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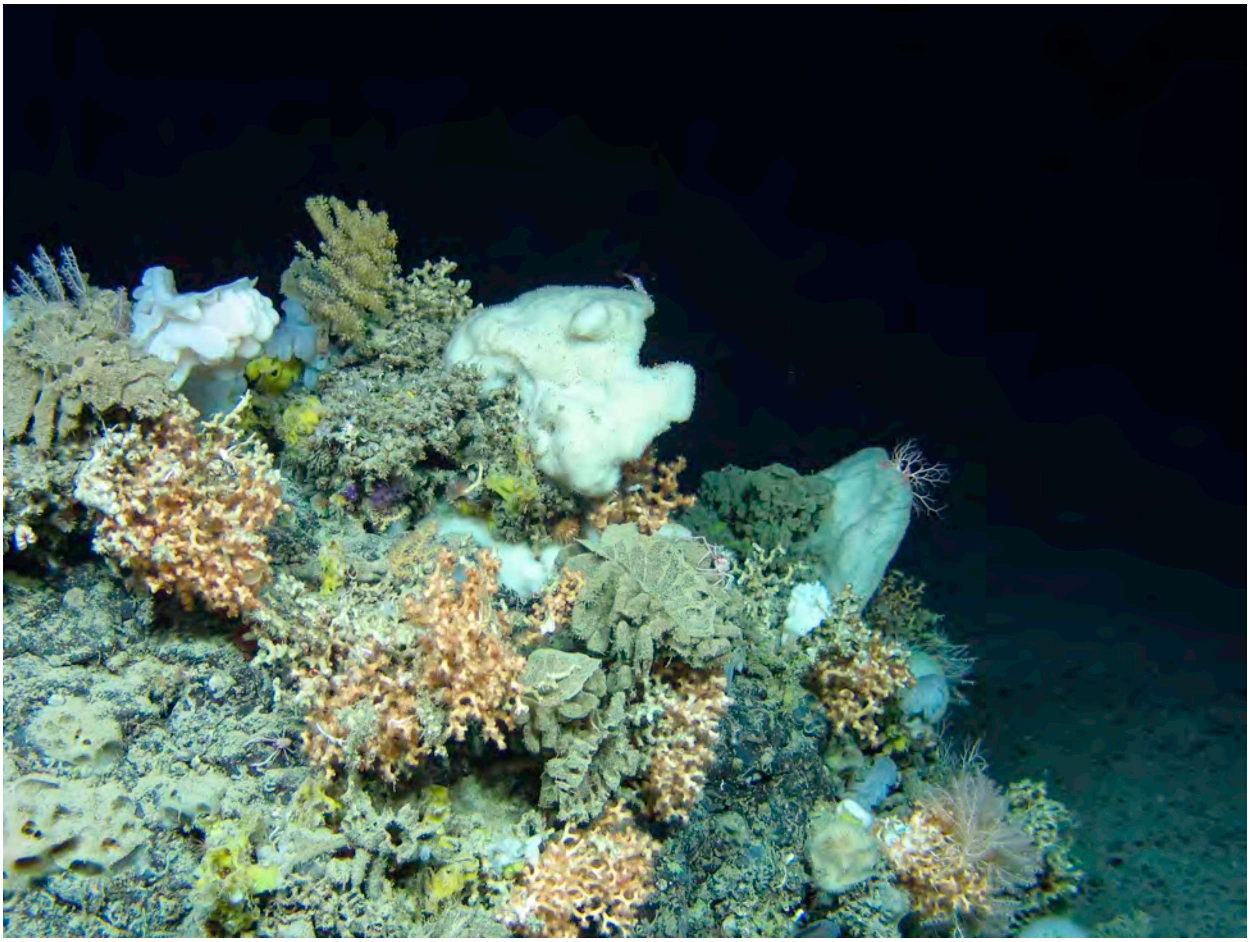
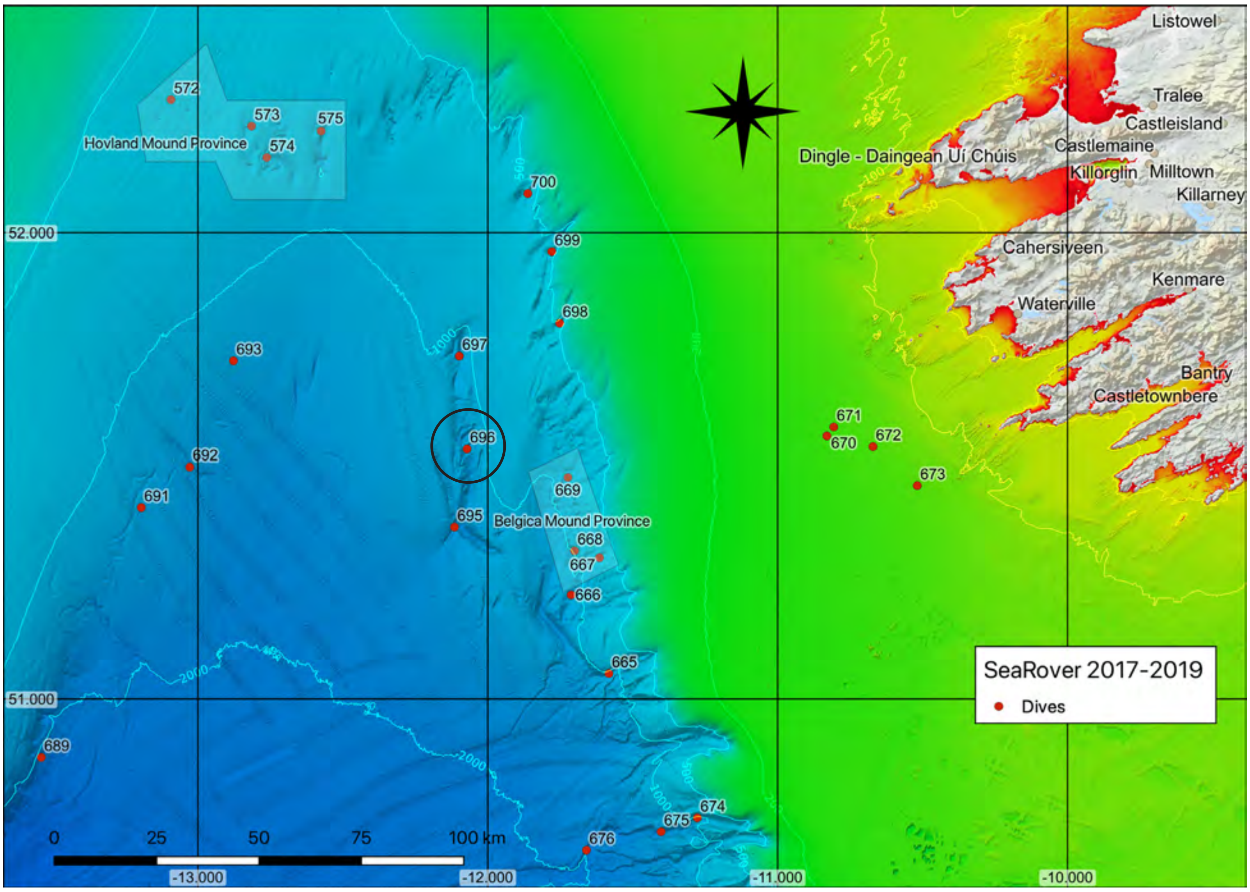


