atlas
UNDERSTANDING DEEP ATLANTIC ECOSYSTEMS

ATLAS COMPENDIUM OF RESULTS

UNLOCKING THE POTENTIAL OF THE DEEP ATLANTIC OCEAN

JUNE 2020

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TOGETHER, WE CAN ENSURE THE ATLANTIC OCEAN IS THE BEATING HEART OF OUR WORLD FOR GENERATIONS YET TO COME.

PREFACE

This compendium summarises the key achievements 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 – July 2020).

ATLAS is the largest and most ambitious assessment of deep-sea Atlantic ecosystems ever undertaken. The consortium numbers over 70 scientists including oceanographers, marine ecologists, social scientists, policy experts, professional communicators and outreach specialists. This consortium of 25 partners from 12 different countries worldwide have worked closely together over four years. They have explored the depths of the North Atlantic Ocean, improved our understanding of deep-sea ecosystem complexities, and helped to predict future shifts and vulnerabilities of these ecosystems and their associated species.

Alongside traditional approaches, **ATLAS** scientists have used the latest technology and developed new methods and models, including environmental DNA approaches and innovative low-cost camera systems, to search water and sediment samples for known and undiscovered deep-sea species. **ATLAS** has carried out pioneering research and discovered new benthic communities and species, developing a vast knowledge base that has already contributed to international policies and strategies. This knowledge ensures that deep-sea Atlantic resources are managed effectively, and lays the foundations for future Blue Growth.

To develop this compendium, we have reviewed a large volume of reports, research articles and project reports to capture the **ATLAS** team's key outputs, results and activities. Here, we present these, demonstrate their transfer and impact, and outline the next steps needed to ensure **ATLAS** results unlock the potential of the deep Atlantic.

CONTENTS

ATLAS COMPENDIUM OF RESULTS – INTRODUCTION

INTRODUCTION

The North Atlantic Ocean is a key marine region that comprises fragile, beautiful and essential ecosystems, from deep cold-water corals to hydrothermal vents. It provides goods and services that are essential for our well-being. Exploitation of these goods and services has been a key driver for growth and wealth creation. However, this fragile environment is under threat.

Almost 150 years since the *HMS Challenger* Expedition, still very little is known about deep-ocean ecosystems, their roles as reservoirs of biodiversity and genetic resources, or their health under future scenarios of climate change and human exploitation. Large-scale ocean observation is needed to improve our understanding of marine ecosystems, their biogeographic patterns, biodiversity, biogeochemistry, ecosystem services, and the goods they support. The capacity to model, understand and predict shifts in the dynamics of North Atlantic ecosystems will support preservation and will enable sustainable production of new products and industrial applications.

In response to these needs, in 2015 the European Commission launched the 'Blue Growth' call under the Horizon 2020 programme, calling for ideas and plans from research consortia to improve the preservation and sustainable exploitation of Atlantic marine ecosystems, to which **ATLAS** responded.

Launched in 2016, over a four-year period **ATLAS** has explored the world of deep-sea habitats (200 – 2000 m) and generated a wealth of diverse knowledge on deep-Atlantic ecosystems.

THE MIGHTY ATLANTIC OCEAN IS A PLACE LIKE NO OTHER.

AT A GLANCE

TITLE: A trans-Atlantic assessment and deep-water ecosystem-based spatial management plan for Europe (**ATLAS**)

CALL: Blue Growth: Unlocking the potential of seas and oceans (H2020-BG- 2015-2)

TOPIC: Improving the preservation and sustainable exploitation of Atlantic marine ecosystems (BG-01-2015)

INSTRUMENT: Research and Innovation Action

DURATION: May 2016 – July 2020 (51 months)

CONSORTIUM: 25 partners plus one linked 3rd party, from 12 countries

COORDINATOR: The University of Edinburgh, Edinburgh, Scotland, UK

ATLAS PROJECT OBJECTIVES

Centred around four primary objectives, **ATLAS** has created a strengthened knowledge base, advanced understanding of deep-sea functioning and connectivity, improved capacity to predict the response of deep-sea ecosystems to future changes in human use and ocean climate, and supported the development of adaptive management plans for sustainable exploitation and use of marine resources in the North Atlantic Ocean basin.

ATLAS METHODOLOGY

Multidisciplinary approach

Through its multidisciplinary approach, **ATLAS** has achieved a greater understanding of deep-sea ecosystems in the North Atlantic Ocean than ever before.

Intensive data gathering, new measurements, and samples from previously unexplored areas have provided essential knowledge on ocean circulation, dynamics, deep-sea ecosystem functioning, biodiversity and biogeography, and connectivity of resources. Through greater understanding of deep-sea ecosystems services and Blue Growth potential, **ATLAS** has addressed gaps in marine valuation and in its use as an aid to decision making. Networking and collaboration across sectors have supported better monitoring. Together, integrated new knowledge and new data have allowed **ATLAS** to improve predictive models. Using these predictions, various scenarios of ocean dynamics and cross-sectoral Blue Growth, an adaptive Atlantic marine strategic planning approach was developed.

ATLAS case studies

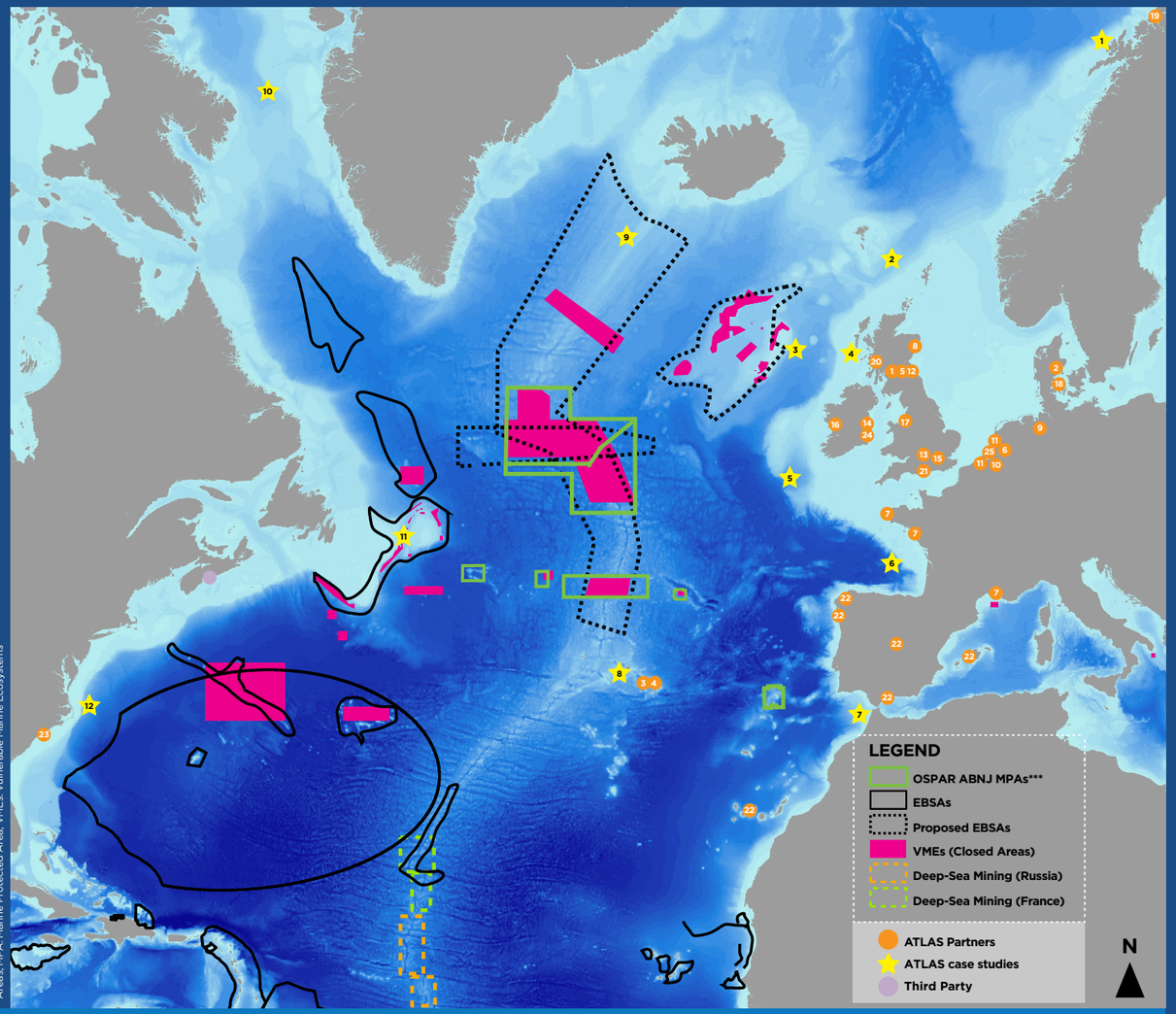
ATLAS assembled 12 case studies to assess Blue Growth potential at the trans-Atlantic basin scale, and to incorporate the diversity of sensitive deep-water ecosystems. Following the major Atlantic current patterns, these case studies covered a wide biogeographic, regulatory and jurisdictional range, and regions encompassing Vulnerable Marine Ecosystems (VMEs), Ecologically or Biologically Significant Areas (EBSAs) or Marine Protected Areas (MPAs). These sites were selected based on proximity to Blue Growth activities, presence of focal ecosystems, availability of existing data or samples, and opportunities for offshore expeditions.

The case studies have allowed **ATLAS** to integrate diverse data sources (including information on ocean circulation, ecosystem functioning, biological diversity, genetic connectivity and socioeconomic values), to predict deep-sea ecosystem response to shifts in human use and climate change, and to develop management strategies that focus on sustainable Blue Growth. A full breakdown of **ATLAS** case studies can be found on pages 10 and 11.

ATLAS CASE STUDIES

ATLAS BLUE GROWTH SECTORS

Fisheries · Oil & Gas · Tourism · Blue Biotechnology · Seabed Mining



*Data source: OSPAR Commission
ABNJ: Area Beyond National Jurisdiction; EBSAs: Ecologically or Biologically Significant Areas; MPA: Marine Protected Area; VMEs: Vulnerable Marine Ecosystems

ATLAS PARTNERS & THIRD PARTY

1. THE UNIVERSITY OF EDINBURGH (UEDIN)
2. AARHUS UNIVERSITY (AU)
3. IMAR – INSTITUTO DO MAR (IMAR-UAz)
4. SECRETÁRIA REGIONAL DO MAR, CIÊNCIA E TECNOLOGIA (DRAM)
5. BRITISH GEOLOGICAL SURVEY (BGS/NERC)
6. GIANNI CONSULTANCY (GC)
7. INSTITUT FRANCAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER (Ifremer)
8. MARINE SCOTLAND SCIENCE (MSS)
9. UNIVERSITY OF BREMEN (UniHB)
10. IODINE (IODINE)
11. ROYAL NETHERLANDS INSTITUTE FOR SEA RESEARCH (NIOZ)
12. DYNAMIC EARTH (DE)
13. OXFORD UNIVERSITY (UOX)
14. UNIVERSITY COLLEGE DUBLIN (UCD)
15. UNIVERSITY COLLEGE LONDON (UCL)
16. NATIONAL UNIVERSITY OF IRELAND, GALWAY (NUIG)
17. UNIVERSITY OF LIVERPOOL (ULIV)
18. UNIVERSITY OF SOUTHERN DENMARK (USD)
19. THE ARCTIC UNIVERSITY OF NORWAY (UiT)
20. THE SCOTTISH ASSOCIATION FOR MARINE SCIENCE (SAMS)
21. SEASCAPE CONSULTANTS (SC)
22. INSTITUTO ESPAÑOL DE OCEANOGRAFÍA (IEO)
23. UNIVERSITY OF NORTH CAROLINA WILMINGTON (UNCW)
24. AquaTT UETP CLG (AQUATT)
25. SEASCAPE BELGIUM (SBE)

FISHERIES AND OCEANS CANADA (DFO)

ATLAS COMPENDIUM OF RESULTS – METHODOLOGY

CASE STUDY 1

LOVE OBSERVATORY (NORWAY)

COLLABORATORS: NIOZ*, Equinor, UEDIN

FOCUS ECOSYSTEMS: Cold-water coral (CWC) reefs, sponges

Due to its narrow continental shelf, this area is described as the gateway to the Barents Sea. It is an important habitat and spawning ground for key species such as Northeast Atlantic cod and the cold-water coral *Lophelia pertusa,* which forms substantial framework reefs in this area.

The reef building cold-water coral *Lophelia pertusa* ©Solvin Zankl, GEOMAR

CASE STUDY 2

FAROE-SHETLAND CHANNEL (UK)

COLLABORATORS: UEDIN*, BP, OGUK[1], MSS

FOCUS ECOSYSTEMS: Sponge grounds

This area's seafloor morphology leads to different benthic communities: stalked sponges occupy deep-water sandy sediments, brittle star beds are found on gravel, sponges and soft corals colonise mixed gravel-cobble-boulder bottoms, and well-developed communities inhabit coarse sediments. A distinct sponge belt occurs between depths of 400–600 m.

[1]Oil & Gas UK

Giant carnivorous club sponge *(Chondrocladia sp.)* ©SERPENT project

CASE STUDY 3

ROCKALL BANK (UK – IRELAND)

COLLABORATORS: MSS, IEO, UOX

FOCUS ECOSYSTEMS: CWC reefs, coral gardens, carbonate mounds, sponge grounds, cold seeps

Enhanced oceanographic circulation around the Rockall Bank may give rise to highly localised and specialised biological communities such as sponge aggregations, coral reefs and gardens. Large and productive fish stocks are supported, some of which may be endemic. It has been proposed as an Ecologically or Biologically Significant Area under the Convention on Biological Diversity.

Blackbelly rosefish *(Helicolenus dactylopterus)* ©J Murray Roberts

CASE STUDY 4

MINGULAY REEF COMPLEX (UK)

COLLABORATORS: UEDIN, MSS

FOCUS ECOSYSTEMS: CWC reefs

This rare inshore ecosystem at 100–200 m depth has distinctive mounds formed by the stony coral *L. pertusa* over the last 7,000 years. It is an ideal site to study the vulnerability of cold-water corals to ocean warming and acidification. Sharks use the reefs for egg-laying and resting. It is part of a Special Area of Conservation under the European Commission's Birds and Habitats Directive.

Pandalid shrimp *(Pandalina brevirostris)* ©Henry et al. 2013, doi:10.5194/bg-10-2737-2013

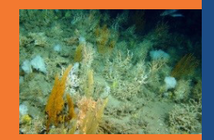
CASE STUDY 5

PORCUPINE SEABIGHT (IRELAND)

COLLABORATORS: NUIG, Woodside

FOCUS ECOSYSTEMS: CWC reefs, coral gardens, carbonate mounds, sponge grounds

The intensely researched cold-water corals in this area form part of the Belgica Mound province, a Special Area of Conservation. With different stakeholders involved in fishing, telecommunications, oil and gas exploration, research and conservation, this area is ideal to develop Maritime Spatial Planning approaches.



Deep-sea corals ©AWI and Ifremer

CASE STUDY 6

BAY OF BISCAY (FRANCE)

COLLABORATOR: Ifremer

FOCUS ECOSYSTEMS: CWC on slope and in canyon settings

Recent studies have confirmed the occurrence of cold-water coral habitats in this Bay. The genetic continuum of coral reef populations between Iceland and the Mediterranean Sea shows that *L. pertusa* have genetically homogeneous populations, whereas *Madrepora oculata*, also called zigzag coral, are genetically distinct. A Natura 2000 network has been proposed for reefs in this area.

Small coral reefs at 1,545 m deep in the Lampaul canyon ©Ifremer, campagne BobEco 2011

*Underlined collaborators are leading the investigation

CASE STUDY 7

GULF OF CÁDIZ, STRAIT OF GIBRALTAR, ALBORÁN SEA (SPAIN – PORTUGAL)

COLLABORATORS: IEO, Ifremer, IMAR-UAz

FOCUS ECOSYSTEMS: CWC reefs, coral gardens, sponge grounds

The interconnection and interdependency of many deep-sea species found in both the Atlantic Ocean and the Mediterranean is unknown. Focus on Atlantic-Mediterranean biodiversity and connectivity will address the role of these waters in supporting intensive human activity.

Sponges of the species *Pheronema carpenteri* ©IEO-MEDWAVES/ATLAS

CASE STUDY 8

AZORES (PORTUGAL)

COLLABORATORS: IMAR-UAz, IEO

Focus ecosystems: Hydrothermal vents, seamounts, coral gardens, sponge grounds

The seafloor of this volcanic archipelago comprises various open ocean deep-sea habitats, from seamounts to hydrothermal vents and abyssal plains. Prominent cold-water corals support commercially important fishes, while little is known about the extensive sponge aggregations. These Vulnerable Marine Ecosystems are included in the OSPAR network of Marine Protected Areas.

Menez Gwen hydrothermal vent field, Azores ©DEEPFUN project

CASE STUDY 9

REYKJANES RIDGE (ICELAND)

COLLABORATORS: UCD

FOCUS ECOSYSTEMS: Hydrothermal vents, CWC reefs, coral gardens, sponge grounds

Our understanding of the effects of ridges on the composition and distribution of pelagic and benthic fauna is limited. Ridge communities may be endemic to that area and may also influence the processes affecting the slope and shelf biota. Coral and sponge gardens are associated with V-shaped ridges in the Mid-Atlantic Ocean and can be found on both sides of the Reykjanes Ridge.

CWC garden ©MARUM – Center for Marine Environmental Sciences, University of Bremen

CASE STUDY 10

DAVIS STRAIT (CANADA AND GREENLAND), LABRADOR SEA

COLLABORATOR: DFO

FOCUS ECOSYSTEMS: CWC reefs, coral gardens, sponge grounds

The Davis Strait is known for its complex hydrography. A ridge along the Labrador Sea slopes to 2,500 m, supporting corals and sponges, including the only known *L. pertusa* reef in Greenlandic waters. These waters support high phytoplankton biomass and copepod grazers, a valuable food source in the pelagic and the benthic environment.

