLAS has been consistently represented during the evolution of the international legally binding instrument on the conservation and sustainable use of marine biological diversity of Areas Beyond National Jurisdiction (BBNJ Negotiations). At the third meeting of the BBNJ Preparatory Committee (March 2017), **ATLAS** co-hosted a side event, "Ocean-scale science for effective marine governance: A new approach to managing Atlantic ecosystems", which highlighted the need for basin-scale research and the importance of international cooperation, as envisioned by the 2013 Galway Statement.

During each of the following Intergovernmental Conference (IGC) sessions, different elements of the **ATLAS** Project were showcased:

- IGC-1 (September 2018): the **ATLAS** side event, "Building MSP frameworks to enable Blue Growth" emphasised the utility of Maritime Spatial Planning as a tool to be included in the Implementing Agreement.
- IGC-2 (March 2019): **ATLAS** co-hosted a side event, "Capacity Development in the Context of Climate Change", which discussed the impacts of climate change in areas beyond national jurisdiction as well as mechanisms to build capacity in area-based management, environmental impact assessments and the use of marine genetic resources.
- IGC-3 (August 2019): **ATLAS** presented at a side-event co-ordinated by the Global Ocean Biodiversity Initiative (GOBI), showcasing the utility of habitat suitability models to identify areas for conservation or blue growth, the challenges and opportunities for assessing Good Environmental Status in the deep sea, and the predicted impact of climate change on habitat availability for cold-water corals and commercially important fishes.

International Seabed Authority (ISA)

During the period for public comment, **ATLAS** provided a written submission commenting on the Draft Regulations on Exploitation of Mineral Resources in the Area developed by the International Seabed Authority[53]. The submission called upon the work of **ATLAS** to emphasise the importance of making data fully available to stakeholders as well as the potential benefits of data sharing, which can help reduce costs of future Environmental Impact Assessments by creating a pool of regional data that can be used by industry. The submission also highlighted **ATLAS**' palaeoceanographic work and the potential impact climate change may have on the resilience of fauna to deep-sea mining impacts, an important consideration when developing regional environmental management plans and accounting for cumulative impacts on the marine environment.

ATLAS results have also been used in the supporting material for an ISA workshop on developing a regional environmental management plan for the area of the northern Mid-Atlantic Ridge (November 2019, Evora). **ATLAS** research on the distribution of zoantharians[67], changing ocean circulation patterns[15], the threat of climate change to ABMTs in the North Atlantic[25,30] and the VME index[41] were included in the draft regional environmental assessment and (or) accompanying data report[68,69].

Northwest Atlantic Fisheries Organization (NAFO)

The **ATLAS** IEO-Vigo team have mapped human-activity footprints in the Flemish Cap-Flemish Pass area, including: the distribution of fishing activity, oil and gas exploration and exploitation, undersea cables, MPAs[70] and the distribution of litter on the seabed[71]. This mapping exercise highlights potential conflicts between users and threats to sensitive ecosystems, as well as potential tension between different regulatory frameworks because areas closed to bottom fishing to protect VMEs are open to other activities such as oil and gas exploration and exploitation[70]. The results of this mapping exercise have been presented to different NAFO Working Groups as well as the NAFO Scientific Council[70]. **ATLAS** data have been included in the NAFO Ecosystem Summary Sheets for Division 3LNO, which will help NAFO apply an ecosystem approach to fisheries management[72]. The NAFO Working Group on Ecosystem Science and Assessment (WG-ESA) have also recommended to the Scientific Council that standardised protocols for litter data collection should be implemented as part of all groundfish surveys conducted by Contracting Parties, in order to improve knowledge on litter distribution[72].

International Council for the Exploration of the Sea (ICES)

ATLAS research outputs were used to identify potential fisheries closures during the ICES workshop on EU regulatory area options for VME protection (WKEUVME, May 2020). Featured research included: data from the 2016 MEDWAVES cruise[4]; research highlighting the variety of VME habitats associated with submarine canyons in the Bay of Biscay[73]; research showing the presence of deep-sea sponge aggregations in the Faroe-Shetland Channel[2], and the VME index developed by **ATLAS** in collaboration with the ICES Working Group on Deep-water Ecology[41].