Dive 696 - 19-08-2019. Description: Rich geogenic reefs including mud, pebble field and boulders hosting various and abundant epifauna. -12.07757983, 51.54346883, -1255.5 m.



Sensitive Ecosystem Assessment and ROV Exploration of Reef (SeaRover) Synthesis Report

Authors

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Commissioned by Marine Institute, Rinville, Oranmore, Co Galway

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This work was commissioned as part of extensive offshore reef survey of Ireland's Northwest Continental margin delivered by the Marine Institute in partnership with the National Parks and Wildlife Service (NPWS), funded by the European Maritime and Fisheries Fund (EMFF), and coordinated and led by INFOMAR (Integrated Mapping for Sustainable Development of Ireland's Marine Resources).

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INFOMAR
Integrated Mapping for the Sustainable Development of Ireland's Marine Resource

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann
An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

An Roinn Comhshaoil, Aeráide agus Cumarsáide
Department of the Environment, Climate and Communications

An Roinn Tithíochta, Rialtais Áitiúil agus Oidhreachta
Department of Housing, Local Government and Heritage

MERC Consultants
environmental and conservation services

Executive Summary

A requirement exists to quantify the abundance and distribution of offshore biogenic and geogenic reef habitats in Irish waters to fulfil Ireland's legal mandate and to generate baseline data from which appropriate monitoring systems can be established. To address this an extensive offshore reef survey of Ireland's continental slope was commissioned by the Marine Institute in partnership with the National Parks and Wildlife Service (NPWS), funded by the European Maritime and Fisheries Fund (EMFF), and coordinated and led by INFOMAR (Integrated Mapping for the Sustainable Development of Ireland's Marine Resources).