Diverse assemblage of corals, sponges and other benthic fauna in Davis Strait off Greenland ©DFO

CASE STUDY 11

FLEMISH CAP (CANADA)

COLLABORATORS: IEO, DFO, UOX, NAFO[2]

FOCUS ECOSYSTEMS: Coral gardens, sponge grounds

Flemish Cap is an offshore Bank located in an Area Beyond National Jurisdiction within the Northwest Atlantic Fisheries Organisation regulatory area. The main focal ecosystems are sponge grounds and cold-water corals, and include important international fishing grounds.

[2]Northwest Atlantic Fisheries Organisation

Deep-sea starfish ©NEREIDA project

CASE STUDY 12

MID ATLANTIC CANYONS

COLLABORATORS: UNCW, TU[3], NOAA[4]

FOCUS ECOSYSTEMS: CWC reefs on slope and in canyon settings

The oceanography and geology of the sub-marine Baltimore and Norfolk canyons greatly influence the benthic community. Methane-seeps support chemosynthetic communities and many diverse organisms. Vulnerable habitats in the Middle Atlantic Bight canyons and surroundings have been given protected area status.

[3]Temple University, [4]National Oceanic & Atmospheric Administration

Bubblegum coral, *Paragorgia arborea* ©Steve Ross

Knowledge Transfer

Communication and dissemination of **ATLAS** results have been integral components of the **ATLAS** approach, ensuring widespread awareness, engagement with the public and targeted transfer of **ATLAS** knowledge to all users. Recognised as a critical process in bringing research forward, with a focus on research being conducted on wider societal and industrial needs, **ATLAS** employed an adapted version of the proven knowledge management and transfer methodology originally developed by AquaTT in the Framework Programme 7 MarineTT project (Grant Agreement No 244164), and further developed and applied by the Horizon 2020 COLUMBUS project (Grant Agreement No 652690).

This methodology was integrated into the **ATLAS** project design, allowing knowledge to be fast-tracked to target and end-users. This ensured the timely delivery of key knowledge outputs and results to **ATLAS** stakeholders, accelerating and facilitating greater impact.

Throughout the project, the **ATLAS** knowledge transfer methodology has focused on collecting, analysing and transferring high-potential Knowledge Outputs and Key Exploitable Results. The **ATLAS** consortium, as a whole, has participated in a variety of communication, dissemination and knowledge transfer activities across the triple helix of academia, industry and society. Key messages and results from **ATLAS** have been presented to stakeholders at conferences and events, published in high-impact scientific journals, and informed policy processes and discussions. Exploitation workshops have facilitated two-way dialogues and transfer of **ATLAS** knowledge to industrial stakeholders, while the use of open-access data management platforms ensures pioneering **ATLAS** research is accessible beyond the project, creating an impactful legacy.


© Dick van Oevelen


© Douglas Robertson


© David Johnson

ATLAS END-USERS AND STAKEHOLDERS

This table identifies relevant stakeholders and end-users for the key knowledge outputs presented as output studies in this compendium. Please note this is not an exhaustive list.

ATLAS end-users and stakeholders	ATLAS knowledge outputs
SCIENTISTS, RESEARCHERS, ACADEMICS	• **Output study 1.1:** Weakening of Atlantic Meridional Overturning Circulation (AMOC) through the industrial era **p19** • **Output study 2.1:** Cold-water coral and sponge physiology database **p28** • **Output study 2.2:** New approach to identify the key environmental parameters that control cold-water coral ecosystem performance **p29** • **Output study 4.2:** New climate model projects major impacts on coral and commercially important fish habitats in the deep Atlantic due to climate change **p48**
POLICY MAKERS, DECISION MAKERS, OCEAN GOVERNANCE ADVISORS, REGULATORY BODIES	• **Output study 3.1:** Approaching the assessment of Good Environmental Status in the deep sea **p37** • **Output study 3.2:** Current deep-sea Area-Based Management Tools are unprepared for climate change **p39** • **Output study 3.3:** New evidence to support the protection of deep-sea sponge ecosystems at Tropic Seamount **p41** • **Output study 4.1:** Novel Marine Spatial Planning decision support protocol **p46** • **Output study 4.2:** New climate model projects major impacts on coral and commercially important fish habitats in the deep Atlantic due to climate change **p48** • **Output study 4.3:** Contribution to the development of NAFO Ecosystem Summary Sheets **p50**
BLUE ECONOMY, BLUE GROWTH INDUSTRIES (AQUACULTURE, TOURISM, BIOTECHNOLOGY, TRANSPORT, ENERGY, MINING)	• **Output study 1.2:** An expert assessment of risks posed by climate change and anthropogenic activities to ecosystem services in the deep sea **p20** • **Output study 2.3:** Using eDNA and quantitative PCR to assess biodiversity in the open ocean **p31** • **Output study 4.1:** Novel Marine Spatial Planning decision support protocol **p46** • **Output study 4.2:** New climate model projects major impacts on coral and commercially important fish habitats in the deep Atlantic due to climate change **p48** • **Output study 4.3:** Contribution to the development of NAFO Ecosystem Summary Sheets **p50**
GENERAL PUBLIC, EUROPEAN, CANADIAN AND AMERICAN CITIZENS, MARINE EDUCATORS, PUBLIC ENGAGEMENT EXPERTS, TEACHERS	• **Output study 1.3:** Atlantic Adventures with **ATLAS** – The **ATLAS** educational outreach portfolio **p22**

ACHIEVEMENT 1

ATLAS ADVANCED

Understanding of deep Atlantic marine ecosystems and populations

Atlantic Ocean circulation

New measurements from the Eastern Subpolar North Atlantic

SLOW

The Atlantic Meridional Overturning Circulation is weaker today than it has been for over 1,000 years!

Insights into cold-water coral population history

Last glacial period — Now

Ecosystem engineer control theory

Seabed topography formed by cold-water corals can focus food supply

Deep-sea ecosystem services in the North Atlantic are impacted by human activities and are at risk to climate change.

Society recognises the value of these services and supports new marine management plans

>30 benthic communities described or discovered

cold-water **coral** gardens, deep-sea **sponge** grounds, hydrothermal **vents**

'Atlantic Adventures with ATLAS'

Outreach educational programme

34,000+
direct engagements at Dynamic Earth

ATLAS KEY ACHIEVEMENTS

ACHIEVEMENT 2

ATLAS IMPROVED

Capacity to monitor, model and predict responses of deep - water ecosystems to future change

New methods and approaches

Using eDNA and quantitative PCR to assess biodiversity in the open ocean

Non-invasive oxygen flux measurements

CO_2 O_2

Mapping coral reef biomass

Identifying key environmental parameters that control cold-water coral ecosystems performance

Indicators for monitoring vulnerable deep-sea ecosystems

Low cost deep-sea imaging systems

Cold-water coral and sponge physiology database

An index – multi-criteria assessment – for identifying Vulnerable Marine Ecosystems & biodiversity hotspots

Hydrodynamic, biogeochemical and habitat suitability models

VITAL STATISTICS

12+ new species discovered including *Myonera atlasiana*

ATLAS videos, film and YouTube channel with 360° videos

20+ press releases

39k+ views & **5.4k+** downloads in dedicated open-access **Research Topic in Frontiers in Marine Science,** *'Managing Deep-sea Ecosystems at Ocean Basin Scale'*

Transatlantic cooperation **Canada/EU/USA**

>10 exhibitions

ATLAS results have reached:
9K people in policy
25K people in industry
85K members of the scientific community

OUR REACH

Hosted 35+ workshops & conferences

200+ **peer-reviewed publications** (including papers in Nature and Science)

25 partners **+12** countries

40+ research expeditions

>105m people have been reached by **ATLAS** media coverage

Participation in **450+** conferences, workshops and events

70+ researchers, **10 PhD** students

OUR HEADLINES

'Luso' hydrothermal vent field declared as Marine Protected Area by the Regional Government of the Azores

ATLAS science policy panels x3

ATLAS policy briefs

"climate-proofing the Marine Protected Area network in the North Atlantic Ocean."

Good Environmental Status and biodiversity assessments

Contributions to **UN negotiations** on an international, Legally Binding Instrument on the **conservation and sustainable use** of marine Biodiversity in Areas Beyond National Jurisdiction

6 cases, describing features that meet **Ecologically or Biologically Significant Areas** criteria, submitted to the **Convention on Biological Diversity:** Gulf of Cádiz; Tropic Seamount; North Azores Plateau; Charlie-Gibbs Fracture Zone; Southern Reykjanes Ridge; Hatton and Rockall Banks + Basin

OUR LEGACY

Area-based resource management plans

Predicted habitat suitability Maps

>50% of cold-water coral habitat at risk

Contribution to **NAFO Ecosystem Summary Sheets** as a piece of Northwest Atlantic Fisheries Organization's Roadmap for an ecosystem approach to fisheries.

Industry data sharing & revised business practices

- LoVe Observatory (Equinor)
- West of Shetland (BP)

Novel Marine Spatial Planning decision support tool

Blue Growth scenarios tested in ATLAS case studies

ACHIEVEMENT 3

ATLAS TRANSFORMED

Data and transferred new knowledge for effective ocean governance and sustainable exploitation

ATLAS GeoNode
www.atlas-horizon2020.eu
Discover, Visualise, & Download ATLAS Data

ACHIEVEMENT 4

ATLAS DEVELOPED

And tested sustainable adaptive management strategies for deep-sea resources stimulating Blue Growth

ATLAS ACHIEVEMENTS

OBJECTIVE 1

Advance

Our understanding of deep Atlantic marine ecosystems and populations

ATLAS advanced our understanding of deep Atlantic marine ecosystems and populations **by collecting and integrating high-resolution measurements** of ocean circulation with functioning, biological diversity, genetic connectivity, and socioeconomic values.


© Alex Ingle


© ROV Luso, Portuguese Task Force for the Extension of the Continental Shelf, Blue Azores Expedition 2013


© Edda Steinman

KEY ACHIEVEMENTS AND ACTIVITIES

1. Deep-sea discoveries: ATLAS partners discovered and described more than 30 benthic communities, including cold-water coral reefs and gardens, deep-sea sponge aggregations and hydrothermal vents in the North Atlantic. **ATLAS** has contributed to the identification of at least 12 new or putative new species to science, including the discovery of a bivalve, *Myonera atlasiana* (dedicated to the **ATLAS** project) at mud volcanoes on the northern Gulf of Cádiz. The team has also found approximately 35 new records of species in areas where they were previously unknown.

More information: See full species list on p62 | **Contact:** Telmo Morato, Marina Carreiro-Silva, IMAR-UAz | José Rueda, IEO | Ellen Kenchington, DFO.

2. Implications of climate change for global deep-sea benthos: This 2017 review provides the first comprehensive overview of the impacts of changing environmental parameters on deep-sea floor ecosystems. The work details how such changes, combined with other anthropogenic stressors, will further impact deep-sea floor ecosystems. Possible societal implications were also reviewed. Conducted by **ATLAS** researchers together with trans-Atlantic collaborators, this work acts as a key reference and increases understanding of climate change on deep-sea ecosystems globally.

More information: bit.ly/3ctJdz4 | **Contact:** J Murray Roberts, UEDIN

3. Evidence that ocean currents in the North Atlantic have slowed dramatically: ATLAS researchers have published studies, including a Nature paper, showing significant weakening of surface and deep ocean currents, including the Deep Western Boundary Current and the subpolar gyre, which are part of the Atlantic Meridional Overturning Circulation. These changes caused unprecedented ecosystems shifts in the industrial era with wide-ranging impacts on species distribution and ecosystem functioning.

More information: go.nature.com/2LXXJUw | see output study 1.1 | **Contact:** David Thornalley, Peter Spooner, UCL

4. In-situ measurements from the eastern subpolar North Atlantic: A one-year timeseries of chemical measurements (pH and dissolved oxygen) and water samples were obtained for the first time through **ATLAS** collaboration with the Overturning in the Subpolar North Atlantic Program (OSNAP) and EU H2020 AtlantOS project. The samples and data from the Ellett Array are the first long-term measurements from the area and contribute to fundamental baseline oceanography.

More information: bit.ly/2TjqleO | **Contact:** Clare Johnson, Stuart Cunningham, SAMS

5. Understanding drivers of Atlantic Meridional Overturning Circulation (AMOC) variability: The Overturning in the Subpolar North Atlantic Program (OSNAP) was launched in 2014 to provide an observational basis for the Intergovernmental Panel on Climate Change. The first results from the OSNAP array, published in Science with contributions from **ATLAS** researchers, reveal that processes east of Greenland determine AMOC variability, rather than those in the Labrador Sea as previously thought. The measurements changed global understanding of the AMOC and contribute to fundamental baseline oceanography.

More information: bit.ly/3dQkVzl | **Contact:** Stuart Cunningham, SAMS

6. Better understanding of deep-sea ecosystem services: ATLAS has demonstrated the socioeconomic value of deep-sea ecosystems, and the importance of considering these for future Blue Growth. The team assessed the economic and social value of these services and evaluated the risks posed by climate change and anthropogenic activities. Across four case studies in the Azores, Norway, Scotland and Flemish Cap, survey participants conclusively recognised the value of ecosystem services, the current ecological crisis, and the need for sustainable deep-sea management. Despite a lack of familiarity with deep-sea ecosystems, the public support future management strategies with strong preferences for the environment ahead of job creation, prioritising in the following order: marine litter, commercial fish stock health, size of protected areas, and new jobs in future management strategies.

More information: bit.ly/2ZomTUf | bit.ly/2LPD3xX | Xuan et al (*in submission*) | see output study 1.2
Contact: Claire Armstrong, UiT

7. Learnings from the Ocean Literacy survey: Results from Ocean Literacy surveys in the Azores provided measurable insights into public understanding and opinions on the ocean's ecosystem services. There is a great deal of public interest in the deep sea, with 77% of respondents stating that their wellbeing is dependent on the deep sea. Understanding what the public knows and perceives about the deep sea allows for meaningful communication, site-specific adapted management strategies, and social acceptability towards specific conservations strategies.

More information: bit.ly/2LO8o4c | **Contact:** Adriana Ressurreição, IMAR-UAz

8. New insights into the history of Atlantic cold-water coral populations: Genetic evidence collected over the last decade has revealed that two species of reef-building cold-water corals; *Lophelia pertusa* and *Madrepora oculata*, colonised the North East Atlantic margin after the Last Glacial Maximum (~22,000 years ago) from the West Mediterranean Sea through different routes. The results show the impact of past climate change on the distribution and genetic diversity, and fill knowledge gaps on these two species that are structurally essential for Vulnerable Marine Ecosystems.

More information: bit.ly/2zf2uFX | **Contact:** Joana Boavida, Sophie Arnaud Haond, Ifremer

9. Educational outreach programme: A portfolio of outreach resources was developed for educators, teachers and researchers to advance Ocean Literacy and appreciation of the deep Atlantic Ocean. The portfolio enables life-long learning in people of all ages and backgrounds, and contains free tools and tips which provide innovative ways to communicate **ATLAS** research and results.

More information: bit.ly/367Xn6S | see output study 1.3
Contact: Hermione Cockburn, Dynamic Earth

KEY ACHIEVEMENTS AND ACTIVITIES

10. 'Ecosystem engineer control theory' for cold-water coral (CWC) growth: **ATLAS** researchers have coined a new term to encompass the factors that control CWC distribution in the deep sea. Combining hydrodynamic, biogeochemical and habitat suitability models, they have shown that seafloor topography created by coral frameworks leads to enhanced food supply, showing that corals act as ecosystem engineers. 'Ecosystem engineer control theory' is therefore a more appropriate term than 'Environmental control theory', used to describe the ability of CWCs to thrive in the food-limited deep ocean.

More information: bit.ly/2VJZdpX | **Contact:** Karline Soetaert, Dick van Oevelen, NIOZ

11. Evidence that human-made offshore structures can improve deep-sea coral expansion: Using data from industrial stakeholders in the North Sea, this study demonstrates for the first time that anthropogenic structures can support conservation of protected marine species. It also shows that oil, gas and other non-natural installations can help to create highly connected systems by acting as bridges within oceanic coral networks - aiding larvae settlement, improving resilience and supporting ecological conservation. The study highlighted the importance of data sharing and science-industry collaborations, a key feature of the **ATLAS** project.

More information: bit.ly/2RVIYF4 | **Contact:** Lea-Anne Henry, UEDIN

12. Coral larvae dispersal is strongly correlated to atmospheric and ocean circulation patterns: Results from 40-year particle tracking models show that the dispersal of cold-water coral larvae (*Lophelia pertusa*) are sensitive to atmospheric-driven changes in ocean circulation. These findings provide much-needed guidance for establishing well-connected Marine Protected Areas.

More information: bit.ly/3aq7kgK | **Contact:** Alan Fox, SAMS | J Murray Roberts, UEDIN

13. Coral larvae behaviour is species-specific and greatly impacts on ocean connectivity: **ATLAS** scientists have shown that coral larvae behaviour, including upward and downward swimming, have a significant impact on dispersal and connectivity in the North Atlantic Ocean. These findings have important implications for future connectivity models and conservation planning. **More information:** bit.ly/2YMBit8 | go.nature.com/3dWazxY **Contact:** Alan Fox, SAMS | J Murray Roberts, UEDIN

14. Establishing a relationship between Mediterranean Outflow Water (MOW) and benthic fauna in the North Atlantic Ocean: Internal waves travelling at the interface of two different water masses (North Atlantic Central Water and MOW) improve conditions for benthic suspension feeders. These waves result from the impingement of MOW flow against sloping topographies and propagate at the interface of the two water masses.

More information: bit.ly/3eJon0G | **Contact:** Ángela Mosquera Giménez, IEO

15. Understanding the importance of spatial scale when distinguishing drivers of change in the deep sea: **ATLAS** scientists have shown that the effects of anthropogenic activities can only be separated from natural environmental controls when both small and large spatial scales are assessed in a study area. As human activities are increasingly taking place in the deep sea, the findings of this study highlight the need for similar large-scale analysis to disentangle the complex influences between environmental changes and human impacts on deep-sea ecosystems, an important consideration for marine spatial planners and industry stakeholders such as oil, gas, and mining companies.