The **ATLAS** team participating at the third session of the Intergovernmental Conference for the UN BBNJ treaty negotiations i[illegible] York, August 2019(c) J Murray Roberts

Third **ATLAS** Science-Policy Panel, May 2019, Brussels, Belgium © **ATLAS** project Office

Box 4. ATLAS Policy Briefs

Recognising connectivity and climate change impacts as essential elements for an effective North Atlantic MPA network
Link: DOI: 10.5281/zenodo.4063323

Summary:
This policy brief highlights the need to recognise connectivity and climate change within Marine Protected Area (MPA) network design and to develop higher resolution predictions of changing environmental conditions over the next 20 to 50 years. Until such predictions are available, the brief calls for a shift in perspective regarding the precautionary approach whereby planning efforts could declare discrete zones of resource exploitation within a protected ocean, instead of declaring MPAs within an exploitable ocean.

Influence of valuations of ecosystem goods and services on Atlantic marine spatial planning
Link: DOI: 10.5281/zenodo.3843084

Summary:
This brief emphasises the utility of economic valuations to highlight the importance of marine ecosystem services, allowing decision makers to draw comparisons with the value of marketed marine products (e.g., fish and shellfish). Monetary valuations are one tool that can measure the value of some ecosystem services; however, to reduce potential conflicts between stakeholders other forms of evidence and perspectives (e.g., social, cultural and ethical) should also be considered in decision-making[74-76].

Policy opportunities and challenges for Blue Growth
Link: DOI: 10.5281/zenodo.3843135

Summary:
This policy brief highlights the opportunities and challenges for sustainable Blue Growth and the need for collaboration between science, industry and policy[77]. There is an opportunity for Blue Growth to contribute to the United Nations Sustainable Development Goals; however, a sustainable Blue Economy requires detailed knowledge of the marine environment and the multiple ocean uses in an area[77]. Collaboration is needed between science, industry and policy makers in order to: i) identify suitable areas for different activities, including conservation actions, ii) identify opportunities for offshore co-location and shared infrastructure and iii) ensure spatial planning decisions take into account climate change[77].

Changing Ocean State and its Impact on Natural Capital
Link: DOI: 10.5281/zenodo.3946683

Summary:
This joint **ATLAS** and iAtlantic policy brief emphasises how changes in ocean circulation can impact the distribution of deep-sea species, the productivity of our seas and connectivity between different ocean areas, whilst also highlighting remaining uncertainties as to how variable the Atlantic Meridional Overturning Circulation (AMOC) will be over the coming decades. Current climate models are known to underestimate variability in the North Atlantic; therefore, continued funding is needed for sustained monitoring efforts and larval biology research in order to improve our ability to predict ecosystem responses to future change. This brief highlights the importance of recent investments in ocean monitoring programmes, including the new set of biogeochemical sensors installed onto the OSNAP (Overturning in the Subpolar North Atlantic Project) Eastern Boundary Array[78].

ATLAS industry engagement and data sharing

The **ATLAS** Project has worked to build productive relationships with industry stakeholders and to ensure that **ATLAS** results are shared with industry partners. Industry engagement has been encouraged through the inclusion of representatives from BP, Woodside Energy and Equinor (formerly Statoil) on the **ATLAS** Advisory Board; their involvement has helped to facilitate data sharing for **ATLAS** work in the Faroe-Shetland Channel, Porcupine Seabight and at Lofoten-Vesterålen observatory respectively.

To further facilitate data sharing, the **ATLAS** GeoNode (**www.atlas-horizon2020.eu**) was developed as a one-stop-shop for stakeholders to visualise and download geospatial data, ensuring that **ATLAS** data meet European Commission expectations for being Findable, Accessible, Interoperable and Reusable (FAIR[57]). Data submitted to the **ATLAS** GeoNode will be transferred to EMODnet for long-term data archiving, ensuring that **ATLAS** data remain FAIR into the future.