The objectives of the survey were to implement the EMFF's Marine Biodiversity Scheme - Natura Fisheries, by mapping offshore reef habitats with a view to protecting them from deterioration due to fishing pressures. The reef project aligns with sub-article 6.2 of the Habitats Directive (EC 92/43/EEC) which requires member states to take measures to avoid deterioration of protected habitats.

The Sensitive Ecosystem Assessment and ROV Exploration of Reef (SeaRover) survey took place between 2017 to 2019. The 2017 and 2018 surveys took place onboard the ILV *Granuaile* whilst the third survey leg in 2019 employed the Marine Institute's RV *Celtic Explorer.* The Marine Institute's remotely operated vehicle (ROV) *Holland I* was used for each of these cruises. The *Holland I* was equipped with a high-definition (HD) camera, various composite video feeds and a robotic arm for sample collection.

The primary aim of the survey was to map the distribution and abundance of biogenic and geogenic reef habitat along Ireland's continental margin using HD video.

Survey transects were pre-selected following a consultation process between the Marine Institute and the National Parks and Wildlife Service. Selection criteria included depth range, areas of highly sloping terrain, geographical spatial discreteness, historical fishing activity, historical scientific studies and the presence or absence of certain target geomorphological features which included, canyons and canyon walls, gullies, escarpments, ridges, carbonate mounds and cobble fields.

A total of 154 transects were surveyed, the locations of the transects are shown in Figure 16. The findings of the SeaRover survey will contribute to the establishment of site specific conservation objectives for the offshore Special Areas of Conservation (SAC) for NPWS. The survey recorded 553 Vulnerable Marine Ecosystems (VMEs) (Table 7). The locations of these VMES are shown in Figure 75. The findings will contribute to the Department of Agriculture, Food and Marine (DAFM) obligation to map Ireland's vulnerable fisheries resources.

SeaRover surveyed just the continental slope and not the extensive areas of level seabed making up the continental shelf, nor the abyssal seabed below -3000 m depth, nor the Rockall Bank outside Ireland's Exclusive Economic Zone (EEZ) but within Ireland's continental shelf territory. Ireland's area of continental slope targeted by SeaRover (-540 to -2600 m depth) was calculated as approximately 94456 km^2, SeaRover surveyed 0.91 km^2 which is 0.00096% of this area. This is an indication of the amount of Ireland's offshore area that remains relatively unexplored. The survey data acquired improves our understanding of the distribution and ecological requirements for these vulnerable ecosystems and can be used in combination with detailed bathymetric data to predict the likely extent of these ecosystems and help support the sustainable management of Ireland's valuable and vulnerable marine resources. The survey data establishes the need to build on what has been collected to date, and in conjunction with detailed bathymetric data, will help target future mapping of reef habitat.

The SeaRover data will ensure the availability of comprehensive biological baseline datasets which will be critical to the formulation of future policy on the management, monitoring and conservation of Ireland's deep-water ecosystems.

Below is a summary of the main findings of the SeaRover Survey.

Occurrence of Coldwater Reef/Non-reef

- 89 dives (58%) encountered reef habitats
- 78 dives encountered geogenic reef
- 47 dives encountered biogenic reef
- 65 dive sites (42%) hosted neither biogenic nor geogenic reef.

Diversity

491 putative species were identified from HD video footage supplemented by high resolution imagery (using an operational taxonomic unit (OTU) system as it is often not possible to identify fauna to species level)

- Dive 488/Transect 20 was the most diverse with 137 OTUs
- 49 OTUs were identified on the average dive
- Only 7 OTUs were found in more than half of the transects
- 65 OTUs were found in only one transect

Biotopes

139 biotopes and potential biotopes were identified in line with the Marine Habitat Classification for Britain and Ireland (MHCBI, v.15.03), of which:

- 85 are existing biotopes, un-altered from the MHCBI listing
- 10 are minor variants of existing biotopes
- 44 are potential new biotopes, or variants which may warrant becoming new child biotopes