More information: bit.ly/3btMmi3 | **Contact:** Johanne Vad, J Murray Roberts, UEDIN

OUTPUT STUDIES

Output study 1.1	Weakening of Atlantic Meridional Overturning Circulation (AMOC) through the industrial era
Description	The AMOC plays an essential role in regulating the Earth's climate through its redistribution of heat. **ATLAS** researchers from University College London, UK and the Department of Fisheries and Oceans, Canada have found comprehensive evidence of a marked weakening of Atlantic circulation over the past 150 years. The study provides, for the first time, palaeo-oceanographic reconstructions of AMOC over the last 1,500 years, suggesting that leading climate models are insufficiently sensitive to certain inputs and could be overestimating stability.
Need addressed	There is an increasingly urgent need to understand deep-ocean ecosystems: their current state, future state, current changing climates and increased exploitation pressures. To better predict future changes in ocean health, associated effects of climate change and impacts of planned activities (e.g. mining), scientists need a strong understanding of ocean circulation.
Approach	By examining the size of sediment grains deposited by deep-sea currents, where larger grains imply stronger currents and vice versa, **ATLAS** researchers have reconstructed past circulation patterns. The abundance of marine organisms that prefer warm and cold water was then measured in different sediment layers to work out changing near-surface temperatures. Comparing reconstructions with climate change models, **ATLAS** researchers found evidence that AMOC significantly weakened at the end of the Little Ice Age, around 1850 AD. The results suggest that, at this time, a combination of the onset of the industrial revolution and melting of glaciers and sea ice caused an influx of freshwater that disturbed ocean currents.
Target audience	Scientists, researchers, and academics within and beyond **ATLAS** who can use the results to further global understanding of ocean circulation and deep ocean ecosystems.
Knowledge Transfer	**Science to science** ○ Nature publication: Thornalley DJR, Oppo DW, Ortega P, Robson J I, Brierley CM, Davis R, Hall IR, Moffa-Sanchez P, Rose NL, Spooner PT, Yashayaev I, Keigwin LD (2018) Anomalously weak Labrador Sea convection and Atlantic overturning during the past 150 years. *Nature* 556, 227–230. doi.org/10.1038/s41586-018-0007-4 ○ Presentations at conference and workshops: including Fall AGU, San Francisco (USA), December 2016; PAGES, Zaragoza (Spain), May 2017; UK PACS meeting, Cardiff (UK) September 2017. **Science to society** ○ Extensive media coverage: TV news broadcasts on Sky News, BBC and Channel 5; Radio interviews on BBC Radio World at One, BBC 5 Live Up All Night, BBC World Service Morning Show, BBC Radio Wales, NPR podcast; Print coverage in The Guardian, The Financial Times, The Washington Post, The Daily Mail, Scientific American, BBC News online.

Impact	**Initial measures of impact (June 2020):** ○ *Nature* publication: 5,888 access | 87 citations ○ Scientific audience at conferences and workshops: 850 + ○ Media reach: 1 million + **Longer term impact:** ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	We now have evidence that North Atlantic circulation is weaker today than it has been for over a thousand years. **ATLAS** has provided the first comprehensive ocean-based record to place AMOC in the context of centennial climate change. This has significant implications for future model scenarios on climate resilience and effects on deep-sea ecosystems.
Next steps	UCL and the authors of this work are committed to sharing this new knowledge with others and applying it to develop better ocean circulation and climate model scenarios. Through **ATLAS** Science-Policy Panel meetings and at future policy meetings (e.g. the 4th Intergovernmental Conference UN General Assembly resolution 72/249) **ATLAS** continues to inform policy makers about the limitations and accuracy of past and future climate model scenarios.
Contact and contributors	**David Thornalley (UCL)** **ATLAS Partners: UCL, DFO**
More information:	Horizon Results Platform: **bit.ly/2To3K1f** Other: **bbc.co.uk/news/science-environment-43713719**

Output study 1.2	**An expert assessment of risks posed by climate change and anthropogenic activities to ecosystem services in the deep sea**
Description	Focusing on the services provided by deep-sea ecosystems, including supporting, provisioning, regulating and cultural services, **ATLAS** partners have shown that pollution and temperature change pose a high risk to more than 28% of deep-sea ecosystem services, and over 19% are at high risk from ocean acidification and fisheries. Projected negative impacts from temperature change and ocean acidification, fishing, pollution, and oil and gas activities are overwhelmingly more probable than the projected positive impacts. Ecosystem services are not seen to be at serious risk from tourism and blue biotechnology. The services to human wellbeing considered to be most at risk from anthropogenic activities are biodiversity and habitat as supporting services, biodiversity as a cultural service, and fish and shellfish as provisioning services.
Need addressed	The European Commission, under its Blue Growth Strategy, is seeking to support sustainable growth in the North Atlantic across five sectors known as the Blue Economy. To ensure such growth is sustainable, there is a need for greater understanding of deep-sea ecosystems and the various risks to services provided by deep-sea ecosystems. Managing the cumulative impact of human activities is essential to safeguard such services.
Approach	The 'Delphi Approach' was employed to consider the delicate equilibrium between societal needs and environmental sustainability. An interactive expert-based survey was used to assess potential impacts or risks posed by different human activities on deep-sea ecosystems, services in the North Atlantic Ocean from climate change, the Blue Economy, and their cumulative effects.

ATLAS COMPENDIUM OF RESULTS – OBJECTIVE 1: ADVANCE

Target audience	EU and member state policy makers, intergovernmental organisations and policy makers (IPBES, CICES, TEEB), academia, researchers, economists.
Knowledge transfer	**Science to science** ○ Frontiers in Marine Science publication: Armstrong C W, Vondolia Godwin K, Foley N S, Henry L-A, Needham K, Ressurreição A (2019) Expert Assessment of Risks Posed by Climate Change and Anthropogenic Activities to Ecosystem Services in the Deep North Atlantic. *Frontiers in Marine Science* 6, 158. doi. org/10.3389/fmars.2019.00158 ○ Participation in experiments: deep-sea scientists participated in the Delphi Survey between 2017-2018; Round 1 – attendees of the second **ATLAS** General Assembly, April 2017; Round 2 – online survey for **ATLAS** project members, October – November 2017; Round 3 – EU H2020 project SponGES' General Assembly, April 2018. **Science to society** ○ Article in **ATLAS** Project Newsletter, Issue 6, August 2019: **bit.ly/3fvGuGW**
Impact	**Initial measures of impact (June 2020):** ○ *Frontiers in Marine Science publication:* 3,236 views | 4 Citations ○ Scientific audience via survey participation: 55 + ○ Newsletter readers: 200 + **Longer term impact:** ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	Deep-sea ecosystem services in the North Atlantic Ocean are impacted by human activities and are at risk from climate change. **ATLAS** has shown the importance of considering these services for future Blue Growth and Marine Spatial Planning (MSP) in the deep sea. In addition, services should be considered to inform intergovernmental science-policy decisions (e.g. IPBES, CICES, TEEB) and the development of future frameworks designed to manage and conserve ecosystems and the services they provide.
Next steps	Supporting the development of future frameworks to manage and conserve ecosystems and the services they provide, **ATLAS** partners are interested in collaborations to implement this work into MSP and future Blue Growth scenarios. Further communication of these findings to researchers and funding bodies should be considered, shaping and unifying future research on the Atlantic deep sea.
Contact and contributors	**Claire Armstrong (UiT)** **ATLAS Partners: UiT, NUIG, UEDIN, UAz**
More information	Horizon Results Platform: **bit.ly/2IvRIgd**

Output study 1.3	Atlantic Adventures with ATLAS – The ATLAS educational outreach portfolio
Description	**ATLAS** developed a strong educational programme comprising a suite of resources highlighting the importance of the deep ocean and the key methods and achievements of the project. The portfolio contributes to improving Ocean Literacy, and empowering ocean-literate citizens. Topics addressed include ocean acidification; pressure in the deep; technology used in deep-sea exploration; cold-water coral reefs and hydrothermal vents. Educational resources include a large-scale 'reef survey' image, which can be printed for use as a floor mat and allows exploration of a cold-water coral ecosystem at various learning levels in a fun and easy way. Augmented reality colouring sheets, and an associated online information portal, were developed to bring three of the **ATLAS** case studies (p10) to life through the Spectacular app in collaboration with Quiver Vision Ltd. For other topics, education packs for hands-on experiments were created, including a kit-list, method and background. A script and explanatory film of the Atlantic Adventures with **ATLAS** interactive show for children, primarily delivered by Dynamic Earth, was produced to support other informal science educators and teachers to deliver the workshop. A Remote Operating Vehicle (ROV) simulator computer game allows people an insight into the work of scientists on board a research vessel and to experience piloting an ROV to explore two further **ATLAS** case study sites. Licenses were made available to project partners and a 3D model version is available on the **ATLAS** project website. An animal flow chart "Which deep-sea creature are you?", a 360° video recorded onboard the Canadian icebreaker, CCGS *Amundsen*, to be viewed with an **ATLAS**-branded cardboard viewer and 3D coral model of *Lophelia pertusa* were also produced. An 'Atlantic Adventures with **ATLAS**' film was created to demonstrate how to run the deep-sea outreach workshop. The resources are freely available to download from the project website, and selected resources are available in English, French, German, Portuguese and Spanish.
Need addressed	Improving public understanding and appreciation of the deep sea are vital steps towards greater conservation and protection of this important ecosystem via informed decision making and societal support for policy development.
Approach	Ocean Literacy is a foundational concept of the Galway Statement and the Atlantic Action Plan. In line with the Transatlantic Ocean Literacy Implementation Strategy (AORA, 2016), **ATLAS** has generated unique, dynamic and innovative educational materials to promote and enhance Ocean Literacy. All resources are free to download from **ATLAS** and are available in several languages, ensuring access for all.
Target audience	Educators, public engagement experts, deep-sea researchers, children, general public.
Knowledge transfer	**Science to society** o "Atlantic Adventures with **ATLAS**" activities and workshops, in-house public engagement programme at Dynamic Earth, Edinburgh (UK), 2019-2020 o Edinburgh International Science Festival (Panel presentations and interactive family workshops) April 2017, 2018, 2019 (UK) o Science Festival exhibitions throughout the UK including Caithness Science Festival, Scotland (UK), March 2019; Orkney Science Festival, Scotland (UK), August 2019; and Midlothian Science Festival, Penicuik, Scotland (UK), October 2019 o Exhibition at 'Science is Wonderful', Brussels (Belgium), September 2019 o *Amundsen* expedition Q&A Postcard Exchange, CCGS Amundsen (Canada) August 2018, 2019 o European Research & Innovation Days, Brussels (Belgium), September 2019 o European Researchers' Night at the Spanish Institute of Oceanography, Vigo (Spain), September 2019 o Articles in ATLAS Project Newsletter, Issue 3 (April 2018), 5 (March 2019), and 6 (August 2019): **bit.ly/3fvGuGW**

Knowledge transfer	**Science to science / teachers / marine educators** o CommOCEAN, Southampton (UK), December 2018 o European Marine Science Educators Association (EMSEA) conference, Newcastle (UK), October 2018 o Inspiring STEM learning, Edinburgh (UK), February 2018 o EMSEA conference, Azores (Portugal), September 2019 o BIG STEM Conference, Edinburgh (UK), July 2019 o Irish Ocean Literacy Network meeting, Dublin (Ireland), November 2019 **Science to policy** o Presentation at Scottish Parliament 20th Anniversary Celebration, Edinburgh (UK), June 2019 o Resources presented during the third **ATLAS** Science-Policy Panel, Brussels (Belgium), May 2019 o All-Atlantic Ocean Research Forum, Brussels (Belgium), February 2020 Free access to resources for all on the **ATLAS** website, Dynamic Earth website, SeaChange website and Zenodo
Impact	**Initial measures of impact (June 2020):** o In-house delivery at Dynamic Earth (April 2019 – Present): 26,138 o Newsletter readers: 200 + o Roadshows, Science Festivals (March 2019 – present): 6,640 + o Scientific / teachers / educators: 485 + o Policy audience: 30 + o Policy/Public audience at the EC 'Science is Wonderful': 3,200 + **Total direct engagement: 34,000 +** **Longer term impact:** o Contribution to UN Strategic Development Goal 14: Life below water o Contribution to UN Strategic Development Goal 4: Quality Education
Take home message	An ocean-literate person: o Understands the importance of the ocean to humankind o Can communicate about the ocean in a meaningful way o Can make informed and responsible decisions regarding the ocean and its resources **ATLAS** has generated unique, dynamic and innovative educational materials to promote and enhance Ocean Literacy for all citizens.
Next steps	The goal of the portfolio is to increase Ocean Literacy for all citizens, so the next steps would be to continue engaging with educators, marine professionals and members of the general public and promote the use of the **ATLAS** Educational Outreach Portfolio. Dynamic Earth are also committed to embedding some of the Ocean Literacy-focussed **ATLAS** resources into free Continuous Learning and Professional Development online courses for teachers in the UK and are also developing a new exhibition and ocean-literacy programme, "Discovering the Deep" which will feature people and results from **ATLAS** from April 2021. Further research into European School curricula and link with other initiatives e.g. Blue Schools in Portugal, to facilitate the use of the resources in schools across the globe should also be considered. AquaTT will use and promote the portfolio in all future relevant projects and initiatives related to Ocean Literacy, being a founding member of the Irish Ocean Literacy Network.
Contact and contributors	**Hermione Cockburn (Dynamic Earth)** **ATLAS Partners: DE, UEDIN, AquaTT**
More information	Horizon Results Platform: **bit.ly/2x745g0** **ATLAS** Educational Outreach Portfolio resources: **eu-atlas.org/education/intro**

> BRINGING NATURE INTO THE CLASSROOM CAN KINDLE A FASCINATION AND PASSION FOR THE DIVERSITY OF LIFE ON EARTH AND CAN MOTIVATE A SENSE OF RESPONSIBILITY TO SAFEGUARD IT.
>
> *David Attenborough*

OBJECTIVE 2

Improve

Our capacity to monitor, model and predict shifts in deep-water ecosystems and populations

ATLAS improved the capacity to monitor, model and predict shifts in deep-water ecosystems and populations in response to future change through a **better understanding of the connections** between physical parameters and biological characteristics to support sustainable exploitation in the North Atlantic.

KEY ACHIEVEMENTS AND ACTIVITIES

ATLAS researchers have developed new and improved methods for measuring and monitoring the deep sea and North Atlantic Ocean including:

1. A non-invasive method to quantify oxygen uptake by cold-water corals (CWCs): **ATLAS** researchers developed a new non-invasive method that estimates current velocity and dissolved oxygen concentration to quantify oxygen uptake rates of CWC gardens. The results obtained through the new techniques demonstrate that CWCs are important to carbon and nitrogen mineralisation at habitat scale. This provides additional information to help assess the implications of climate-driven shifts in carbon supply for deep-sea ecosystems.

More information: bit.ly/3bPusG7 | bit.ly/31vX31p **Contact:** Lorenzo Rovelli, Ronnie N. Glud, USD

2. A new approach to map coral reef biomass: Using a combination of collected samples, high-definition video footage, environmental variables extracted from multibeam and respiration data from literature, **ATLAS** researchers have developed a new approach to estimate the biomass of important cold-water coral reefs. This information is vital to understand their contribution to key ecosystem processes such as the carbon cycle.

More information: De Clippele L *(in review)* | bit.ly/3idy3ID **Contact:** Laurence De Clippele, J Murray Roberts, UEDIN

3. Low-cost imaging systems to observe the deep sea: Two custom-made underwater camera systems (live-view drift camera and a stereo-baited remote video) have been developed by **ATLAS** partners, in collaboration with the MapGES and iAtlantic projects, allowing greater data collection and spatial coverage at a reduced cost. The design and development of both systems will improve capacity to monitor and explore the deep-sea bed and commercially important fish populations.

More information: bit.ly/38ceDZH | **Contact:** Carlos Dominguez Carrió, Telmo Morato, IMAR-UAz

4. An index to identify biodiversity hotspots: **ATLAS** developed a novel multi-criteria assessment method to more objectively identify Vulnerable Marine Ecosystems (VMEs) in the North-East Atlantic Ocean, often biodiversity hotspots. The method evaluates how likely a given area of seafloor is to represent a VME, providing a more systematic and standardised approach (robust and repeatable numeric method) for assessing and identifying VME regions in the North-East Atlantic Ocean.

More information: bit.ly/2VrDu73 | **Contact:**Telmo Morato, IMAR-UAz

5. Common protocols to advance understanding of deep-sea sponge grounds: **ATLAS** researchers have published evidence showing that fragile deep-sea sponge aggregations are vulnerable to fisheries and changes in water mass properties, along with a catalogue and suite of indicators to assess their vulnerability and environmental status. Common protocols and procedures were developed to maximise the impact of new technological developments (such as towed cameras and remotely-operated vehicles) to monitor deep-sea sponges and associated ecosystems. This work supports and improves assessments of anthropogenic and climate change impacts in the deep sea, guiding future management and conservation strategies.

More information: bit.ly/34VG9Je | **Contact:** Georgios Kazanidis, J Murray Roberts UEDIN

6. Coupled hydrodynamic and physiological models to predict deep-sea ecosystem distribution and function: **ATLAS** partners have developed a new approach, combining hydrodynamic models and physiological models, to predict coral and sponge distributions, biomass and metabolic activity in deep-sea ecosystems. Results from three **ATLAS** case studies at Rockall Bank, Condor Seamount and Davis Strait have shown that cold-water corals contribute to biogeochemical cycles and can have a significant impact over large spatial scales.

More information: ATLAS Deliverable 2.4 and 2.5 (see p61) | **Contact:** Dick van Oevelen, NIOZ

7. Using eDNA and quantitative PCR to assess biodiversity in the open ocean: **ATLAS** partners have developed and tested six species-specific environmental (e)DNA assays. This work demonstrates that eDNA methods can be developed for detecting the presence of target species in pelagic and deep-water environments, and can be used to assess species distributions over space and time.