ATLAS has also worked to promote the utility of EMODnet as a central data repository during a series of three industry workshops. At each of the workshops, participants recognised the wealth of data produced by maritime industries and the need to gather and store data in a central repository[50]. Increased data sharing was seen to be mutually beneficial as it can help to reduce industry costs, improve mitigation and monitoring strategies and ultimately support sustainable Blue Growth[50].

Through industry engagement, **ATLAS** has identified four primary barriers to data sharing[58]:

I. Data are not collected to a uniform standard (e.g., Marine Environmental Data Information Network standards);

II. Creating datasets that are suitable for submission to data portals comes at an additional cost, in time and (or) money;

III. Some data are commercially sensitive; and

IV. There is reluctance to lose control of data use.

These barriers may be overcome with enhanced collaboration between industry, regulatory bodies, data portals and academic institutions[58]. For example, the cost and staff time needed to process data may be reduced by standardising reporting across a sector, which would then allow automated approaches for data processing to be developed. Guidelines can be developed to provide clear distinctions between data products and information products, and to ensure appropriate credit is given to those who generate raw data, process the data and those who create information from the data. End-user agreements can also be established that retain data ownership but transfer responsibility for data interpretation, avoiding liability if conclusions drawn from the data are later found to be false[58].

Overall, the science-industry collaborations initiated during **ATLAS** will hopefully enhance data sharing in the future. However, to better incentivise data sharing it is recommended that: data repositories (such as EMODnet) are continually promoted in order to attract data submissions; the benefits of data sharing are better communicated to industry stakeholders; and steps are taken to reduce the perceived risks to data sharing. At present, there is concern that if a company chooses to release data they would be at a disadvantage due to the additional processing costs and the risk of other companies capitalising on the publicly available data[58]. Steps to reduce this risk may include regulatory requirements for environmental data to be open access so that no single company is disadvantaged by sharing data[50,58]. Ultimately, these actions would help to promote data sharing (a key goal within the Galway Statement) and support sustainable Blue Growth by enabling better application of the mitigation hierarchy.

ATLAS engagement with society and commitment to ocean literacy

Through its dedicated outreach team, **ATLAS** has ensured that research outputs are shared with a wide range of end-users through a variety of dissemination channels (e.g., the project website, Twitter, YouTube) and by developing a large portfolio of dissemination materials (e.g., factsheets, newsletters and education packs). Innovative methods have been employed to promote and enhance ocean literacy, including the development of a series of classroom activities, augmented reality colouring sheets and a Remotely Operated Vehicle simulator that allows people to explore **ATLAS** case study areas[59]. A major strength of the project has been its partnership with science communication experts at AquaTT as well as the science and cultural learning centre Dynamic Earth (Edinburgh, UK). By investing in science communication from the outset, **ATLAS** has been able to meaningfully contribute to efforts to enhance ocean literacy; a foundational concept of the Galway Statement, which aims to "*promote...understanding of the value of the Atlantic by promoting oceans literacy*"[1]. Educational resources will remain available via the project website[a], the SeaChange website[b] and the Dynamic Earth website[c], ensuring the resources can be used beyond the lifetime of the project. **ATLAS**' contributions to ocean literacy will also continue through the work of Dynamic Earth, which was awarded UK National Lottery Heritage Funding to build an exhibition and outreach programme focused on deep-sea exploration in the Atlantic Ocean and will feature stories from the **ATLAS** Project.