Conservation targets

147 dives encountered conservation listed habitats, being either an International Council for the Exploration of the Sea (ICES) Vulnerable Marine Ecosystem, and/or an OSPAR Threatened and/or Declining Habitat

- 111 Mud & sand emergent fauna
- 69 Coral gardens
- 17 Deep sea sponge aggregations
- 35 Coral reefs
- 35 dives encountered conservation listed species (ICES/IUCN)

Two conservation listed species were encountered repeatedly:

- 26 dives encountered *Hoplostethus atlanticus* (Orange Roughy) including one dive where they were aggregated and abundant (D464B/T18)
- 17 dives encountered *Centrophorus squamosus* (Leafscale Gulper Shark)

Seabed Pressures

The SeaRover survey recorded the presence and category of marine litter. The majority of non-fishing gear and fishing gear was found in the NW sector of the continental slope. The most commonly recorded gear was nylon gill nets and long lines, but trawl nets were also observed. On the continental slope adjacent to Ireland the SeaRover survey covered approximately 0.76 km^2 of seabed, this area between -540 to -2600 m was calculated to be 88267 km^2 (just over 0.0009% was surveyed visually by SeaRover)(Table 6). SeaRover observed discarded fishing gear on 42 dives within this area. Based on these figures, if the entire area of the continental slope was surveyed it is estimated that there would be more than 4 million encounters with lost fishing gear.

Testing predictive models for coral and sponge distribution

The SeaRover survey collected data to ground truth published models of habitat suitability for *Lophelia* reef and the bird's nest glass sponge *Pheronema carpenteri* (Ross & Howell, 2013). The models' predicted distribution was shown relative to where they were recorded by SeaRover. The model was mostly accurate at predicting the distribution of the cold water coral *Lophelia*. The ground truthing of the bird's nest glass sponge *Pheronema carpenteri* gave more mixed results. Whilst *Pheronema* was recorded at two of the predicted sites, it wasn't observed at two of the sites where it was predicted to occur and was present at a number of sites where the model had not predicted it.

Observations of note for the individual cruises

2017

The pigtail coral, *Radicipes* cf *gracilis*, has only rarely been recorded in the Rockall Trough, but was encountered on 7 SeaRover dives, and was twice encountered in loose aggregations (D467/T22, D469/T23).

Solenosmilia variabilis reefs were encountered as deep as 1757m (on D458/T43).

The community found on D453/T5 included many species that were either not encountered again, or that were found only rarely on other dives (e.g. the bamboo coral *Keratoisis* sp. OTU1157 (a fine, branched morphotype), was common on this dive but never encountered again). This dive offered the most unique community, probably due to being one of only a very few dives below 2000m on hard substratum. There were also multiple elasmobranch egg cases encountered here suggesting that this mound may be a nursery area.

2018

Cauliflower coral *Drifa glomerata* was recorded on 3 dives (D487, D491, D572), these observations represent the first records of this species from Ireland. The Global Biodiversity Information Facility shows records of this species from the northwest Atlantic from Greenland and as far south as off the coast of Connecticut and from the coasts of Sweden, Norway and the Russian Federation.

The Atlantic boreo-arctic deep sea sponge *Stryphnus fortis* was encountered on 3 SeaRover dives (D575/PB21, D531/RB06, D545/RB30), and once with the epibiont sponge *Hexadella dedritifera*. This is the first record of *S. fortis* in the Rockall and Porcupine Bank.

Sub-fossil corals were encountered for the first time in the Rockall and Porcupine Bank. They were found in 3 SeaRover dives (D557/PB17, D559/PB27, D564/PB16) between 2070 and 2700 m depth.

A large school of blackmouth catsharks (*Galeus melastomus*) was found around thousands of elasmobranch egg cases in 1 SeaRover dive (D573/PB23). Egg cases were found on dead coral rubble and no juveniles were observed.

The most epifaunally diverse dive was the D538/RB15 at 900 m depth. The community included many species of sponges (e.g. *Asconema*, *Phakellia ventilabrum* and *Aphrocallistes* sp.) and coral gardens (including colonies of *Lophelia* and *Madrepora oculata*) on hard substrata.

D567 The pink frogmouth, *Chaunax pictus*, is a deep sea anglerfish that is found around the world on continental shelves in tropical and temperate waters, at depths of between 200 and 660 m. It was found at Dive 567 on the outer side of Porcupine Bank at a depth between 794 – 946m. According to the Global Biodiversity Information Facility, this is the furthest north this species has been found and is only the second time it has been recorded from Ireland.