More information: bit.ly/3cg6KUr | see output study 2.3 | **Contact:** Laura Gargan, Jens Carlsson, UCD

8. Use of Google Compute Engine to reduce processing time for ocean simulations: In collaboration with ParallelWorks (a Chicago start-up), **ATLAS** partners have reduced the processing time for coral larvae simulations from two weeks to one hour by running the calculation via Google Compute Engine. The simulation results provide new insights into how cold-water corals spread across the ocean and show the connectivity of colonies. The workflow design can be adapted and applied by other researchers working on ocean population simulations.

More information: bit.ly/3f62Jn7 | **Contact:** Stefan Gary, Stuart Cunningham, SAMS

9. Impact of climate change on food supply and survival of deep-sea ecosystems: Results from a series of **ATLAS** experiments on the physiology of cold-water corals and deep-water sponges revealed that cumulative effects of climate change on food supply and ocean acidification impact the distribution and function of corals. This work highlighted that, as a result of climate change, predicted decreases in food availability and responses to ocean acidification will likely impact long-term growth and life cycles of corals. Better understanding of the interactive effects of climate change on deep-sea ecosystems supports accurate monitoring, modelling and future predictions.

More information: ATLAS Deliverable 2.2 (see p61) | **Contact:** Marina Carreiro-Silva, IMAR-UAz

OUTPUT STUDIES

Output study 2.1	Cold-water coral and sponge physiology database
Description	Deep-sea cold-water coral (CWC) and deep-water sponge (DWS) ecophysiology and physiology have been active areas of research over recent years, providing previously unknown and valuable new information on these vulnerable ecosystems and facilitating models to predict future scenarios. However, much of the new information and data from scientific publications in this field can be overlooked or is unusable due to factors such as unstandardised units. Addressing this problem, **ATLAS** partners have assembled existing literature and data into an accessible inventory and database for specific, standardised ecophysiology and physiology processes. The inventory of existing relevant publications lists papers on CWCs and DWSs which supply data on ecophysiology and general papers containing information of the functioning of DWS grounds and CWC reefs. Physiological data for CWC species (*Lophelia pertusa*, *Desmophyllum dianthus*, *Dendrophyllia cornigera*, *Madrepora oculata*, Antarctic octorals (*Primnoisis Antarctica*, *Primnoella sp.* and *Primnoella scotiae*), a sea pen (*Pteroides griseum*), a CWC from the Pacific (*Primnoa pacifica*) and Red Sea corals (*Eguchipsammia fistula* and *Dendrophyllia sp.*) have been compiled. Data on the following DWS are included: *Geodia barretti*, *Geodia atlantica*, *Geodia macandrewii, Stylocordila borealis*, *Cynachira antarctica*, *Mycale acerata*, *Mycale lingua*, *Isodyctia kerguelensis*, *Baikallospongia intermedia*, *Baikallospongia bacillifera*, *Phakellia ventilabrum*, *Antho dichotoma*, *Hymedesmia coriacea*, *Thenea muricata* and for other *Porifera indet*. where otherwise useful information was available. This valuable database has applications for future modelling efforts (addition of faunal components to coupled biogeochemical models) and scientific research.
Need addressed	Scientists need a better understanding of the connections between physical parameters and biological characteristics to support sustainable management in the North Atlantic Ocean. One such key connection is linking metabolic activity and biomass of DWSs and CWCs to the supply of organic matter sources from the water column, something that was hitherto challenging due to the lack of a coherent database of CWC and DWS physiology.
Approach	An extensive literature review of 95 papers (31 general publications; 47 specific to ecophysiology of scleractinian CWCs; 4 papers refer to physiological research with other cnidarians species; 13 dealing with DWS) has been conducted by **ATLAS** researchers. All existing publications on this topic have been compiled into an excel inventory, and data (533 entries) from the publications have been standardised and stored in databases, transforming the vast knowledge into a more user-friendly format.
Target audience	Scientists, researchers, and academics within and beyond **ATLAS** who can use the results to further global understanding of ocean circulation and deep ocean ecosystems.
Knowledge Transfer	**Science to science** ○ Chapter in book: Orejas C, Taviani M, Ambroso S, Andreou V, Bilan M, Bo M, Brooke S, Buhl-Mortensen P, Cordes E, Dominguez-Carrió C, Ferrier-Pagès, Godinho A, Gori A, J Grinyó, Gutiérrez-Zárate C, Hennige S, Jiménez C, Larrson A I, Lartaud F, Lunden J, Maier C, Maier S R, Movilla J, Murray F, Peru E, Purser A, Rakka M, Reynaud S, Roberts JM, Siles P, Strömberg, Thomsen L, van Oevelen D, Veiga A, Carreiro-Silva M (2019) Cold-water corals in aquaria: advances and challenges. A focus on the Mediterranean. *In Mediterranean Cold-Water Corals: Past, Present and Future. Understanding the Deep-Sea Realms of Coral.* Springer. doi.org/10.1007/978-3-319-91608-8 ○ Presentations at conferences and workshops: ICES Annual Science Conference, Gotheburg (Sweden), September 2019; **ATLAS** Science-Policy Panel, Brussels (Belgium), March 2017; ANFORE WS, Lecce (Italy), May 2018.

Impact	**Initial measures of impact (June 2020):** ○ Scientific Publication: 1 Citation | 369 downloads ○ Scientific audience at conferences and workshops: 300 + **Longer term impact:** ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	**ATLAS** has compiled a substantial body of literature on CWC and DWS ecophysiology and physiology, standardised a number of processes and created a database, the first coherent and standardised database of its kind. The literature review and database are useful tools for researchers working on deep-sea ecology. The database, which includes values on food capture and ingestion, respiration, (dissolved and particulate organic carbon) mucus excretion and calcification rate/growth rate, will be useful for comparing novel results with those previously obtained and placing newly obtained results in the context of the existing data.
Next steps	The database will be published and made accessible to all researchers interested in CWC and DWS ecophysiology and physiology. **ATLAS** researchers are planning to apply this information to design new experiments, leading to further knowledge creation in addition to collaborating with other researchers and feeding this comprehensive new knowledge into models for predicting shifts in deep-water ecosystems.
Contacts and contributors	**Covadonga Orejas (IEO), Evert De Froe (NIOZ), Dick van Oevelen (NIOZ)** **ATLAS Partners: IEO, NIOZ**
More information	Horizon Results Platform: **bit.ly/2NHnzx0** Other: **ATLAS** Deliverable 2.1: Compilation of existing physiological data on CWC response to different conditions of food supply and oceanographic change scenarios **zenodo.org/record/321898#.Woqica5l-Uk**

Output study 2.2	New approach to identify the key environmental parameters that control cold-water coral ecosystem performance
Description	As “ecosystem engineers”, cold-water corals (CWCs) build reefs that are unique biodiversity hotspots in the deep sea. They are considered to be Vulnerable Marine Ecosystems (VMEs) that provide important ecosystem services. The fate of CWCs amidst ongoing global change is difficult to assess as there are limited data on factors that could have a potential negative impact. Therefore, **ATLAS** developed a new approach, utilising geological data documenting past CWC ecosystem shifts, and correlated them with palaeoceanographic data describing past environmental changes. The results revealed that CWC ecosystem disappearance and reappearance in the North Atlantic Ocean during glacial to warm phase transitions is mostly likely linked to changes in either food supply or bottom water oxygenation, rather than temperature. Changes in these key factors could push CWCs beyond their critical tipping points, possibly triggering their demise, as well as that of the surrounding ecosystem. The outcome improves the prediction of the fate of CWCs and their functions under global change.
Need addressed	To assess the current state accurately, and to predict the future fate of CWCs under changing climates, scientists need a better understanding of the past. Therefore, new approaches to use information from the past are needed to understand past environmental changes and CWC response to climate change. The ability to understand and predict future changes will support sustainable management in the North Atlantic Ocean.

Approach	Using sediment-based approaches, the vitality of CWCs was traced through time at eight case studies in the North Atlantic Ocean. The chemical composition of calcite shells of benthic foraminifera were used as a proxy to infer bottom temperature, salinities, pH, and bottom water provenance. Accumulation rates were used to provide information on food supply and productivity, while grain-size analysis was used to reconstruct hydrodynamic conditions at the seabed.
Target audience	Scientists, researchers, academics, within and beyond **ATLAS**, who can use the approach to further global understanding of CWC ecosystems.
Knowledge transfer	**Science to science** o Scientific publication: Hebbeln D, da Costa Portilho-Ramos R, Wienberg C, and Titschack J (2019) The fate of cold-water corals in a changing world: a geological perspective. *Frontiers in Marine Science*, 6. doi:10.3389/fmars.2019.00119 o Presentations at conference and workshops: International Conference on Palaeoceanography, Sydney (Australia), September 2019; **ATLAS** General Assembly, Mallorca (Spain), April 2019. o Data available on PANGAEA for exploitation. doi.pangaea.de/10.1594/PANGAEA.908558
Impact	**Initial measures of impact (June 2020):** o Publication: >2,600 views | 4 Citations o Scientific audience at conferences and workshops: 50 to 100 scientists **Longer term impact:** o Contribution to UN Strategic Development Goal 14: Life below water
Take home message	Combining several palaeoceanographic and sediment-based approaches, the conditions controlling the growth and distribution of CWCs in the past have been evaluated. This knowledge has great capacity to improve the modelling/prediction of the fate of cold-water corals and their ecosystem functions under future global change.
Next steps	This work represents an additional key approach for assessing the sensitivity of deep-sea organisms to global change, and is of great importance for other scientists active in this field. Developing this work further, the next step would be to use this novel approach not only to differentiate between coral absence and presence, but to define the optimum conditions for their performance, which could guide the selection of areas where these species should be protected. This approach could also be applied to other deep-sea organisms.
Contact and contributors	**Dierk Hebbeln (MARUM - UniHB)** **ATLAS Partners: UniHB**
More information	Horizon Results Platform: **bit.ly/2VpYR8O**

Output study 2.3	**Using eDNA and quantitative PCR to assess biodiversity in the open ocean**
Description	Observing and sampling deep-sea species poses considerable challenges, such as high costs, lack of opportunity, and difficulties in sampling without causing damage. Addressing the need for new approaches to investigate species/population connectivity in the deep sea, a species-specific, probe-based quantitative PCR (qPCR) assay for detection of target DNA has been developed by **ATLAS** researchers. Results show that eDNA can be used as a sensitive detection method in the open ocean. With further development, the method has several applications for conservation biology as a non-invasive, rapid and relatively inexpensive tool for monitoring species where traditional surveying methods are not feasible.
Need addressed	Scientists need new tools and approaches to assess biodiversity in the deep sea and open ocean, particularly for those areas that are of conservation concern and/or are difficult to visually observe. Modern molecular techniques (eDNA assays) offer a powerful tool for detecting and assessing the spatial and temporal distribution of target species. Addressing several needs, eDNA assays offer a low-cost alternative to invasive sampling techniques and time-consuming visual surveys.
Approach	To assess the capability of using eDNA to detect transient pelagic marine animals, a species-specific probe-based qPCR assay for detection of target DNA assay was developed, followed by a pilot study to evaluate the capability of this method to determine the presence of the target organism in the field. The assay was developed for the Chilean devil ray, *Mobula tarapacana* (IUCN Red Listed as Vulnerable species). Seawater samples taken at seamounts around the Azores were tested to determine the suitability of this approach for detecting the target species. The assay successfully detected *M. tarapacana* at four out of five seamount sampling opportunities where the species was observed.
Target audience	Scientists, researchers, academics, within and beyond **ATLAS**, who can use the results to increase future utility of eDNA assays as a sensitive tool to detect and assess spatial and temporal distribution of target species.
Knowledge transfer	**Science to science** o Scientific Publication: Gargan LM, Morato T, Pham CK, Finarelli JA, Carlsson JEL, Carlsson J (2017) 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* 164. doi.org/10.1007/s00227-017-3141-x o Presentations at conference and workshops: UK Environmental DNA Working Group Meeting, Bangor, Wales (UK) September 2015; The International Society for Fish Biology (FSBI) Symposium, Bangor, Wales (UK), July 2016.
Impact	**Initial measures of impact (June 2020):** o Publication: 1,200 Access | 8 Citations o Scientific audience at conferences and workshops: 300-500 scientists **Longer term impact:** o Contribution to UN Strategic Development Goal 14: Life below water
Take home message	**ATLAS** researchers developed a sensitive detection method to survey pelagic biodiversity using eDNA and quantitative PCR. They found that eDNA can be used as a sensitive detection method in the open water and can effectively detect biodiversity hotspots and areas of conservation such as seamounts. The tool has the potential to delineate the spatial and temporal distribution of so far poorly understood species. Combined with visual observations data and presence/absence data based on eDNA, this new method would be an essential precursor to establishing modelling approaches to improve our capabilities to identify important seamounts for conservation and our knowledge of the distribution of *M. tarapacana* both in the Azores and globally.

Next steps	**ATLAS** researchers are committed to progressing this work through collaborations with other researchers in the field. The next steps include investigating how degradation and transport of eDNA impacts its use for inferring species presence in the open ocean environments and expanding this pilot to other species and regions. Furthermore, combining these results with modelling approaches would improve capabilities to identify important areas for conservation. Developing this work further, temporal and spatial sampling should be extended in order to delineate the distribution of this species and inform conservation management decisions. This approach could be adapted for other oceanic species that are of conservation concern by developing, testing and deploying other species-specific assays.
Contact and contributors	**Laura Gargan (UCD – Area 52 research group)** **ATLAS Partners: UCD, IMAR -UAz**
More information	Horizon Results Platform: **bit.ly/3eMR9wG**

ATLAS COMPENDIUM OF RESULTS – OBJECTIVE 2: IMPROVE

TOGETHER, WE CAN ENSURE THE ATLANTIC OCEAN IS THE BEATING HEART OF OUR WORLD FOR GENERATIONS YET TO COME.

OBJECTIVE 3

Transform

New data, tools and understanding into effective ocean governance

ATLAS transformed new data, tools and understanding into robust ocean governance in line with an adaptive ecosystem-based Maritime Spatial Planning (MSP) approach to **achieve ecosystem preservation, sustainable exploitation, and Blue Growth.**

KEY ACHIEVEMENTS AND ACTIVITIES

1. 'Luso' hydrothermal vent field declared as Marine Protected Area: The Luso hydrothermal vent field was discovered during the Blue Azores Expedition in 2018, in which **ATLAS** led Remotely Operated Vehicle operations. In September 2019, the Regional Government of the Azores declared the Luso hydrothermal vent field a Marine Protected Area (Portaria no. 68/2019), based on the **ATLAS** findings. This transformation of **ATLAS** research into policy will ensure deep-sea ecosystems in the Azores are preserved and can be incorporated into plans for sustainable exploitation.

More information: bit.ly/3cF1xFr | **Contact:** Telmo Morato, IMAR-UAz

2. ATLAS policy briefs: ATLAS produced three policy briefs outlining key policy messages from the project and circulated these briefs at relevant intergovernmental events. The three briefs highlight: (i) the need to recognise connectivity and climate change within Marine Protected Area network design, (ii) 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, and (iii) the challenges and potential for collaboration across Blue Growth sectors to enhance synergies and avoid conflicts as a key component of marine spatial planning.

More information: bit.ly/2xT9oQS | bit.ly/3ggYN3T | bit.ly/2LVVAIT | see output study 3.2 | **Contact:** Rob Tinch, Iodine | Philip Turner, David Johnson, Seascape Consultants Ltd

3. ATLAS Science-Policy Panels: Three **ATLAS** Science-Policy panels were held in Brussels, Belgium (March 2017; May 2019) and Ottawa, Canada (May 2018). These events included presentations from **ATLAS** researchers, discussions on challenges and opportunities, and highlighted the relevance of **ATLAS** research to specific European policies such as the European Marine Strategy Framework Directive. These events facilitated the direct delivery of **ATLAS** research results to senior policy makers at international level.

More information: bit.ly/2VuLvs7 | **Contact:** David Johnson, Seascape Consultants Ltd | J Murray Roberts, UEDIN

4. ATLAS GeoNode marine data visualisation tool: ATLAS developed an open-access geospatial data repository and visualisation tool using the open-source geospatial content management system (GeoNode) developed by OSGeo. The **ATLAS** GeoNode allows users to share, visualise and download **ATLAS** project data and other relevant data layers (e.g. from EMODnet). The repository facilitates the collaborative use of geospatial data and the creation of interactive maps as well as the transfer of **ATLAS** data and scientific outputs to wider stakeholders in industry and policy.

More information: bit.ly/3c0n6A8 | **Contact:** Kate Larkin, Tim Collart, Seascape Belgium

5. Contribution to the European Commission's Marine Strategy Framework Directive (MSFD) by approaching the future assessment of Good Environmental Status (GES) in the deep sea: ATLAS partners have analysed the definition of GES as well as its descriptors, criteria and indicators, and conducted an initial assessment of GES in the deep sea at nine **ATLAS** case study sites in European waters. Considering characteristics specific to the deep-sea realm, the current state of the scientific knowledge and current and future threats, **ATLAS** has proposed a new definition and indicators for GES in the deep sea, and made recommendations to inform future revisions of the MSFD for GES assessments in European waters and in areas beyond national jurisdiction.

More information: Kazanidis et al (*accepted*) | Orejas et al (*in review*) | see output study 3.1 | **Contact:** Covadonga Orejas, IEO | Georgios Kazanidis, UEDIN

6. Input to the Convention on Biological Diversity (CBD) regional workshop on Ecologically or Biologically Significant marine Areas (EBSA) in the North-East Atlantic Ocean: ATLAS contributed to the workshop and report organised by the Secretariat of the CBD (Stockholm, Sweden, September 2019). The data provided by **ATLAS** contributed to the description of six features that meet the EBSA criteria: (i) The Gulf of Cádiz, (ii) Tropic Seamount, (iii) North Azores Plateau, (iv) Charlie-Gibbs Fracture Zone, (v) Southern Reykjanes Ridge and (vi) the Hatton and Rockall Banks and Basin. This work supports the implementation of the EBSA process and informs future management measures in the deep sea.