ATLAS coral reef survey and augmented reality colouring sheets © Annette Wilson

[a]**ATLAS** educational resources: https://www.eu-atlas.org/learn
[b]SeaChange educational resources: https://www.seachangeproject.eu/resources#
[c]Dynamic Earth educational resources: https://www.dynamicearth.co.uk/learning/atlantic-adventures-with-atlas

CONCLUSION

The **ATLAS** Project has shown that, by providing resources for interdisciplinary basin-scale research, advances can be made to **i)** better understand deep-sea biodiversity, ecosystems and ocean dynamics, **ii)** help inform sustainable management decisions, and **iii)** contribute to an ocean literate society that is better informed about ocean issues. By bringing together experts from diverse scientific fields and fostering engagement with industry, society, governments and intergovernmental organisations, **ATLAS** has helped to contribute to the objectives of the Galway Statement. For similar advances to be made in future research projects, consideration should be given to parallel funding calls across geographic regions, which would help to ensure international partnerships continue. In line with the Galway Statement, this concept of *unified funding* would encourage more *unified science* that is better placed to answer the most pressing research and ocean management questions.

POLICY IMPLICATIONS OF THE ATLAS PROJECT

REFERENCES

1. *Galway Statement on Atlantic Ocean Cooperation: Launching a European Union-Canada-United States of America Research Alliance.* (2013).

2. Kazanidis, G. *et al.* Distribution of Deep-Sea Sponge Aggregations in an Area of Multisectoral Activities and Changing Oceanic Conditions. *Front. Mar. Sci.* **6**, 163 (2019).

3. Morato, T. *et al. ATLAS Deliverable 3.3: Biodiversity, biogeography and GOODS classification system under current climate conditions and future IPCC scenarios.* (2019).

4. Orejas, C. *et al. Cruise Summary Report – MEDWAVES survey MEDiterranean out flow WAter and Vulnerable EcosystemS (MEDWAVES) 21st September - 26th October 2016 Research Vessel Sarmiento de Gamboa.* (2017) DOI:10.5281/zenodo.556516.

5. Ramiro-Sánchez, B. *et al.* Characterization and Mapping of a Deep-Sea Sponge Ground on the Tropic Seamount (Northeast Tropical Atlantic): Implications for Spatial Management in the High Seas. *Front. Mar. Sci.* **6**, 278 (2019).

6. de Froe, E. *et al.* Benthic Oxygen and Nitrogen Exchange on a Cold-Water Coral Reef in the North-East Atlantic Ocean. *Front. Mar. Sci.* **6**, 665 (2019).

7. Rovelli, L. *et al.* (in prep.). Benthic O2 uptake by garden-forming octocorals communities on Condor Seamount (Azores).

8. Wolff, G. *et al. ATLAS Deliverable 2.3: Community respiration rates, biogeochemical characteristics of organic matter and fauna at ATLAS Case Study Sites.* (2019).

9. van Oevelen, D. *et al. ATLAS Deliverable 2.5: Integrative and coupled model based on hydrodynamics, biogeochemistry and physiology for the prediction of biomass and biogeochemical dynamics, projections under future oceanic conditions and marine spatial planning.* (2019).

10. De Clippele, L. H. *et al.* (in prep.). Mapping cold-water coral biomass: an approach to derive ecosystem functions.

11. Ankamah-Yeboah, I. *et al. ATLAS Deliverable 5.4: Willingness to Pay for Conservation in the North Atlantic Deep-Sea Ecosystems.* (2019).

12. EC. *Commission Decision 2017/848/EU: Laying down criteria and methodological standards on good environmental status of marine waters and specifications and standardised methods for monitoring and assessment, and repealing Decision 2010/477/EU.* (2017).

13. EC. *Commission Decision 2010/477/EU: Criteria and methodological standards on good environmental status of marine waters.* (2010).

14. Thornalley, D. *ATLAS Deliverable 1.3: Recent AMOC and N Atlantic Gyre Properties and Dynamics.* (2018) DOI:10.5281/zenodo.3548860.

15. Thornalley, D. J. R. *et al.* Anomalously weak Labrador Sea convection and Atlantic overturning during the past 150 years. Nature **556**, 227–230 (2018).