2019

Two shipwrecks on the NW of the Porcupine Seabight were observed (D670/T20 and D671/T21). Attempts to identify the shipwrecks using the National Monuments Service are presented in this report. Noteworthy, GPS locations are yet to be confirmed and further investigation is required to report the shipwrecks visits to the official authorities.

In D696/T13, the ROV and science team on watch attempted to circumnavigate a large boulder with geogenic reef habitat for potential use in photogrammetry.

The most epifaunally diverse dive was the D696/T13 at 1200 m depth. The community included many species of sponges and coral gardens (including colonies of *Solenosmilia variabilis*) on hard substrata.

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List of acronyms

AFM	Department of Agriculture, Food and the Marine
AUV	Autonomous Underwater Vehicle
BIM	Bord Iascaigh Mhara
BSI	Back Side Illuminated
CBD	Convention on Biological Diversity
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CFP	Common Fisheries Policy
CTD	Conductivity Temperature Depth
CWR	Cold Water Reef
DNA	Deoxyribonucleic Acid
EEZ	Exclusive Economic Zone
EMODnet	European Marine Observation and Data Network
EMFF	European Maritime and Fisheries Fund
FAO	Food and Agriculture Organisation
FEAS	Fisheries Ecosystem Advisory Services
GAPS	Global Acoustic Positioning System
GBIF	Global Biodiversity Information Facility
GEBCO	General Bathymetric Charts of the Ocean
GES	Good Environmental Status
GIS	Geographic Information System
GMIT	Galway Mayo Institute of Technology
GPS	Global Positioning System
GSI	Geological Survey of Ireland
HDTV	High Definition Television
HERMES	Hotspot Ecosystem Research on Europe's Deep Water Margins
HERMIONE	Hotspot Ecosystem Research and Mans Impact on European Seas
ICES	International Council for the Exploration of the Sea
ILV	Irish Lights Vessel
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Marine Resource
INSS	Irish National Seabed Survey
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservancy Committee
MI	Marine Institute
MESH	Mapping European Seabed Habitats
MHCBI	Marine Habitat Classification for Britain and Ireland
MNCR	Marine Nature Conservation Review
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NBDC	National Biodiversity Data Centre
NMEA	National Marine Electronics Association
NOCS	National Oceanographic Centre Southampton
NPWS	National Parks and Wildlife Service
NUIG	National University of Ireland, Galway
OBIS	Ocean Biodiversity Information System
OFOP	Ocean Floor Observation Protocol
OSPAR	Oslo Paris Convention
OTU	Operational Taxonomic Unit
PC	Personal Computer
PI	Principal Investigator
PSA	Particle Size Analysis
QA	Quality Assurance
RFMO	Regional Fisheries Management organisations
ROV	Remote-Operated Vehicle
RV	Research Vessel
SAC	Special Area of Conservation
SACFOR	Abundance scale – Super-abundant, Abundant, Common, Frequent, Occasional, Rare
SBE	Sea-Bird Scientific equipment
SeaRover	Sensitive Ecosystem Assessment and ROV Exploration of Reef
SEA	Strategic Environmental Assessment environmental report
SEM	Scanning Electron Microscopy
SQL	Structured Query Language
SSMBLG	Submarine Structures Made By Leaking Gas
SWAN	Sustainable Water Network
TDWG	Taxonomic Data Working Group
UCC	University College Cork
UCD	University College Dublin
UNGA	United Nations General Assembly
USBL	Ultra-Short Baseline
UTC	Universal Time Code
VME	Vulnerable Marine Ecosystem
VMS	Vessel Monitoring System
WGDEC	Working Group on Deep-water Ecology

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1. Introduction

1.1 Background

Exploration leads to discovery – in 1869 the Royal Society commissioned the paddle steamer HMS *Porcupine* to survey the deep-water to the west of Ireland to investigate whether life could exist on the deep ocean floor. At the time the widely held belief was that organisms could not survive below 550 m.

The HMS *Porcupine* both discovered and gave her name to the Porcupine Bank.