More information: cbd.int/meetings/EBSA-WS-2019-01 | see output study 3.3 | **Contact:** Christopher Barrio Frojan, David Johnson, Seascape Consultants Ltd | Lea-Anne Henry, J Murray Roberts, UEDIN

7. Work with the International Seabed Authority (ISA): The **ATLAS** team made a submission to the ISA regarding draft regulations on Exploitation of Mineral Resources in the Area (beyond national jurisdictions). The submission addressed two questions from the ISA council and highlighted the importance of open access data, data sharing, particularly with industry, and cumulative impact of climate change on the resilience of the marine environment. **ATLAS** results (on AMOC, food web dynamics and vulnerability of Marine Protected Areas to changes in the ocean) were also used in the supporting materials at an ISA workshop and data report (November 2019).

More information: doi.org/10.5281/zenodo.2021044
Contact: Rachel Boschen-Rose, David Johnson, Seascape Consultants Ltd

8. Submission to the UK Government's Sustainable Seas Inquiry: The UK Government's Sustainable Seas Inquiry (April 2018) examined how ocean life can be protected from ocean acidification, overfishing, resource extraction and pollution. The **ATLAS** submission to the inquiry was cited eight times in the resulting Environmental Audit Committee Report and used to highlight the potential impact of deep-sea mining and as evidence for the threat of climate change. Since the inquiry, the UK Government has reaffirmed its commitment to the UN Framework

More information: doi.org/10.5281/zenodo.1544234 | **Contact:** Rachel Boschen-Rose, David Johnson, Seascape Consultants Ltd

9. Contributions to the United Nations negotiations on the conservation and sustainable use of marine biodiversity: **ATLAS** has contributed to the development of an International Legally Binding Instrument (ILBI) on the conservation and sustainable use of marine Biodiversity in areas Beyond National Jurisdiction (BBNJ) by the UN. **ATLAS** partners participated in the four Preparatory Committee sessions (March 2016, August 2016, March 2017, July 2017). In addition, the team contributed an article that provided information on the process, highlighted some of the features of the putative instrument under discussion, and outlined some of the issues at play in the process for regional groupings of states, countries with significant maritime interests and non-governmental representatives. The team also attended the Intergovernmental Conferences (September 2018, March 2019, August 2019), on the development of an ILBI for BBNJ. In 2019, **ATLAS** researchers ran a project examining how BBNJ stakeholders perceived the importance of science to the negotiations. These contributions have ensured both that **ATLAS** results are shared in a timely manner with delegations as they discuss and develop policy and that the significance of scientific input is better understood.

More information: bit.ly/3b5mHMo | **Contact:** Ronan Long, WMU | David Johnson, Seascape Consultants Ltd | Christine Gaebel, J Murray Roberts UEDIN

10. Contributions to the United Nations' Inter-governmental Panel on Climate Change (IPCC) special report on the ocean and cryosphere in a changing climate: Providing guidance and recommendations on ocean governance and conservation to global policy makers, **ATLAS** research and results on ocean acidification and larval modelling were included in the IPCC's latest report on Changing Oceans, Marine Ecosystems, and Dependent Communities (2019). **More information:** bit.ly/2KnKKKV | **Contact:** Alan Fox, Sebastian Hennige, J Murray Roberts, UEDIN | Jake Rice (**ATLAS** Advisory Board Chair), DFO

11. Contributions to the International Council for the Exploration of the Sea (ICES) Vulnerable Marine Ecosystem (VME) database: **ATLAS** has provided unequivocal evidence for several new VME habitats at Formigas and Ormonde seamounts and Gazul Mud volcano (**ATLAS** case study 7). These new VME habitat records have been added to the ICES VME database which is used to provide scientifically robust advice on the distribution of VMEs and to guide possible management solutions to protect VMEs.

More information: bit.ly/2XeYNZu | **Contact:** Covadonga Orejas, IEO

OUTPUT STUDIES

Output study 3.1	Approaching the assessment of Good Environmental Status in the deep sea
Description	The suitability of the definition, descriptors, criteria and indicators applied to determine Good Environmental Status (GES) in the deep sea has been assessed. Significant gaps were found in the current GES assessment, since they failed to account for specific deep-sea characteristics. Taking these into consideration, **ATLAS** partners have proposed a new definition of GES for the deep sea that considers the current state of scientific knowledge and understanding of present and future threats. *ATLAS defines GES in the deep sea to mean that the extraction of living marine resources is occurring at sustainable levels and the extraction of non-living resources does not produce significant adverse impacts that cause serious harm in the whole ecosystem, i.e. levels of extraction ensure continued delivery of goods and services for future generations. In particular, deep-sea GES is achieved when habitat-forming species are in 'good' condition, defined by acting as biodiversity hotspots and ensuring the continued ecosystem functionality, including all associated benthic, suprabenthic and demersal components. Areas dominated by soft sediments (e.g. the abyssal plains) maintain biodiversity at a level that ensures persistence of functional groups and thus ecosystem function. Impacts on the seabed and their effects on benthos and fish (commercial and non-commercial species) do not increase the risk of altered or lost ecosystem functioning, ensuring the sustainable use of deep-sea resources and the continued resilience of ecosystems in the face of a changing climate.* Considering the difficulties of establishing monitoring programmes in these remote areas, future GES in the deep sea should be assessed at habitat and ecosystem level (rather than species level) and at large spatial and temporal scales. Intersectoral collaborations and online data archiving of assessment of deep-sea environmental status are both vitally important. **ATLAS'** results outline important considerations for future GES assessments by regulatory bodies and the development of policy tools. **ATLAS** recommendations can be used to inform future revisions of the European Commission's Marine Strategy Framework Directive (MSFD) and as a basis for the assessment of the deep sea, including Areas Beyond National Jurisdiction (ABNJs).
Need addressed	There is a clear need for robust ocean governance, based on the best and latest data, tools, and understanding of the ocean at large. The current methodology to define and describe Good Environmental Status (GES) needs to be adapted for the specific characteristics of the deep sea. **ATLAS** investigated a new definition of GES for the deep sea.
Approach	The Nested Environmental status Assessment Tool (NEAT) developed within the European DEVOTES project, was evaluated as an appropriate tool to assess the environmental status of the deep sea. NEAT was applied to nine European deep-sea case study areas to identify indicators that are suitable for the deep sea due to their intrinsic characteristics, as well as to the level of available information (e.g. density of megabenthic structuring species as cold-water corals). Additional indicators, not included in the NEAT tool, were added to include the EC's MSFD descriptors. An extensive literature review was conducted to facilitate the selection of threshold values for each GES indicator. The results highlighted the scarcity of deep-sea data currently available, even in 'well-studied' case study areas and that the selection of indicators, thresholds and spatial scale, habitats and ecosystem components, can have a significant impact on the NEAT results.
Target audience	International organisations (e.g. OECD, FAO, UN), policy makers, EU and member state policy makers, managers, scientists, researchers, academics.

Knowledge transfer	**Science to science** ○ Scientific publications: • Orejas C, Kenchington E, Rice J, Kazanidis G, Palialexis A, Johnson D, Gianni M, Danovaro R, Roberts JM *(in review in Marine Policy)* • Kazanidis G, Orejas C, Borja A, Kenchington E, Henry L-A, Callery O, Carreiro-Silva M, Egilsdóttir H, Giacomello E, Grehan A, Menot L, Morato T, Ragnarsson SA, Rueda JL, Stirling D, Stratmann T, van Oevelen D, Palialexis A, Johnson D, Roberts JM (*accepted in Ecological Indicators*) ○ Presentations at conference and workshops: • Implementing European Marine Policies in the deep waters of the North Atlantic. Marine Alliance for Science and Technology for Scotland webinar youtube.com/watch?v=MRyvQ6HERuY&t=12s • International Council for the Exploration of the Sea Working Group on Fisheries Benthic Impacts and Trade-Offs (ICES WGFBIT), Ancona (Italy), September 2019 • International Council for the Exploration of the Sea (ICES) – Northwest Atlantic Fisheries Organization (NAFO) Joint Working Group on Deep-water Ecology (WGDEC), Copenhagen (Denmark), March 2017; Dartmouth (Canada), March 2018; Mallorca (Spain), June 2019 • IDEM project meeting, Rome (Italy), March 2019. • Academic visit and presentation at the European Commission's Joint Research Centre, Ispra (Italy) 2019 • Scotland's International Marine Conference, Glasgow (UK), February 2019 • Implementation of the MSFD to the Deep Mediterranean Sea workshop, University of Malta, Msida (Malta), 2018 • Data available on PANGAEA for exploitation: from July 2020 **Science to policy** ○ Presentations at conference and workshops: • **ATLAS** Science-Policy Panel, Brussels (Belgium), May 2019 • ICES/NAFO WGDEC, Copenhagen (Denmark), March 2017; Dartmouth (Canada), March 2018; Mallorca (Spain), June 2019 • European Commission's Joint Research Centre, March 2019 ○ Contribution to ICES. 2017. ICES/NAFO WGDEC. bit.ly/3d2QPJD ○ Contribution to ICES. 2019. Annex 4 within: 2018 Report of the Working Group on Fisheries Benthic Impact and Tradeoffs (WGFBIT). bit.ly/3anWbwQ ○ Contributed, through consultations, to the Marine Strategy Coordination Group_22-2018-06 document [Good environmental status for MSFD Descriptor 1 (seabed habitats) and Descriptor 6 (sea-floor integrity)] prepared by the European Commission's Directorate-General for Environment. bit.ly/2xTtydJ **Science to industry** ○ Presented at Ocean Business 2019, Southampton (UK), April 2019 ○ Article in **ATLAS** Project Newsletter, Issue 7, February 2020. **bit.ly/3fvGuGW**
Impact	**Initial measures of impact (June 2020):** ○ Scientific audience at conferences and workshops: 360 + scientists ○ Newsletter readers: 200 + **Longer term impact:** ○ Contribution to regional governance policies through recommendations made from ICES ○ Contribution to revisions of the European Commission's Marine Strategy Frameworks ○ Contribution to the deliberations surrounding the negotiation of the United Nations Biodiversity Beyond National Jurisdiction Treaty regulation ○ Contribution to UN Strategic Development Goal 14: Life below water

Take home message	**ATLAS** proposes a new assessment, including a new definition of GES, which better addresses the specific characteristics of the deep sea, as well as a set of the most suitable indicators (24 in total) and threshold values for each indicator to appropriately assess GES in the deep sea. The results and recommendations proposed by **ATLAS** for future GES assessments have important implications for regulatory bodies and the development of policy tools. They should be used to inform future revisions of the European Commission's MSFD and as a basis for the assessment of the deep sea in Areas Beyond National Jurisdiction (ABNJs).
Next steps	This work will facilitate identification and establishment of future research priorities and address challenges in the assessment of deep-sea environmental status. To inform policy, next steps should be to present this work at the European Commission, Regional Sea Conventions (OSPAR), International Council for the Exploration of the Sea and the United Nations. **ATLAS** is committed to engaging with regional and international organisations to achieve this.
Contacts and contributors	**Covadonga Orejas (IEO), Georgios Kazanidis (UEDIN)** **ATLAS Partners: IEO, UEDIN, DFO, NUIG, IMAR-UAz, MFRI, Seascape Consultants Ltd, UK, Ifremer, MSS, NIOZ, UNC-W. Other contributors: AZTI, Utrecht University, European Commission Joint Research Centre, Deep Sea Conservation Coalition, Center for Marine Science, Polytechnic University of Marche, Stazione Zoologica Anton Dohrn Naples.**
More information	Horizon Results Platform: **bit.ly/2CVSJyB**

Output study 3.2	**Current deep-sea Area-Based Management Tools are unprepared for climate change**
Description	The functionality of several Area-Based Management Tools (ABMTs) designed to protect biodiversity in Areas Beyond National Jurisdiction (more than 200 nautical miles) in the North Atlantic Ocean have been assessed. **ATLAS** partners have found spatial and temporal scale issues with current climate models and identified knowledge gaps. Currently, ABMTs are being applied on the basis of contemporary environmental conditions and habitat distribution. However, climate change and geographic shifts in environmental gradients will likely affect individual species, habitat integrity and representativeness. Different ecosystem components will react/respond differently to individual environmental stressors, and to the cumulative effects of a changing environment driven by climate change. Therefore, it is critically important to understand if, and when, these ecological features may change in response to climate change, potentially reducing or negating the value of ABMTs and their associated management systems. The results have important implications for future policy plans and decisions designed to protect biodiversity in the deep ocean.
Need Addressed	To create fit-for-purpose, adaptive, ecosystem-based maritime spatial plans, there is a need to know how well current Marine Protected Area network designs work, and recognise weaknesses that can be addressed in future plans.
Approach	A Pressure-State-Response (PSR) framework was used to (i) identify and characterise pressures on ABMTs; (ii) characterise the ecological / biological state of ABMTs and predict shifts in response to pressures and; (iii) to identify potential responses and measures to fill gaps identified. Three ABMTs were assessed: 1) OSPAR Marine Protected Areas, 2) Convention on Biological Diversity (CBD) Ecologically or Biologically Significant Areas (EBSAs), and 3) Regional Fisheries Management Organisations' (RFMOs') closures to protect Vulnerable Marine Ecosystems (VMEs). They were assessed for a 20-to 50-year timeframe, using a stepwise methodology based on five key variables, building on available technical and scientific information.

Approach	The five variables assessed showed differing levels of uncertainty with respect to impacts on key taxa under climate change projections. With the exception of one EBSA, all of the conservation targets in all of the current MPAs, EBSAs and areas closed to fishing to protect VMEs may be impacted by changes in at least one of the five climate change oceanographic variables before 2050.
Target audience	International organisations (e.g. CBD, FAO, OSPAR, NAFO, NEAFC), policy makers, EU and member state policy makers, managers, scientists, researchers, academics.
Knowledge transfer	**Science to science** ○ Scientific publication: Johnson D, Ferreira MA, Kenchington E (2018) Climate change is likely to severely limit the effectiveness of deep-sea ABMTs in the North Atlantic. *Marine Policy*, 87, 111-122. doi.org/10.1016/j.marpol.2017.09.034 ○ Presentations at conference and workshops: IUCN experts' meetings, Gland and Paris (France), October 2018; OSPAR IGC-MPA, Marstand (Sweden), October 2018; CBD COP14, Sharm El-Sheikh (Egypt), November 2018; FAO GEF Deep Sea Project meeting, Reunion (France), January 2019; IGC (2) UN New York (USA), March 2019; IDDRI expert meeting, Paris (France), April 2019; DOSI expert workshop, San Diego (USA), June 2019; European Aquarium Congress, Nausicaa (France), October 2019. **Science to policy** ○ Part of **ATLAS** Policy Brief presented to the UN Intergovernmental Conference, New York (USA), March 2019 ○ Presented at **ATLAS** Science-Policy Panel, Brussels (Belgium), May 2019 ○ Presented at OSPAR Intersessional Correspondence Group on MPAs, Sweden, October 2019 **Science to industry** ○ Presented at Ocean Business 2019, Southampton (UK), April 2019 ○ Article in **ATLAS** Project Newsletter, Issue 6, August 2019. **bit.ly/3fvGuGW**
Impact	**Initial measures of impact (June 2020):** ○ Publication: > 170 reads | 17 Citations ○ Scientific audience at conferences and workshops: 100 + ○ Newsletter readers: 200 + ○ Policy audience at conferences and workshops: 150 + **Longer term impact:** ○ This work has informed planning considerations by the OSPAR Commission and internal meetings of projects, workshops and conferences considering biodiversity protection in the deep sea (see previous list above). ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	There is a need for more complete impact assessments, and further research including the impact of additional variables and more precise and reliable spatial and temporal models. Conservation targets for highly mobile species can likely be met by relocating ABMTs, and for sessile/low mobility species, there are a number of mitigation options to support short-term conservation efforts.
Next steps	Detailed work on ABMTs on a case-by-case basis could inform future conservation priorities. A specific focus for future studies could be on ecosystem tipping points. **ATLAS** is committed to share this work with policy makers and international organisations (e.g. CBD, FAO, OSPAR, NAFO, NEAFC) to inform future impact assessments and research to achieve appropriate conservation targets.
Contact and contributors	**David Johnson (Seascape Consultants Ltd)** **ATLAS Partners: Seascape Consultants Ltd, DFO**
More information	Horizon Results Platform: **bit.ly/2XTnSuR**

Output study 3.3	**New evidence to support the protection of deep-sea sponge ecosystems at Tropic Seamount**
Description	**ATLAS** partners have developed new information and data to support robust ocean governance by contributing to data describing six features that meet the Ecologically or Biologically Significant marine Areas (EBSAs) criteria, including Tropic Seamount. With the support of new models and habitat suitability maps, **ATLAS** discovered extensive monospecific grounds of the hexactinellid sponge *Poliopogon amadou* at Tropic Seamount, a potential Vulnerable Marine Ecosystem (VME), located in an Area Beyond National Jurisdiction (ABNJ) in the subtropical North Atlantic. *P. amadou*, the only member of its genus in the Atlantic Ocean, is a large, fan-shaped pheronematid sponge that reaches up to 35 cm in height. Even though it is a habitat-forming VME indicator species, its occurrence was poorly understood. An ensemble species distribution model and local habitat suitability maps for the sponge in the Atlantic Ocean were produced and tested by direct observation during a subsequent research expedition. The results from this study have implications for spatial management and describing additional VMEs and EBSAs. Working towards a high seas marine protected area network, the results have been used to inform a submission to the Convention on Biological Diversity (CBD) to designate the Tropic Seamount as an EBSA. Designating the seamount as an EBSA is an important first step towards any future sustainable management and protection measures.
Need addressed	To achieve ecosystem preservation and sustainable exploitation, there is an urgent need to transform new data into ocean governance measures. The ability to predict the presence of VMEs will support future measures and guide Blue Growth.
Approach	First, to gather new information and to predict the distribution of this VME indicator sponge on the Tropic Seamount, **ATLAS** partners created an ensemble habitat suitability map for *P. amadou* distribution. Three different modelling techniques were used; Maximum Entropy, General Additive Models, and Random Forest, for the purpose of management applications. These models can help fill gaps and create distribution maps in areas where data is not available, thereby proving some guidance (where previously there were none) before any exploitation activities. Increasing spatial coverage beyond the range of Remotely Operated Vehicles and Autonomous Underwater Vehicles surveys in the area, predictive maps are useful tools to inform ongoing high seas management efforts such as Maritime Spatial Planning, environmental impact assessments, conservation of biogeographically unique provinces, and UN negotiations of a new treaty to protect Biodiversity Beyond National Jurisdiction (BBNJ). For example, the information generated from this research contributed to scientific information submitted to describe an EBSA to the CBD.
Target audience	International organisations, policy makers, EU and member state policymakers, managers, scientists, researchers, academics.
Knowledge transfer	**Science to science** ○ Scientific Publication: Ramiro-Sánchez B, González-Irusta JM, Henry L-A, Cleland J, Yeo I, Xavier JR, Carreiro-Silva M, Sampaio I, Spearman J, Victorero L, Messing C G, Kazanidis G, Roberts JM, Murton B (2019) Characterization and Mapping of a Deep-Sea Sponge Ground on the Tropic Seamount (Northeast Tropical Atlantic): Implications for Spatial Management in the High Seas, *Frontiers in Marine Science* 6, 278. doi.org/10.3389/fmars.2019.00278 **Science to policy** ○ CBD Regional Workshop EBSAs in the North East Atlantic, Stockholm (Sweden), September 2019 ○ **ATLAS** Science-Policy Panel, Brussels (Belgium), May 2019 ○ Submission of scientific information to Describe Ecologically or Biologically Significant marine Areas to Convention on Biological Diversity. cbd.int/meetings/EBSA-WS-2019-01, October 2019