16. Spooner, P. T. *et al.* Exceptional 20th Century Ocean Circulation in the Northeast Atlantic. *Geophys. Res. Lett.* **47**, (2020).

17. Douarin, M. *et al.* North Atlantic ecosystem sensitivity to Holocene shifts in Meridional Overturning Circulation. *Geophys. Res. Lett.* **43**, 291–298 (2016).

18. Portilho-Ramos, R. C. *et al. ATLAS Deliverable 1.4: Deep-sea ecosystem tipping points.* (2019) DOI: 10.5281/zenodo.3548813

19. Hennige, S. J. *et al.* Crumbling Reefs and Cold-Water Coral Habitat Loss in a Future Ocean: Evidence of "Coralporosis" as an Indicator of Habitat Integrity. *Front. Mar. Sci.* **7**, 668 (2020).

20. Hennige, S. J. *et al.* Hidden impacts of ocean acidification to live and dead coral framework. *Proc. R. Soc. B Biol. Sci.* **282**, 20150990 (2015).

21. Henry, L. A. *et al. ATLAS Deliverable 3.2: Water masses controls on biodiversity and biogeography.* (2019) DOI: 10.5281/zenodo.3548888.

22. Findlay, H. S. *et al.* Tidal downwelling and implications for the carbon biogeochemistry of cold-water corals in relation to future ocean acidification and warming. *Glob. Chang. Biol.* **19**, 2708–2719 (2013).

23. Carreiro-Silva, M. *et al. ATLAS Deliverable 2.2: Integrated physiological experiments and models.* (2019).

24. Morato, T. *et al.* Climate-induced changes in the suitable habitat of cold-water corals and commercially important deep-sea fishes in the North Atlantic. *Glob. Chang. Biol.* **26**, 2181–2202 (2020).

25. Johnson, D. *et al.* Climate change is likely to severely limit the effectiveness of deep-sea ABMTs in the North Atlantic. *Mar. Policy* **87**, 111–122 (2018).

26. Armstrong, C. W. *et al. ATLAS Deliverable 5.2: Expert assessment of risks to ecosystem services from diverse human drivers in the Atlantic deep sea.* (2017) DOI: 10.5281/zenodo.1147685

27. Armstrong, C. W. *et al.* Expert Assessment of Risks Posed by Climate Change and Anthropogenic Activities to Ecosystem Services in the Deep North Atlantic. *Front. Mar. Sci.* **6**, 158 (2019).

28. Johnson, D. E. *et al. ATLAS Deliverable 7.2: Report on priorities for an expert assessment of North Atlantic MPAs, EBSAs, and VMEs in ABNJ.* (2017) DOI: 10.5281/zenodo.997986.

29. Tinch, R. *et al. ATLAS Deliverable 7.4: Policy brief on MPA network design.* (2019) DOI: 10.5281/zenodo.3275209.

30. Fox, A. D. *et al.* Sensitivity of marine protected area network connectivity to atmospheric variability. *R. Soc. Open Sci.* **3**, (2016).

31. Henry, L.-A. *et al.* Ocean sprawl facilitates dispersal and connectivity of protected species. *Sci. Rep.* **8**, 1–11 (2018).

32. Carreiro-Silva, M. *et al. ATLAS Deliverable 4.4: Reproduction, dispersal and genetic connectivity in benthos and fishes.* (2019).

33. Larsson, A. I. *et al.* Embryogenesis and Larval Biology of the Cold-Water Coral Lophelia pertusa. *PLoS One* **9**, 14 (2014).

34. Boavida, J. *et al.* Out of the Mediterranean? Post-glacial colonization pathways varied among cold-water coral species. *J. Biogeogr.* **46**, 915–931 (2019).

35. Fox, A., *et al. ATLAS Deliverable 1.6: Biologically realistic Lagrangian dispersal and connectivity.* (2018) DOI: 10.5281/zenodo.3548735

36. Gary, S. F. *et al.* Larval behaviour, dispersal and population connectivity in the deep sea. *Sci. Rep.* **10**, 1–12 (2020).