During the cruise led by naturalist J Gwyn Jeffreys the crew of the Porcupine collected animals from as deep as 3000m to the west of the Porcupine Bank. Amongst the organisms that were dredged up was the cold-water coral *Lophelia pertusa* (now often called *Desmophyllum pertusum* - we have followed the opinion of Cairns (2019) and retained the use of *Lophelia pertusa* throughout this review for clarity and readability) and giant foraminera (presumably the Xenophyophore *Syringammina fragilissima*). This was a revolutionary discovery at the time, overturning the azoic theory proposed by Edward Forbes and David Page who had hypothesised that life could not exist below 550 m due to the great pressure. The results of this expedition were published in the first volume of the prestigious scientific journal Nature.

It was concluded that life must exist everywhere on the ocean floor. Following from this discovery, the now famous *Challenger* expedition (1872–1876) was organised.

In 1885 the Royal Irish Academy appointed a committee to study the marine fauna within the 100 fathoms contour (-185 m) off southwest Ireland. This was subsequently extended to 1800 m depth (Gordon 2003). Between 1901–1926 there were a series of cruises conducted by Fisheries Ireland Scientific Investigations which explored some of the deep-water habitats off the west coast of Ireland. These were some of the earliest deep-water explorations in the NE Atlantic and led to the discovery of a large number of species that were new to science and are an important part of Ireland's scientific and cultural history.

A short article detailing a fisheries investigation of the Porcupine Bank is inluded in the Sea fisheries report for 1901. It includes a report of steam trawlers fishing Porcupine Bank "with some success".

Jane Stephens (1921) described a number of sponge species that were new to science, most of which were found growing on *Lophelia* dredged in deep-water off the west and southwest coasts of Ireland.

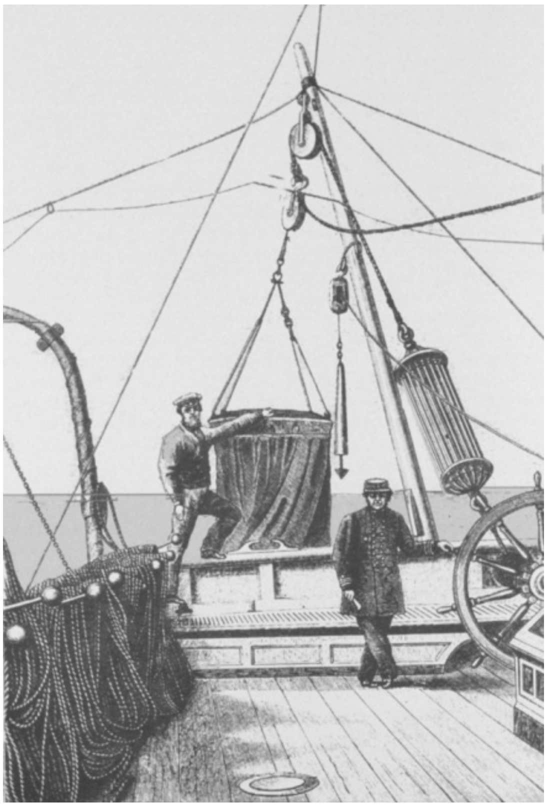


Figure 1. Using the Hodges shock absorber in order to bring a dredge trawl back aboard HMS Porcupine. (C. Wyville Thomson, public domain https://commons.wikimedia.org/wiki/File:HMS_Porcupine_(1844).jpg)

There was very little further research of Ireland's deep-water habitats until the latter half of the 20th century when there was an increase in oceanographic and fisheries research as well as exploration for oil and gas. Various technological advances greatly enhanced our ability to both explore and exploit deep-sea resources. The age of deep-sea exploration had led to a much greater awareness of these diverse and vulnerable habitats and of evidence of the significant threats and pressures they face. In 2004, a general recognition of the degraded state of our oceans and the range of threats to marine ecosystems led to the Convention on Biological Diversity with the aim of identifying and preserving a representative selection of marine habitats through the establishment of a network of marine protected areas (MPAs) (Secretariat of the Convention on Biological Diversity, 2004).

1.2 New knowledge needs

In 2006 the United Nations General Assembly (UNGA) Resolution 61/105 (UNGA, 2007) called on regional fisheries management organisations (RFMOs) to identify areas where vulnerable marine ecosystems (VMEs) occur, or are likely to occur, based on available scientific data, and to prevent significant adverse impacts to these species by activities under their jurisdiction. In 2009, this need was reiterated with increased urgency and UNGA Resolution 64/72 called on states to implement protective measures immediately (Food and Agriculture Organisation of the United Nations (FAO); UNGA, 2009). In 2011, an international workshop reviewing the impact of deep-sea fisheries on VMEs and the implementation of UNGA Resolutions concluded that there had been a failure by RFMOs to collect the necessary data for environmental impact assessments, that many areas where VMEs are likely to occur were still being fished and the precautionary principle was not being implemented (Weaver et al., 2011).