Knowledge transfer	**Science to society** ○ Media coverage: Spanish media EFE: VERDE (October 2019) bit.ly/2XSVusR ○ AAAS Science Magazine (September 2019) bit.ly/3at1XNQ
Impact	**Initial measures of impact (June 2020):** ○ Publication: >3,450 views | 3 Citations ○ Policy audience at meetings and workshops: 100 + ○ Media reach: 500 + **Longer term impact:** ○ Inclusion of Tropic Seamount in the CBD EBSA repository ○ Contribution to cross-sectoral management and ocean governance measures for conservation and sustainable use of deep-sea biodiversity ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	**ATLAS** researchers have established substantial new knowledge on the distribution of sponges, their preferred conditions (water depth and current speed), and toward understanding the environmental drivers and biogeography of species in the Atlantic Ocean. This research has implications for future spatial management and describing VMEs. The results generated contributed to scientific information submitted to the CBD, supporting the description of Tropic Seamount as an EBSA, part of a contribution to addressing biodiversity conservation in Areas Beyond National Jurisdictions.
Next steps	Designating the seamount as an EBSA is the first step. In the future, this could help set spatial planning measures in situ in case of exploitation. From a research perspective, the next steps to continue this work would be community analyses of the vertical distribution of other VMEs observed on the seamount. The methods can be applied and used by others to further increase spatial coverage and further increase knowledge and understanding of VMEs, to improve policy tools and spatial planning in marine exploitation, and ultimately leading to better ocean governance.
Contact and contributors	**Berta Ramiro-Sánchez, Lea-Anne Henry (UEDIN)** **ATLAS Partners: UEDIN, IMAR-UAz, Seascape Consultants Ltd**
More information	Horizon Results Platform: **bit.ly/2RZOW7N**

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OBJECTIVE 4

Develop

And scenario-test science-led, cost-effective adaptive management strategies that stimulate Blue Growth

ATLAS developed and scenario-tested science-led, cost-effective **adaptive management strategies** for sustainable use of living and non-living resources that stimulate Blue Growth.

KEY ACHIEVEMENTS AND ACTIVITIES

1. Area-based resource management plans for ATLAS case studies: **ATLAS** has assessed the science base available to support the development of regional area-based management plans in the North Atlantic Ocean. Existing information about ecosystem components, human activities and governance have been collated for each **ATLAS** case study area. Environmental risk assessments have been conducted in each case study to provide a baseline for planning. Blue Growth scenarios were tested using systematic conservation planning tools, MarXAN and PrioritzR, to help promote global, regional and local conservation targets but also to determine the optimal locations for Blue Growth activities while minimising impacts. These results will contribute to the implementation of the Integrated Maritime Policy (EC COM(2017) 575).

More information: bit.ly/2WcufrU | **Contact:** Anthony Grehan, NUI Galway

2. Blue Growth scenarios tested at ATLAS case studies: A range of different Blue Growth scenarios have been identified and tested across **ATLAS** case studies. Blue Growth scenarios for: oil and gas exploration/exploitation, deep-sea mining, expansion of Arctic fisheries, EU Natura 2000 sites (designated sites protected under the Birds and Habitats Directive), tidal energy, ecotourism and carbon sequestration have been tested at relevant **ATLAS** case study sites. The potential impact of developing these activities on the environment, and for already existing activities in the case studies, was assessed to inform managers of potential Blue Growth scenarios about user conflicts and to provide examples where governance needs to be strengthened to deliver robust area-based management.

More information: **ATLAS** Deliverable 6.3 (see p61) | **Contact:** Anthony Grehan, NUI Galway

3. Novel Marine Spatial Planning (MSP) decision support protocol: **ATLAS** has developed a streamlined workflow to facilitate the implementation of the 'Monitoring and Evaluation of Spatially Managed Area' (MESMA) generic planning framework (developed under the EU Framework Programme 7 project - MESMA) and to test Blue Growth scenarios across **ATLAS** case studies. The workflow supports the production and presentation of transparent information to stakeholders and enables greater connectivity and interoperability.

More information: **ATLAS** Deliverable 6.3 (see p61) | see output study 4.1 | **Contact:** Oisín Callery, Anthony Grehan, NUI Galway

4. Identification of Blue Growth industry drivers: **ATLAS** partners have gained novel insights into business drivers, priorities and challenges facing Blue Economy sectors (blue biotechnology, oil and gas, renewable energy, shipping, tourism, fisheries, offshore aquaculture and deep seabed mining) through a series of interviews and questionnaires. Between now and 2030, important business drivers for Blue Growth sectors in the North Atlantic Ocean include: technology development, regulation development and climate change impacts. This work highlighted shared spatial challenges across several Blue Growth sectors and the need for collective adaptive management strategies.

More information: bit.ly/2LXl20B | bit.ly/3ikxKpc | **Contact:** Rachel Boschen-Rose, Seascape Consulatnts Ltd | Matthew Gianni, Gianni Consultancy.

5. Industry data sharing: Through collaboration among **ATLAS** researchers and international oil companies Equinor and BP, **ATLAS** has supported better monitoring efforts at case study sites including LoVe Observatory, Norway and West of Shetland. **ATLAS** organised three international industry workshops (Edinburgh, UK-2016, Poole, UK-2017, Dublin, Ireland-2019) and two questionnaires to facilitate the dissemination of industry-relevant **ATLAS** innovations. The identified guiding principles for future data sharing are expected to improve business practices and reduce costs. Ensuring stakeholder involvement and use of best available data, through data sharing, this work supports the implementation of the EU Directive on Marine Spatial Planning for sustainable Blue Growth.

More information: **ATLAS** Deliverable 6.4 (see p61) | **Contact:** Lea-Anne Henry, UEDIN

6. Contribution to the development of NAFO Ecosystem Summary Sheets: **ATLAS** research on the impact of human activities, other than fishing, at **ATLAS** case study 11 (Flemish Cap – Flemish Pass) has been incorporated into Ecosystem Summary Sheets developed by the Northwest Atlantic Fisheries Organization (NAFO). These sheets are part of the NAFO's Roadmap for an ecosystem approach to fisheries, and will be used to inform decision making, by both managers and industry, in the Northwest Atlantic Ocean in Areas Beyond National Jurisdiction (ABNJ).

More information: bit.ly/3baBggW (12th NAFO WG-ESA Report, p 120) | see output study 4.3 | **Contact:** Pablo Durán Muñoz, Mar Sacau, IEO

7. Predictive maps for future habitat suitability: **ATLAS** partners have modelled and developed predictive maps of habitat suitability for six cold-water coral and six deep-sea fish species under current conditions and forecast changes under future projected high-emission climate conditions for the whole North Atlantic Ocean. The results forecasted that over 50% of cold-water coral habitat could be at risk, and suitable habitats for commercially important deep-sea fish could shift by up to 100 km northwards. This work has important implications for the designation of effective area-based conservation measures and adaptive management strategies.

More information: bit.ly/36jV2WA | see output study 4.2 | **Contact:** Telmo Morato, IMAR-UAz

OBJECTIVE 4 – DEVELOP | OUTPUT STUDIES

Output study 4.1	Novel Marine Spatial Planning decision support protocol
Description	A novel workflow required to facilitate application to test Blue Growth scenarios in deep-sea areas has been developed by **ATLAS** partners to inform adaptive management. The workflow supports the implementation of the EU Framework Programme 7 'Monitoring and Evaluation of Spatially Managed Areas' (MESMA) generic planning framework in **ATLAS** case studies. The workflow enables greater connectivity and interoperability of marine data, increasing the use and exploitation of available data while also identifying gaps that can be filled by novel modelling approaches. The workflow has been developed using open source R with data visualisation performed using the open source QGIS. This enables transparent presentation of information (and all processing steps) to stakeholders (e.g. mapped cumulative impact scores for **ATLAS** case studies). The workflow will assist marine spatial planning and the delivery of ecosystem-based management as well as highlighting lacunae and issues to be addressed by ocean governance.
Need Addressed	Maritime Spatial Planning in the offshore and deep-sea areas is still in its infancy. To ensure that Blue Growth can take place while protecting biodiversity, a robust MSP framework is required to deliver holistic ecosystem-based management in the ocean. Such a framework should support adaptive management to ensure sustainable use of living and non-living resources as new Blue Growth opportunities present themselves. To support the development of such plans and to facilitate testing, new methods and tools are needed to integrate new data sources (e.g. Global Fishing Watch data) into the MSP framework.
Approach	The 'Monitoring and Evaluation of Spatially Managed Area' (MESMA) generic planning framework includes a series of steps for each spatially managed area including data collection (ecosystem components, human activities, governance); identification of indicators; risk analysis and state assessment; and adaptive management evaluation. The workflow was developed: **i)** to support implementation of MESMA in the Atlantic Ocean, which allows compilation of the relevant data layers (drawn from the **ATLAS** data repository), easily compiling data from different sources with different resolutions and spatial scales **ii)** to enable practitioners with little programming knowledge to perform cumulative effects assessments using pre-packaged R scripts **iii)** to produce raster outputs that can be inputted into QGIS for data visualisation and mapping; and into MarXAN or similar, for testing management scenarios including systematic conservation planning. See also: **zenodo.org/record/3761218#.XrQWoS8ZNNI**
Target audience	International policy advisory organisations (e.g. JNCC, ICES), EU and member state policymakers, managers, offshore operators, oil and gas industry, scientists, researchers, academics.
Knowledge transfer	**Science to science** ○ Scientific Publications: • Kazanidis et al (*accepted*) • Combes et al (*in review*) • Callery et al (*in preparation*) ○ Presentations at conferences and workshops: including **ATLAS** MSP Webinar, Department of Fisheries and Oceans, March 2020; Science Foundation Ireland (SFI) – Centre for Marine and Renewable Energy Ireland (MaREI) Science Conference, Limerick (Ireland), November 2019; Socio-Economic Marine Research Unit (SEMRU) 10th Annual Economics and Policy Research Symposium, Galway (Ireland), November 2019.

Knowledge transfer	**Science to policy** ○ Presentations at conference and workshops: • ICES Workshop on EU regulatory area options for VME Protection (WKEUVME), online, May 2020. bit.ly/2zaYruP • Irish MPA Expert Advisory Group meetings, Department of Housing, Planning and Local Government. Multiple meetings held in Dublin (Ireland) and online, December 2019, February, April 2020 • ICES Stakeholder Workshop to Disseminate the ICES Deep-Sea Access Regulation Technical Service, and Scope the Required Steps for Regulatory Purposes (WKREG), Copenhagen (Denmark), October 2019 • ICES Workshop on Tradeoffs Scenarios between the Impact on Seafloor Habitats and Provisions of catch/value (WKTRADE2), Copenhagen (Denmark), September 2019 • ICES Working Group on Deep-sea Ecology (WGDEC), Copenhagen (Denmark), June 2018; Mallorca (Spain), June 2019 • ICES Working Group on Marine Planning and Coastal Zone Management (WGMPCZM), Galway (Ireland), April 2019 • **ATLAS** Symposium on Future Prospects for North Atlantic EBSAs, VMEs and MPAs, WCMB, Montreal (Canada), May 2018 • Perspectives on Area-Based Management Tools for ABNJ; Trans-Atlantic Assessment and Deep-water Ecosystem-based Spatial Management Plan International Workshop, Nausicaá, Bologne-sur-Mer (France), June 2018 ○ Contribution to reports: • ICES. 2019. WKTRADE2. bit.ly/2VDsWCd • ICES. 2019. ICES/NAFO WGDEC. bit.ly/3cKZXIA • ICES. 2019. WKREG. bit.ly/351rr3H • ICES. 2020. WGMPCZM (outputs from 2019 meeting). bit.ly/3bFexe8 • Irish MPA expert advisory group. 2020. Expanding Ireland's Marine Protected Area Network report (due in July 2020) **Science to industry** ○ Ocean Business **ATLAS** side event, Southampton (UK), April 2019 ○ **ATLAS**/MaREI/Irish Offshore Operators Association joint industry workshop: 'Supporting Blue Growth' Dublin (Ireland), December 2019 **Science to society** ○ Article in **ATLAS** Project Newsletter, Issue 7, February 2020. **bit.ly/3fvGuGW**
Impact	**Initial measures of impact (June 2020):** ○ Scientific audience at conferences and workshops: 150 + scientists ○ Newsletter readers: 200 + ○ Policy audience at conferences and workshops: 150 + ○ Industry audience at conferences and workshops: 50 + **Longer term impact:** ○ Contribution to national initiatives to establish Marine Protected Areas ○ Contribution to regional governance policies through recommendations made from ICES ○ Contribution to the deliberations surrounding the negotiation of the United Nations Biodiversity Beyond National Jurisdiction treaty regulation
Take home message	Facilitating Marine Spatial Planning, and the development of adaptive management strategies for the deep sea, a novel workflow/tool has been developed to support the implementation of MESMA and to test Blue Growth scenarios at **ATLAS** case studies. The tool facilitates the planning process, potentially reduces business costs (i.e. conducting Environmental Impact Assessments) and supports achievement of global, regional and local conservation targets through systematic conservation planning.

Next steps	The workflow (together with a tool developed in parallel with SFI MaREI) needs to be marketed and disseminated to increase uptake by policy makers and industry. **ATLAS** partner NUI Galway, and MaREI are committed to disseminating this work and carrying out the next steps, including the development of a web application, online tutorials (training) and workshops on how to use the tool, as well as collaborations with potential practitioners (i.e. local, regional and national planners). Trials with stakeholder groups are also envisaged. The workflow will be dynamic and can be improved as new data and knowledge, e.g. our understanding of species responses to pressures resulting from human activities, become available.
Contacts and contributors	**Anthony Grehan, Oisín Callery (NUIG) and MaREI Observation and Operations Spoke (SFI)** **ATLAS Partners: NUIG, DFO**
More information	Horizon Results Platform: **bit.ly/2Zn9YQG**

Output study 4.2	**New climate model projects major impacts on coral and commercially important fish habitats in the deep Atlantic due to climate change**
Description	Understanding how anticipated climate change will affect deep-sea species distributions, including commercially important fishes, is critically important in developing effective management measures. Addressing the need to understand these shifts, **ATLAS** partners have modelled and developed predictive maps. These maps display habitat suitability for six cold-water coral and six deep-sea fish species under current conditions, and also forecast changes under projected high-emission climate conditions for the whole North Atlantic Ocean. The results strongly suggest that warming, acidification, and decreasing food availability will compound to significantly reduce the availability of suitable habitats for deep-sea species by 2100. The models forecast a decrease of 28-100% of suitable habitat for cold-water corals, and a shift in suitable habitat for deep-sea fishes of 2.0° – 9.9° towards higher latitudes. This work highlights the importance of identifying and preserving climate refugia. It also has important implications for fisheries management, for conserving and protecting Vulnerable Marine Ecosystems (VMEs), and for the designation of effective area-based conservation measures, planning and management tools.
Need Addressed	We need adaptive management strategies for sustainable use of living and non-living resources in the deep Atlantic Ocean that stimulate Blue Growth, particularly in response to climate change. Understanding how anticipated climate change will affect deep-sea species distributions, including commercially important fishes, is critically important in developing effective management measures.
Approach	Using the best available species occurrence data, a set of static measures (e.g. depth, slope) and near-bottom dynamic environmental parameters (particulate organic carbon flux to the seabed, near seafloor pH, dissolved oxygen concentration, temperature, and near seafloor aragonite and calcite saturation state) that predict suitable habitats under future climate conditions for VME indicator species and deep-sea fish species have been developed. Habitat suitability for six cold-water coral and six deep-sea fish species under present-day (1951-2000) environmental conditions and forecast changes in a severe, high emissions future (2081-2100, RCP8.5 scenario) have been modelled for the North Atlantic Ocean.