37. Arnaud-Haond, S. *et al. ATLAS Deliverable 4.5: Integrated management considering connectivity patterns.* (2020).

38. Combes, M. *et al.* (in prep.). Systematic conservation planning at an ocean basin scale: identifying a viable network of deep-sea protected areas in the North Atlantic and the Mediterranean.

39. Gary, S. *et al. ATLAS Deliverable 1.1: Lagrangian connectivity of North Atlantic ecosystems.* (2017) DOI: 10.5281/zenodo.997975

40. Boschen-Rose, R. E. *et al.* Engaging with industry to spur Blue Growth. *J. Coast. Res.* **95**, 835–839 (2020).

41. Morato, T. *et al.* A Multi Criteria Assessment Method for Identifying Vulnerable Marine Ecosystems in the North-East Atlantic. *Front. Mar. Sci.* **5**, 460 (2018).

42. ICES. *Report of the ICES/NAFO Joint Working Group on Deep-water Ecology (WGDEC), 5-8 March 2018. Canada. ICES CM* vol. 126 (2018).

43. ICES. New information regarding vulnerable habitats in the NEAFC Regulatory Area. *Rep. ICES Advis. Comm.* **ICES Advic**, 1–11 (2019).

44. ICES. Stakeholder workshop to disseminate the ICES deep-sea access regulation technical service, and scope the required steps for regulatory purposes (WKREG). *ICES Sci. Reports* **1**, 34 (2019).

45. ICES. *WKEUVME ToRs: Workshop on EU regulatory area options for VME protection - Terms of Reference.* (2020).

46. Gallagher, J. *et al.* High Throughput Sequencing and a novel microsatellite genotyping method reveals population genetic structure in Norway lobster, *Nephrops norvegicus. Manuscr. Submitt. Publ.* (2020).

47. Farrell, E. D. *et al.* Next gen pop gen: Implementing a high-throughput approach to population genetics in boarfish (*Capros aper*). *R. Soc. Open Sci.* **3**, (2016).

48. Farrell, E. D. *et al.* (in prep.) Population structure of horsemackerel in the Eastern Atlantic and Mediterranean Sea.

49. National University of Ireland Galway. EU Horizon Results Platform: Novel Marine Spatial Planing decision support protocol. (2020).

50. Henry, L. A. *et al. ATLAS Deliverable 6.4: Improving business practice and costs through data-sharing and the identification of potential mitigation measures for adaptive marine spatial planning.* (2020).

51. EU. *EU Directive 2014/89/EU: Establishing a framework for maritime spatial planning.* (2014).

52. CBD. *CBD/EBSA/WS/2019/1/4: Report of the Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas in the North-East Atlantic Ocean.* (2019).

53. Boschen-Rose, R. E. *et al. ATLAS Submission to the International Seabed Authority regarding Draft Regulations for Exploitation.* (2018) DOI: 10.5281/zenodo.2021044.

54. Boschen-Rose, R. E. *et al. ATLAS Submission to the UK Government Sustainable Seas Inquiry.* (2018) DOI: 10.5281/zenodo.1544234

55. ATLAS & iAtlantic. H2020 ATLAS-H2020 iAtlantic projects response to the proposal to designate a Deep Sea Marine Reserve in Scottish Waters (Response 270421836). (2019).

56. Marine Scotland. *Consultation on proposal to designate a deep sea marine reserve in Scottish waters: Consultation analysis report.* (2020).

57. ERC. *European Research Council (ERC) Guidelines on Implementation of Open Access to Scientific Publications and Research Data.* (2017).

58. Murray, F. *et al.* Data challenges and opportunities for environmental management of North Sea oil and gas decommissioning in an era of blue growth. *Mar. Policy* **97,** 130–138 (2018).

59. Paterson, E. *et al. ATLAS Deliverable 9.4: ATLAS Outreach Educational Portfolio.* (2019). DOI: 10.5281/zenodo.3678127.