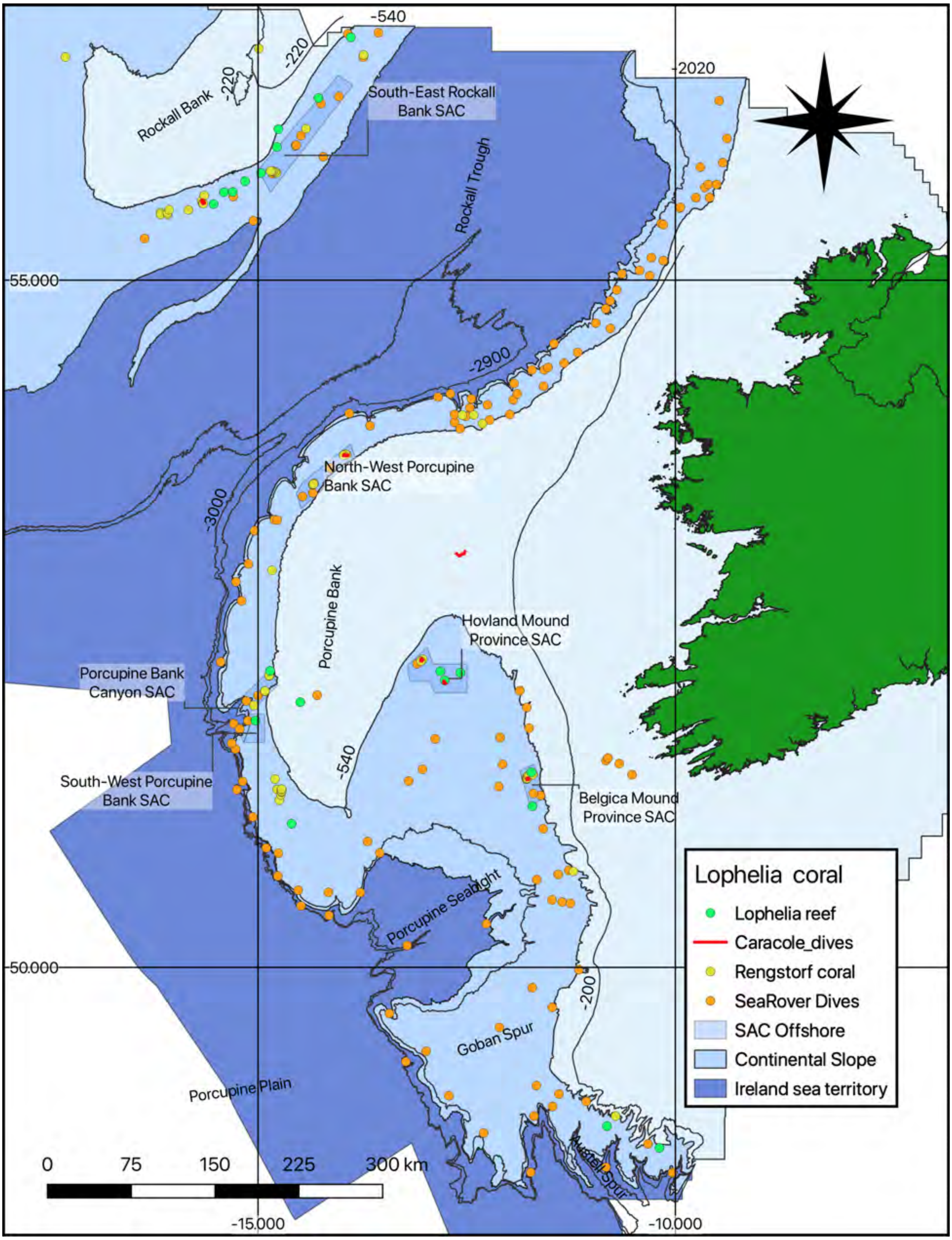


Figure 2. Distribution of Lophelia *reefs off the west coast of Ireland.*

The Atlas of the Commercial Fisheries around Ireland (Marine Institute, 2009) reported that deep-water landings rose sharply around the turn of the millennium and subsequently decreased rapidly, mainly due to the boom and bust cycle of the orange roughy (*Hoplostethus atlanticus*) fishery. Amongst the deep-water landings the most important species were Atlantic redfishes, black scabbardfish, blue ling, greater forkbeard, orange roughy, roundnose grenadier, tusk and deep-water sharks.