Target audience	Marine spatial planners, offshore operators, international organisations, policy makers, scientists, researchers, academics.
Knowledge transfer	**Science to science** ○ Scientific Publication: • Morato T et al (2020) Climate-induced changes in the suitable habitat of cold-water corals and commercially important deep-sea fishes in the North Atlantic. *Global Change Biology.* doi.org/10.1111/gcb.14996 ○ Method for other scientists to access and exploit: • Deep-sea species distribution modelling workshop, Montreal (Canada), May 2018. bit.ly/2WYMG3C **Science to policy:** ○ Scientific Publication: • **ATLAS** Science-Policy Panel, Brussels (Belgium), May 2019 • Data from this work contributed to the description of features meeting the Ecologically or Biologically Significant marine Areas (EBSA) criteria that were presented to the Convention on Biological Diversity (see p34) **Science to society:** ○ Press Release: bit.ly/3d8Civg
Impact	**Initial measures of impact (June 2020):** ○ Publication: 2 Citations ○ Scientific audience at conferences and workshops: 100 + ○ Media coverage: 1000 + hits (AlphaGalileo) | 130 + reached (Altmetric) **Longer term impact:** ○ Contribution to future long-term sustainable environmental management and conservation policies, particularly those relating to VMEs and EBSAs. ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	**ATLAS** research has found that the availability of suitable habitat for cold-water corals and deep-sea fish species is expected to significantly decrease by 2100. Environmental niche modelling is a valuable tool for forecasting changes in habitat suitability. This approach can help to integrate climate change considerations as part of area-based management decisions or conservation and sustainable use of biodiversity in international areas.
Next steps	**ATLAS** hopes that the results will be used to enhance international dialogue on basin-scale management. Habitat suitability models are powerful tools to inform such discussions on conservation policy and environmental management. The model presented here can be used as a template and applied to other taxa or in additional regions to resolve changes in distribution and identification of refugia for monitoring purposes.
Contact and contributors	**Telmo Morato (IMAR-UAz)** **ATLAS Partners: IMAR-UAz, UEDIN, DFO, IEO, NUI Galway, Ifremer, MRFI, Gianni Consultancy, Seascape Consultants Ltd, SAMS, NIOZ**
More information	Horizon Results Platform: **bit.ly/3eJ81o5**

Output study 4.3	Contribution to the development of NAFO Ecosystem Summary Sheets
Description	Supporting the implementation of **ATLAS** research in ocean management and Blue Growth, results from **ATLAS** case study 11, Flemish Cap – Flemish Pass, have been incorporated into NAFO (Northwest Atlantic Fisheries Organisation) Ecosystem Summary Sheets (ESS) as part of NAFO's Roadmap for an Ecosystem Approach to Fisheries. The ESS will be presented to the NAFO Commission in September 2020 and are intended to provide a synoptic perspective on the state of NAFO ecosystems and their management regime. **ATLAS** results (i.e. maps) show the spatial overlap of footprints from human activities, other than fishing. These insights are combined with mapping of other ecosystem components to highlight existing or potential conflicts between users of the NAFO marine space and Vulnerable Marine Ecosystems (VMEs). **ATLAS** results have contributed to several sections of the ESS including VME status, oil and gas activities and pollution, specifically marine litter. Following the recommendations of the NAFO Working Group on Ecosystem Science and Assessment (WGESA) to the NAFO Scientific Council, protocols for collecting marine litter data for monitoring purposes should be implemented by all contracting parties during groundfish surveys in the NAFO regulatory area. The NAFO ESS's constitute a tool for strategic assessment, advice, and planning for the Northwest part of the Atlantic Ocean in Areas Beyond National Jurisdiction (ABNJ), supporting the direct implementation of **ATLAS** research in ocean management and governance.
Need addressed	Organisations governing the use of ocean resources need scenario-tested and science-led adaptive management strategies. Supporting the development of such strategies, **ATLAS** has developed tools (maps) that identify resource use and highlight existing or potential spatial conflict.
Approach	A Maritime Spatial Planning (MSP) framework was applied to produce maps of relevant natural and socio-economic components of the deep-sea ecosystem of the Flemish Cap – Flemish Pass. The maps are useful tools for advising governance measures, particularly in areas of potential spatial conflict, such as the Flemish Pass. For example, at that site, a proposed project for oil and gas development overlaps with the NAFO fisheries area, VMEs, and areas currently closed to bottom fishing to protect cold-water corals and sponges.
Target audience 	International organisations (e.g. OECD, FAO, UN, RFMOs) that can use the information to guide decision making, as well as scientists, researchers, academics, within and beyond **ATLAS**, with technical expertise that further this research.
Knowledge transfer	**Science to science** ○ Scientific Publications: • Garcia-Alegre et al (2020). Seabed litter distribution in the high-seas of the Flemish Pass area (NW Atlantic). *Scientia Marina*, 84. doi.org/10.3989/scimar.04945.27A • Durán Muñoz et al (2020). Cold-water corals and deep-sea sponges by-catch mitigation: Dealing with groundfish survey data in the management of the northwest Atlantic Ocean high seas fisheries. *Marine Policy*, 116. doi.org/10.1016/j.marpol.2019.103712 ○ Presentations at conference and workshops: • World Conference on Marine Biodiversity, Montreal (Canada), May 2018 • VI International Symposium on Marine Sciences, Vigo (Spain), June 2018 • MARTEC-18 International Conference, Vigo (Spain), May 2018. • ICES Annual Science Conference, Gothenburg (Sweden), September 2019. ICES CM 2019/O:36 • 11th and 12th NAFO Working Group on Ecosystem Science and Assessment (WGESA) meetings, Dartmouth (Canada), November 2018, 2019 bit.ly/2YAvSRN; bit.ly/3baBggW

Knowledge transfer	○ **ATLAS** MSP Webinar, Department of Fisheries and Oceans, March 2020 ○ NAFO Scientific Council Research Documents: • Sacau et al (2020). bit.ly/3d3dWn5 • Durán Muñoz et al. (2020). NAFO SCR Doc. 20/022 Serial No. N7068 ○ Data on VMEs available on PANGAEA and EMODnet for exploitation e.g. doi.pangaea.de/10.1594/PANGAEA.911147 **Science to policy** ○ Contribution to the European Commission's (DG MARE) Provision of Scientific Advice for EU Fisheries Beyond EU waters (e.g. NAFO Joint Commission-Scientific Council Working Group on the Ecosystem Approach Framework to Fisheries Management (WG-EAFFM), Dartmouth (Canada), July 2019. bit.ly/3b3pJ3e **Science to industry** ○ Publications: three articles published in local fisheries magazine, Industrias Pesqueras. industriaspesqueras.com • Durán Muñoz P (2018) Pesquerías profundas y prospección de hidrocarburos en el Atlántico Noroeste: Un ejercicio de Planificación Espacial Marina del proyecto **ATLAS**. *Industrias Pesqueras*, 2123, 48. • Durán Muñoz P (2019) Gestión espacial integral en el Atlántico noroeste: ¿es posible compatibilizar las pesquerías de alta mar, la explotación de hidrocarburos "offshore" y la conservación de los ecosistemas? *Industrias Pesqueras*, 2144, 34-35. • Durán Muñoz P (2020) Industria offshore de hidrocarburos, pesquerías del fletán negro y ecosistemas marinos vulnerables en el área NAFO: Conflictos emergentes y posibles soluciones. *Industrias Pesqueras*, 2156, 50-51. ○ Engagement with NAFO Contracting parties at NAFO Working Group meetings (e.g. WG-EAFFM July 2019) **Science to society** ○ Media coverage: Covered by Spanish National Television, Canal 24h and Lab24 magazine. bit.ly/2SxzjVB ○ Articles in **ATLAS** Project Newsletter, Issue 5 (March 2019) and Issue 7 (February 2020). bit.ly/3fvGuGW ○ Outreach events: European Researchers Night (2018, 2019), Vigo, Spain ○ IEO-Vigo YouTube Channel: youtube.com/watch?v=BSWj-wEwJg8
Impact	**Initial measures of impact (June 2020):** ○ Publications: > 160 reads ○ Newsletter readers: 200 + ○ Audience at conferences and workshops (scientists, managers): 100 + ○ Public engagement: 1300 + **Longer term impact:** ○ Contribution to ocean governance in the NAFO area ○ Contribution to future revisions of EU Fisheries policies ○ Contribution to UN Strategic Development Goal 14: Life below water
Take home message	The results contribute to providing a synoptic perspective on the state of NAFO ecosystems and supporting the implementation of **ATLAS** research in ocean management and governance. This work addresses, for the first time, the issue of seabed litter and current challenges facing MSP in the NAFO Regulatory Area. These include difficulties in assessing cumulative impact, tension between different regulatory frameworks that affect fisheries and hydrocarbon activities in ABNJ, and the lack of an appropriate authority needed to undertake MSP in the high seas.

Next steps	The next steps for this work include applying the methodology to other areas and preparing similar advisory information for other regional management organisations. From a research perspective, **ATLAS** would like to continue this work, including cumulative impact assessments and using these methods to present similar cases in other areas.
Contact and contributors	Pablo Durán Muñoz and Mar Sacau (IEO) ATLAS Partners: IEO
More information	Horizon Results Platform: bit.ly/2NE2UK5


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© Dive of the ROV "LUSO" from the hydrographic ship NRP "Almirante Gago Coutinho". Image from Oceano Azul Foundation taken by Nuno Sá

ATLAS HAS PROVIDED ANSWERS TO SOME OF THE MOST FUNDAMENTAL QUESTIONS ABOUT THE NATURE AND MAKE-UP OF OUR PRECIOUS AND ANCIENT MARINE ENVIRONMENTS, AT A TIME WHEN THEY ARE TRULY UNDER THREAT.

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IMPACT AND LEGACY

Healthy oceans and seas are central to our well-being and economic security. The North Atlantic Ocean harbours biologically rich deep-sea ecosystems that provide provisioning, regulatory and cultural services essential to Atlantic nations. To secure these services for future generations, **ATLAS** has made essential contributions to strengthening our knowledge base, developing innovative tools and applying a basin-scale approach to ocean management. This work is crucial for the North Atlantic's preservation and sustainable exploitation.

The results generated by **ATLAS** have, and will continue to:

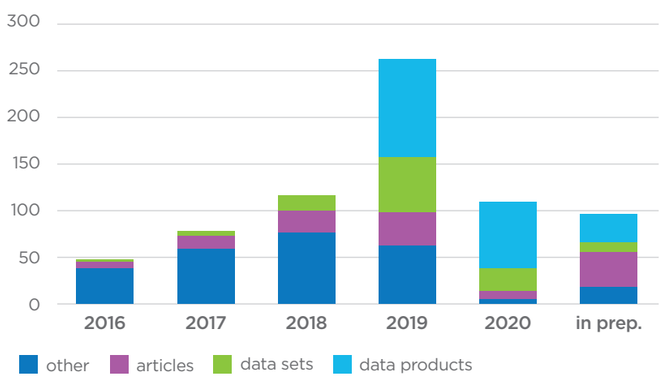
1. **Unlock the potential of resources for the sustainable production of new products and industrial applications through improved management and governance.**
2. **Strengthen cooperation among EU Member States with respect to Atlantic ecosystem-based research, as well as with international partner countries.**
3. **Contribute to the implementation of the EU Integrated Maritime Policy, its environmental pillar the Marine Strategy Framework Directive (MSFD), the Common Fisheries Policy (CFP), the EU 'Maritime Strategy for the Atlantic Ocean Area', and the Galway Statement on Atlantic Ocean Cooperation.**
4. **Contribute to the implementation of international agreements to conserve Vulnerable Marine Ecosystems (VMEs) and Ecologically or Biologically Significant Areas (EBSAs).**

The collective approach to assessing deep-sea Atlantic ecosystems and the commitment to transferring new knowledge to industry and policy partners have been essential aspects of **ATLAS**' work. These activities ensure that **ATLAS** research will have a lasting impact beyond the project's duration.

Ocean science and Ocean Literacy

Europe's Marine and Maritime Research strategy is based on the premise that science and technology are key to sustainable marine economic growth, and the implementation of an ecosystem approach to management. **ATLAS** has been a strong contributor to this strategy, furthering several fields and branches of ocean science, generating 612 research outputs (May 2020) including 85 peer-reviewed publications and 106 data sets that contain new information, observations and measurements on key marine variables, and understanding on past variability and responses (see figure 1 and table 1 below). At the time of writing (June 2020), **ATLAS** had published 96 publications and an additional 105 were in preparation. The team has explored previously unknown areas of the deep Atlantic Ocean and made some of the biggest discoveries in ocean science this decade, including how we understand unprecedented rates of Atlantic Ocean circulation change in the industrial era, describing more than 30 benthic communities and discovering 12 new species. **ATLAS** results support researchers to produce more accurate predictions of marine ecosystems' response to future scenarios.

ATLAS research outputs by years



ATLAS research outputs by type

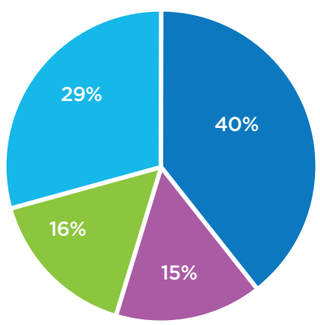


Figure 1: Number of **ATLAS** research outputs published from 2016-2020 including those still in preparation (May 2020). Numbers are separate for peer-reviewed articles, data sets, data products such as georeferenced maps, and "other" research outputs such as deliverables, cruise reports, presentations and posters. Figure adapted from **ATLAS** Deliverable D8.3 (Pesant S, Gafeira J, Collart T and Larkin K, 2020).

Data Type	Research Topic	Parameter Type	Parameters	Methods	Regions	Static Maps	Dynamic Maps
observations	biogeography	biological	1	1	1	1	0
	environmental conditions	biogeochemical	1	1	1	1	1
		geomorphological	7	4	1	2	6
		physical	1	1	1	0	1
	environmental processes	biogeochemical	1	1	1	0	1
	human activity	industry	1	2	1	2	0
modelling	environmental conditions	biogeochemical	4	2	1	4	8
		geomorphological	7	4	6	6	1
		physical	5	14	2	14	6
	environmental processes	biogeochemical	1	2	1	2	2
	habitat suitability	biological	12	4	1	0	48
	habitat distribution	ecological	1	1	5	5	0
	connectivity	biological	1	4	13	42	4
experts assessment	conservation	status	4	2	2	0	4
	human activity	industry	5	5	3	3	4
		research	2	3	3	4	1

Table 1: Summary of **ATLAS** data sets. Table adapted from **ATLAS** Deliverable D8.3 (Pesant S, Gafeira J, Collart T and Larkin K, 2020).

The collective approach of **ATLAS** has also facilitated cooperation amongst Atlantic Ocean researchers through trans-Atlantic initiatives such as ArticNet expeditions, as well as engagement with sister projects (SponGes and MERCES) and connections through the **ATLAS** consortium. The success of **ATLAS**' collaborations will positively impact future Atlantic ecosystem-based research among EU member states and Atlantic nations through a range of initiatives (e.g. iAtlantic).

Contributing to a globally ocean literate society, **ATLAS** initiated a new dialogue with the public and engaged them with the deep ocean. Through innovative education resources, media and communication campaigns, **ATLAS** has reached an estimated 105 million people. The **ATLAS** Educational Outreach portfolio has already been delivered to more than 34,000 people across Europe, been demonstrated to marine educators (European Marine Science Educators Association, Irish Ocean Literacy Network), and further contributes to the Ocean Literacy and Atlantic Action Plan aspects of **ATLAS**' legacy.

Ocean Management and Governance (Industry and Policy)

Supporting the development of adaptive and cross-sectoral management plans for sustainable exploitation and use of marine resource, **ATLAS** conducted the first basin-scale assessment of the North Atlantic Ocean. Transferring the results from this assessment and sharing new information with industrial stakeholders and active engagement with relevant Blue Growth industries (e.g. BP, BMT Cordah, DeepTek, Equinor, Gardline, Hartley Anderson, Irish Offshore Operators Association, Marathon Oil, MEDIN, the Oil and Gas Innovation Centre, Shell, UK Department of Business, Energy & Industrial Strategy), as well as the **ATLAS** Advisory Board, Woodside and Canadian Natural Resources (samples obtained from the North Sea), has ensured the greatest impact of **ATLAS** research and longevity of **ATLAS** legacy.

ATLAS partners developed a strong science-policy interface from the beginning of the project, a key element for successfully informing future ocean governance measures. **ATLAS** results have influenced national, regional, and global level policy discussions, including the EU Integrated Maritime Policy (see figure 2). Implementing the **ATLAS** GeoNode for geospatial data visualisation (with eventual ingestion of data to EMODnet) and curating the **ATLAS** community space on Zenodo have enhanced marine knowledge and the European Commission's vision for "a seamless multi-resolution digital seabed map of European waters by 2020". **ATLAS**' Blue Growth scenario testing has already begun to generate valuable insights as Member States develop and review maritime spatial plans under the MSFD. Furthermore, **ATLAS** revisions to Good Environmental Status assessments support the EU Integrated Maritime Policy, under the MSFD. Knowledge generated by **ATLAS** on the contribution of cold-water

corals to biogeochemical cycles highlight the importance of commitments to protect Vulnerable Marine Ecosystems (VMEs) and support the MSFD and Regional Fisheries Management Organisations (RFMOs). **ATLAS** has also developed useful tools that can be used by RFMOs to identify areas where VMEs are likely to occur.

ATLAS data contributed to the description of six features that meet the criteria of Ecologically or Biologically Sensitive Areas (EBSAs) during the Convention on Biological Diversity's Northeast Atlantic EBSA workshop (September 2019, Stockholm). Other **ATLAS** contributions to international policy include presentations of **ATLAS** results to delegates at the UN Intergovernmental Conferences on developing international legally binding instruments for the conservation and sustainable use of marine biological diversity of Areas Beyond National Jurisdiction.

POLICY LEGACY

NATIONAL	REGIONAL	GLOBAL
UK Sustainable Seas Inquiry	EU Integrated Marine Policy	BBNJ negotiations
Canadian EBSAs	EU MSFD	CBD EBSA Process
Azores MPA conservation targets	EU MSP Directive	2013 Galway Statement
	EU Common Fisheries Policy	ISA Mining Code
	Regional Fisheries Management	

Figure2: ATLAS' Policy Legacy. Figure adapted from ATLAS Deliverable D7.8 (Turner and Johnson, 2020).

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LOOKING FORWARD

The United Nations has proclaimed a **Decade of Ocean Science for Sustainable Development (2021-2030**) to support efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide. As we approach this Decade and responding to the UN's call, the **ATLAS** project shares these key messages and makes the following recommendations:

1. Deep-sea observations: Large-scale ocean exploration and management, as well as detailed deep-sea ecosystem studies require large volumes of high-quality observational data. **ATLAS** collaborations, for example with the Overturning in the Subpolar North Atlantic Program (OSNAP), have supported the collection of new and long-term measurements in areas where previously there were none. These measurements have revealed the true processes determining variability in Atlantic Ocean circulation patterns, contributing to fundamental baseline oceanography, and highlighting the importance of such observations. There is a need for coordinated systematic observation programmes (e.g. EOOS, GOOS) and research expeditions to support future deep-sea observations that underpin ocean science. As exemplified by the **ATLAS** approach, it is critically important that such coordinated observation programmes are strongly linked to ecological assessments and an improved understanding of the basic biology of key species. For example, substantial efforts are needed to understand the larval biology of deep-sea organisms so truly representative models can be built of their dispersal and connectivity.