60. Kazanidis, G. *et al.* Assessing the environmental status of selected North Atlantic deep-sea ecosystems. *Ecol. Indic.* **119**, 106624 (2020).

61. Orejas, C. & Kazanidis, G. *ATLAS Deliverable 3.1: Good Environmental Status and Biodiversity Assessments.* (2018).

62. Teixeira, H. *et al.* A Catalogue of Marine Biodiversity Indicators. *Front. Mar. Sci.* **3**, 207 (2016).

63. Orejas, C. *et al.* Towards a common approach to the assessment of the environmental status of deep-sea ecosystems in areas beyond national jurisdiction. *Mar. Policy* 104182 (2020) DOI:10.1016/j.marpol.2020.104182.

64. Carlsson, J. *ATLAS Deliverable 3.5: Potential and limits of metabarcoding of eDNA and qPCR.* (2019).

65. Gargan, L. M. *et al.* Development of a sensitive detection method to survey pelagic biodiversity using eDNA and quantitative PCR: a case study of devil ray at seamounts. *Marine Biology* vol. 164 112 (2017).

66. Taylor, M. L. & Roterman, C. N. Invertebrate population genetics across Earth's largest habitat: The deep-sea floor. *Mol. Ecol.* **26**, 4872–4896 (2017).

67. Carreiro-Silva, M. *et al.* Zoantharians (Hexacorallia: Zoantharia) Associated with Cold-Water Corals in the Azores Region: New Species and Associations in the Deep *Sea. Front. Mar. Sci.* **4**, 88 (2017).

68. Weaver, P. P. E. *et al. Regional Environmental Assessment of the Northern Mid-Atlantic Ridge.* (2019).

69. Cleary, J. *et al. Data Report: Workshop on the Regional Environmental Management Plan for the Area of the Northern Mid-Atlantic Ridge.* Atlantic REMP Project (2019).

70. Durán Muñoz, P. *et al.* A theoretical exercise of Marine Spatial Planning in the Flemish Cap and Flemish Pass (NAFO Divs. 3LM): implications for fisheries management in the high seas. *North West Atl. Fish. Organ. NAFO SCR Doc. 20/022, Ser. No. N7068.* 24 (2020).

71. García-Alegre, A. *et al.* Seabed litter distribution in the high seas of the Flemish Pass area (NW Atlantic). *Sci. Mar.* **84**, 93–101 (2020).

72. NAFO. Report of the 12th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA). Northwest Atlantic Fisheries Organization. 19-28 November 2019, Dartmouth, Canada. *NAFO SCS Doc. 19/25, Ser. No. N7027* 135 (2019).

73. van den Beld, I. M. J. *et al.* Cold-water coral habitats in submarine canyons of the Bay of Biscay. *Front. Mar. Sci.* **4**, 118 (2017).

74. Tinch, R. *et al. ATLAS Deliverable 5.5: Ocean monetary values to support adaptive Maritime Spatial Planning.* (2019).