2. Limitations and accuracy of past and future models: **ATLAS** partners have found spatial and temporal scale issues with current climate models and identified knowledge gaps. Changes in North Atlantic Circulation are linked to increased greenhouse gas emissions and subsequent climate forcing. Using combined modelling approaches and palaeo reconstructions, **ATLAS** has improved our capacity to model future climate scenarios and highlighted limitations of past models. Past inaccuracies need to be recognised and new approaches incorporated into future climate scenarios. New models combining hydrodynamics and animal physiology are an effective tool to predict coral and sponge distribution, biomass and metabolic activity. In addition, species-specific connectivity models need to be considered as cold-water corals that have seemingly similar ecological roles can still differ in dispersal ability. **ATLAS** has shown that larval behaviour has a greater impact on connectivity than ocean current circulation in the North Atlantic, and that the lack of such behavioural data remains a key knowledge gap. Interactive effects of climate change that affect species survival (e.g. impact on food supply) need to be considered and should be prioritised for future research priorities. Finally, models that aggregate complex spatial information (e.g. by incorporating ecosystem connectivity metrics, habitat suitability models and the VME Index) can provide useful inputs to decision making processes, and should be used as tools to inform these processes.

3. Establishing Good Environmental Status (GES) in the deep sea: Climate change will affect GES in the deep sea, with changing environmental conditions leading to shifts in species distributions and loss of suitable habitat. Assessing GES in the deep sea is challenging but essential for establishing monitoring programs and developing robust ocean governance measures. **ATLAS** has proposed a new definition of GES, that better addresses the specific characteristic of the deep sea, as well as a set of the most suitable indicators and threshold values for each indicator to appropriately assess GES in the deep sea. Future GES assessments should be carried out at habitat and ecosystem level (rather than species level) and at large spatial and temporal scales. These recommendations should be applied to future revisions of the European Commission's Marine Strategy Framework Directive (MSFD) and could constitute a basis for deep-sea assessments, including in Areas Beyond National Jurisdiction (ABNJs).

4. Shaping and unifying future research and policy initiatives in the Atlantic deep sea: To ensure sustainable Blue Growth, there is a need for policy initiatives that focus on safeguarding biodiversity and the multitude of ecosystem services provided by the deep sea, in addition to basin-scale Maritime Spatial Planning that minimises conflict. With many Blue Economy sectors anticipated to expand their activities by 2030, managing the cumulative impact of human activities (including climate change) is crucial for safeguarding biodiversity and other deep-sea ecosystem services. **ATLAS** has shown the importance of considering these services for future Blue Growth, Marine Spatial Planning in the deep sea, as well as the development of future frameworks designed to manage and conserve ecosystems and the services they provide. Monetary valuations are one tool that can identify some of the benefits from ecosystem services. **ATLAS** has also identified limitations in the functionality of current Area-Based Management Tools (ABMTs). There is a need for more complete impact assessments; however, creating a network to use current ABMTs in the North Atlantic could be a starting point to support short-term conservation efforts, and to inform future conservation priorities.

5. Engaging with public stakeholders and models for communication and knowledge transfer: The public are legitimate stakeholders, with rights, responsibilities and obligations, who need to be involved in marine stewardship and governance. **ATLAS** has shown that, despite much of the public being unfamiliar with deep-sea ecosystems, there is societal support for new management plans that aim to improve environmental health and quality. The public's support and recognition of a need to protect deep-sea ecosystems reinforces the importance of Ocean Literacy efforts over the last decade, the continued need to engage with public stakeholders and for researchers to implement knowledge transfer of their results. There is a need to include the public's preferences and valuation into the conservation discussion related to the deep sea, and to align this with scientific efforts to secure biodiversity conservation across large marine spatial areas. Combining scientific efforts with management efforts and achieving successful and measurable transfer of research results can only be achieved if results are adopted and exploited by relevant end users, which requires a revision of current scientific communication models.

BY INCREASING HUMANITY'S UNDERSTANDING OF THE DEEP ATLANTIC, ATLAS HAS THE WELL-BEING, PROSPERITY, AND SECURITY OF OUR WORLD AT ITS HEART.

GLOSSARY

ABMT Area Based Management Tool

ABNJ Areas Beyond National Jurisdiction

AMOC Atlantic Meridional Overturning Circulation

AORA Atlantic Ocean Research Alliance

BG Blue Growth

CBD Convention on Biological Diversity

CICES Common International Classification of Ecosystem Services

CWC Cold-Water Coral

DWS Deep-Water Sponge

EBSA Ecologically or Biologically Significant Areas

ESS Ecosystem Summary Sheets

FAO Food and Agriculture Organization

GFCM-FAO General Fisheries Commission for the Mediterranean

GES Good Environmental Status

ICES International Council for the Exploration of the Sea

ILBI International Legally Binding Instrument

IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services

IPCC Intergovernmental Panel on Climate Change

ISA International Seabed Authority

JNCC Joint Nature Conservation Committee

MESMA Monitoring and Evaluation of Spatially Managed Areas

MPA Marine Protected Area

MSFD Marine Strategy Framework Directive

MSP Maritime Spatial Planning

NAFO Northwest Atlantic Fisheries Organization

NEAFC North-East Atlantic Fisheries Commission

NEAT Nested Environmental status Assessment Tool

OECD Organisation for Economic Co-operation and Development

OL Ocean Literacy

OSNAP Overturning in the Subpolar North Atlantic Program

OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic

RFMO Regional Fisheries Management Organisations

ROV Remotely Operated Vehicle

SDM Species Distribution Model

SDG Sustainable Development Goal

TEEB The Economics of Ecosystems and Biodiversity

UN United Nations

VME Vulnerable Marine Ecosystem

WGDEC Working Group on Deep-water Ecology

WGEAFFM Working Group on the Ecosystem Approach Framework to Fisheries Management

WGESA Working Group on Ecosystem Science and Assessment

WGFBIT Working Group on Fisheries Benthic Impact and Tradeoffs

WGMPCZM Working group on Marine Planning and Coastal Zone Management

WKEUVME Workshop on EU regulatory area options for Vulnerable Marine Ecosystem Protection

WKREG Stakeholder Workshop to Disseminate the ICES Deep-Sea Access Regulation Technical Service, and Scope the Required Steps for Regulatory Purposes

WKTRADE2 Workshop on Trade-Offs Scenarios between the Impact on Seafloor Habitats and Provisions of catch/value

RESOURCES AND LINKS

ATLAS publications

ATLAS partners have published 96 new research articles to date (June 2020), with 105 more currently in preparation or in press. All **ATLAS** publications are open access and a full list of articles can be found on the **ATLAS** website: **eu-atlas.org/resources/atlas-library#Publications**

ATLAS deliverables

All **ATLAS** project deliverables, which have been approved by the European Commission and are not confidential, are available on the **ATLAS** website **eu-atlas.org/resources/atlas-library#deliverables**

ATLAS submissions to the Horizon Results Platform

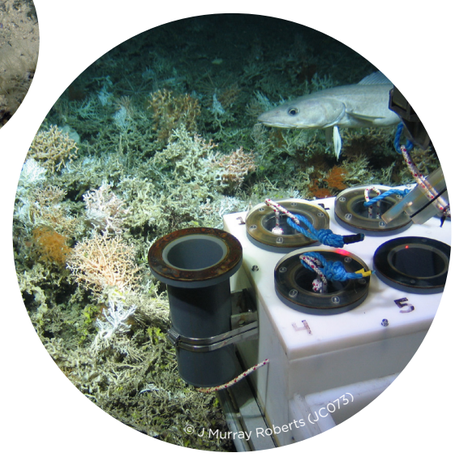
ATLAS has submitted 18 results to the European Commission's Horizon Results Platform (June 2020). All results are available from the EC Funding & tender opportunities portal and a list of results can be found on the **ATLAS** website **eu-atlas.org/resources/horizon-results-platform**

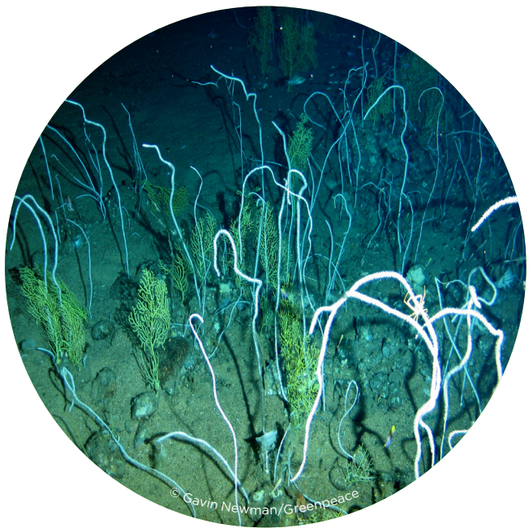
ATLAS communication and outreach resources

- **ATLAS** newsletters: **eu-atlas.org/news/browse-previous-newsletters**
- **ATLAS** factsheet in English, Dutch, Spanish, Portuguese: **eu-atlas.org/resources/public-documents**
- **ATLAS** brochure: **eu-atlas.org/resources/public-documents/215-atlas-brochure**
- **ATLAS** outreach resources: **eu-atlas.org/education/public-engagement**
- **ATLAS** education packs: **eu-atlas.org/education/education-packs**
- **ATLAS** augmented reality colouring sheets: **eu-atlas.org/education/spectacular-colouring-pages**
- **ATLAS** animal flow chart: **eu-atlas.org/education/which-deep-sea-creature-are-you**

ATLAS data

- Geospatial data on the **ATLAS** GeoNode: **atlas-horizon2020.eu**
- **ATLAS** on the European Directory of Marine Environmental Research Projects (EDMERP): **edmerp.seadatanet.org/report/12416**
- **ATLAS** on European MSP Platform: **msp-platform.eu/projects/eu-atlas-trans-atlantic-assessment-and-deep-water-ecosystem-based-spatial-management**
- Data ingestion to EMODnet (expected completion: July 2021) **emodnet.eu**





NEW DEEP-SEA SPECIES

ATLAS has contributed to the identification of at least 12 new or putative new species and 35 new records at the **ATLAS** case study 7: Gulf of Cádiz, Strait of Gibraltar, Alborán Sea, case study 8: Azores and case study 10: Davis Strait, Eastern Arctic. The table below outlines confirmed new records as of June 2020, however additional descriptions are expected.

More information: ATLAS Deliverable 3.3 **bit.ly/2WKZL0i** | **bit.ly/38uowlK** | **bit.ly/3dWsfK0** | **Contact Person:** Telmo Morato IMAR-UAz, Marina Carreiro-Silva, IMAR-UAz | José Rueda, IEO| Ellen Kenchington, DFO.

ATLAS CASE STUDY 7: GULF OF CÁDIZ	
New records	*Veleropilina reticulata* (Seguenza, 1876); *Akritogyra conspicua* (Monterosato, 1880); *Chauvetia balgimae* (Gofas & Oliver, 2010); *Narrimania concinna* (Sykes, 1925); *Dentimargo auratus* (Espinosa, Ortea & Moro, 2014); *Ringicula gianninii* (Nordsieck, 1974); *Pyrgulina stefanisi* (Jeffreys, 1869); *Draculamya porobranchiata* (Oliver & Lützen, 2011); *Reteporella mediterranea* (Hass, 1948); *Reteporella pelecanus* (López de la Cuadra & García-Gómez, 2001); *Jubella enucleate* (Jullien, 1882); *Schizomavella linearis profunda* (Harmelin & d'Hondt, 1992); *Herentia thalassae* (David & Pouyet, 1978); *Palmiskenea gautieri* (Madurell, Zabala, Dominguez-Carrió & Gili, 2013).
New species	*Onoba goyensis* (Utrilla, Urra & Gofas, 2020); *Myonera atlasiana* (Utrilla, Rueda & Salas, 2020); *Reteporella victori* (Ramalho, López-Fé & Rueda, 2018); *Antropora gemarita* (Ramalho & López-Fé, 2020); *Microporella funbio* (Ramalho & López-Fé, 2020).
ATLAS CASE STUDY 7: ALBORÁN SEA	
New records	*Veleropilina euglypta* (Dautzenberg & Fischer, 1897); *Anatoma micalii* (Geiger, 2012); *Terminoflustra baleei* (Busk, 1860); *Marguetta pulchra* (Jullien, 1903); *Schizomavella linearis profunda* (Harmelin & d'Hondt, 1992).
New species	*Mitrella templadoi* (Gofas, Luque & Urra, 2019); *Buskea medwavesae* (under review).
ATLAS CASE STUDY 8: AZORES	
New records	*Corallium tricolor* (Johnson, 1899); *Iridogorgia magnispiralis* (Watling, 2007); *Paramuricea biscaya* (Grasshoff, 1977).
New species	*Zibrowius primnoidus* comb. nov. associated with *Callogorgiaverticillata*; *Zibrowius alberti* sp. n. associated with *Paracalyptrophora josephinae* and *Dentomuricea aff. Meteor*; *Hurlizoanthus hirondelleae* sp. n. associated with *Candidella imbricate; Parazoanthus aliceae* sp. n. associated with stylasterid *Errina dabneyi*; *Epizoanthus martinsae* sp. n. associated with antipatharian *Leiopathes* sp.
ATLAS CASE STUDY 10: DAVIS STRAIT, EASTERN ARCTIC	
New records	*Lophelia pertusa* (Linnaeus, 1758); *Exidmonea atlantica* (Forbes in Johnston, 1847); *Turbicellepora boreale* (Hayward & Hansen, 1999); *Polymastia grimaldii* (Topsent, 1913); *Polymastia thielei* (Koltun, 1964); *Polymastia mamillaris* (Müller, 1806); *Polymastia andrica* (de Laubenfels, 1949); *Spinularia sarsi* (Ridley & Dendy, 1886); *Sphaerotylus capitatus* (Vosmaer, 1885); *Stelletta normani* (Sollas, 1880); *Stryphnus fortis* (Vosmaer, 1885); *Chonelasmachoanoides* (Schulze & Kirkpatrick, 1910); *Mycale* (Mycale) *loveni* (Fristedt, 1887).

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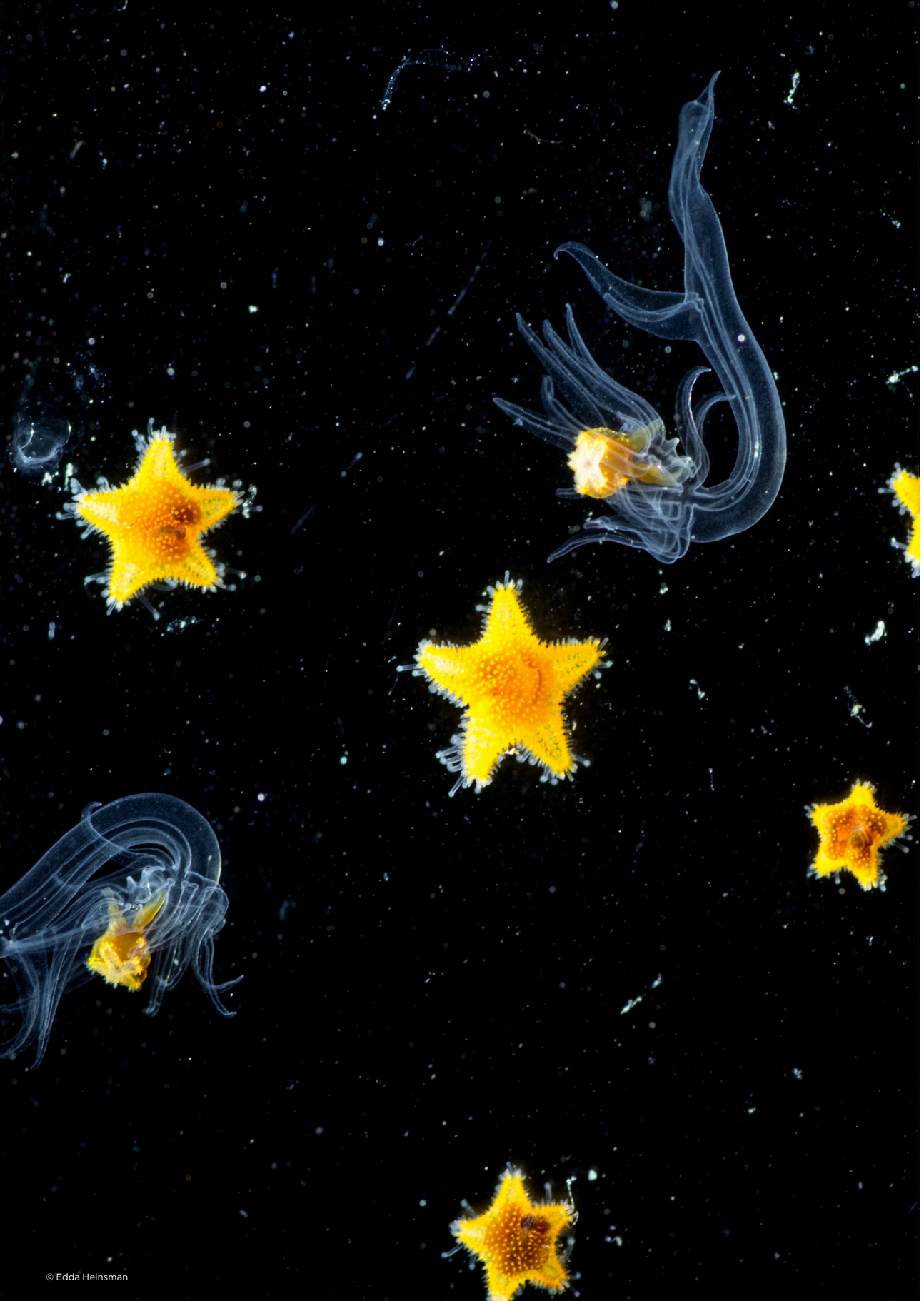

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UNDERSTANDING DEEP ATLANTIC ECOSYSTEMS

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