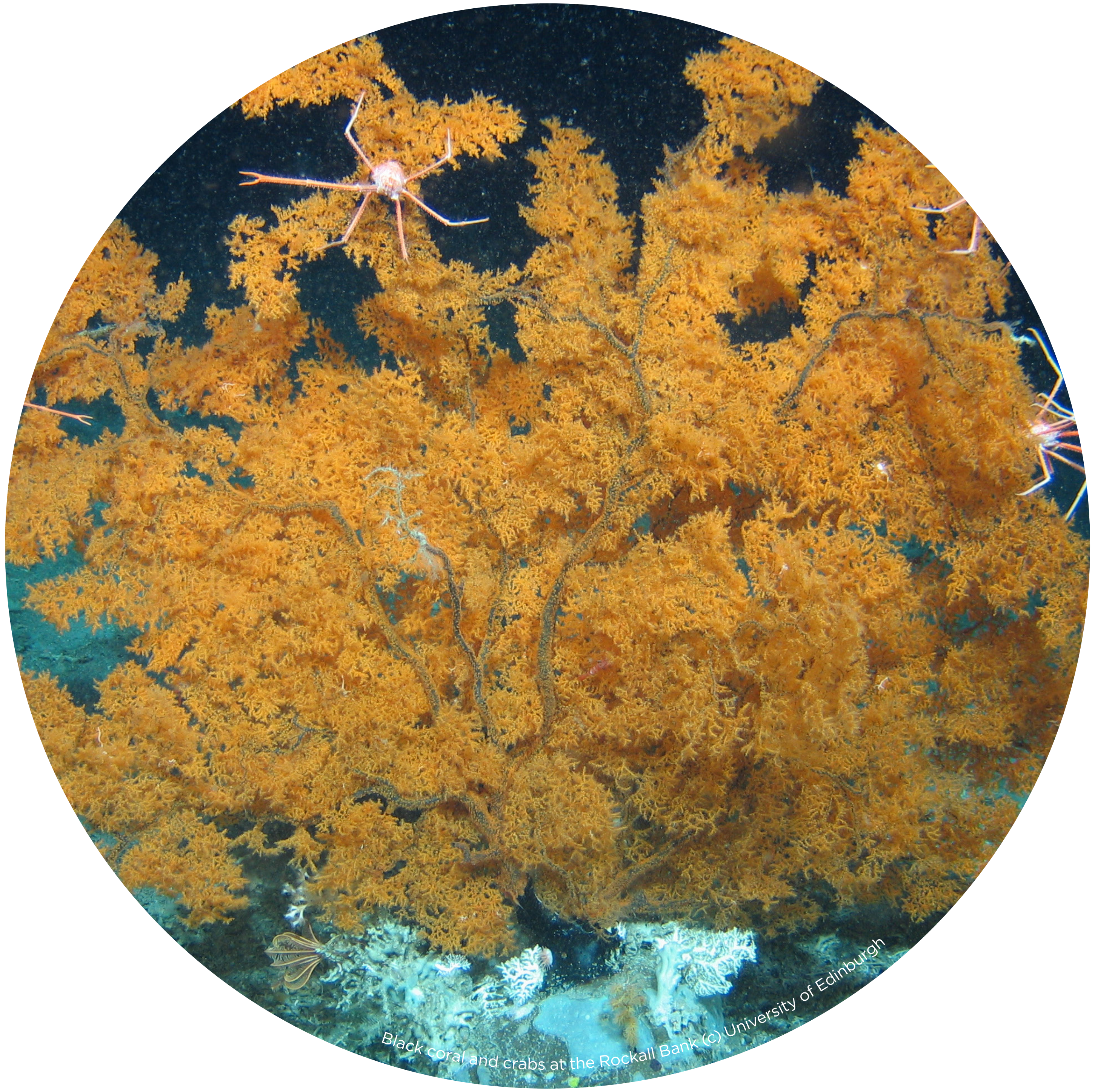
75. Tinch, R. *et al. Economic valuation of ecosystem goods and services: a review for decision makers. J. Environ. Econ. Policy* **8**, 359–378 (2019).

76. Tinch, R. *et al. ATLAS Deliverable 5.3: Validity, legitimacy and acceptability of ecosystem valuations.* (2019).

77. Tinch, R. *et al. ATLAS Deliverable 7.7: Policy brief on opportunities and challenges for Blue Growth.* (2020). DOI: 10.5281/zenodo.3843135

78. Johnson, C. *et al. ATLAS Deliverable 1.7: Physical and ecosystem fluxes in the North Atlantic.* (2019). DOI: 10.5281/zenodo.3832129

A full archive of project results is available via the EU Horizon Results Platform (**www.eu-atlas.org/resources/horizon-results-platform**) and the **ATLAS** community page on Zenodo: **www.zenodo.org/communities/atlas/**



POLICY IMPLICATIONS OF THE ATLAS PROJECT

ATLAS PARTNERS