From the subsequent Atlas of Commercial fishing around Ireland (Gerritsen & Lordan, 2014; Gerritsen & Kelly, 2019) it is apparent that commercial fishing is taking place in areas where deep-water coral grows. The upper areas of the continental slope are where most of the coral reefs are (Figure 2). The occurrence of deep-water fish in these areas make them a target for commercial fishing, despite the difficulties of trawling over such rough ground. It is likely that the coral reefs have been heavily impacted by fishing activity.

The continued existence of these vulnerable reefs and their associated diversity are under imminent threat from human exploitation. There is a need to prioritise detailed mapping of these still largely unexplored ecosystems and to study their biology, ecology and associated biodiversity. The protection of these deep-water vulnerable marine ecosystems should also be prioritised through the addition and expansion of existing SACs.

In 1992 the European commission established the Habitats Directive which required member states to establish a network of SACs and to maintain or restore them to a favourable conservation status. Under the Directive, member states are obliged to introduce measures for the protection and surveillance of the conservation status of habitats and species listed in Annex I, II & IV of the Directive. In 2003 the EC advised that the Habitats Directive should be applied to the EEZ of each member state.

From 2004–2006, there was a review of scientific data that were in existence and this led to the designation of four SACs in the offshore area encompassing c.2500 km^2. These areas were established to protect the Coldwater Coral Reefs. From 2006 to 2007 negotiations took place to agree management arrangements for petroleum exploration and exploitation and scientific research and in late 2007 fisheries management arrangements were agreed for the four sites by the European Council of Fisheries Ministers.

In May 2007 the EC refined the definition of Annex I habitats to include biogenic and geogenic reefs. Biogenic reefs could comprise corals or sponges whilst geogenic reefs could be cliffs, canyons, seamounts, boulder and cobble fields. In addition, the Annex I habitat Submarine Structures made by Leaking Gases (1180) may consist of sandstone slabs, pavements and pillars up to 4m in height formed by aggregated carbonate cement. Importantly, the guidelines also indicated that the Habitats directive was applicable to the Continental Shelf. In Ireland, this meant that the Habitats Directive should be applied to a geographical area of 656,595 km^2 (Guinan & Leahy, 2009). In 2008, the Irish Government approved funding for a research project to investigate the potential distribution of geogenic reefs and submarine structures made from leaking gases and to ground-truth the distribution and extent of these habitats at selected sites.

The Irish National Seabed Survey and INFOMAR (Integrated Mapping for the Sustainable Development of Ireland's Marine Resource) survey commenced in 2000, gathering multibeam bathymetric data to map the Irish Continental Shelf. The surveys also collected geophysical and ancillary datasets including multibeam backscatter, sub-bottom profiles, magnetic and gravity data. As part of INFOMAR, researchers from University College, Cork (UCC) developed a digital elevation model of the entire offshore area highlighting submarine canyons, escarpment and channel features.

In 2007, as part of the Marine European Seabed Habitats (MESH) project the canyons in the Southwest Approaches to Ireland and the United Kingdom were surveyed. This provided detailed bathymetric data and video from a range of habitats, including significant areas of Annex I reef habitat.

In 2009 the National Oceanographic Centre Southampton led a survey to the Whittard Canyon (which is within the South West Approaches) to investigate the biology and geology of the canyon. They recorded significant Annex I geogenic reef habitat (Figure 3). In Whittard Canyon, correlations between trawling activity on the interfluves and excessive levels of suspended material at depth have been noted (Wilson et al., 2015). Canyons are often considered a refuge for species threatened by towed gear on continental slopes, but sensitive filter feeders such as deep-water corals might be severely impacted by this sediment load. Black corals particularly, due to their preference for low sediment cover, susceptibility to abrasion (Wagner et al., 2012) and inability to withdraw their polyps, are likely to be particularly impacted by increased sediment loads, with knock-on effects to overall geogenic reef diversity because of their structural role. It should be noted that canyons, due to their complex morphology that precludes trawling activity, may be the last refuges for many habitat forming species (Huvenne et al., 2011), (Forde et al., 2017).

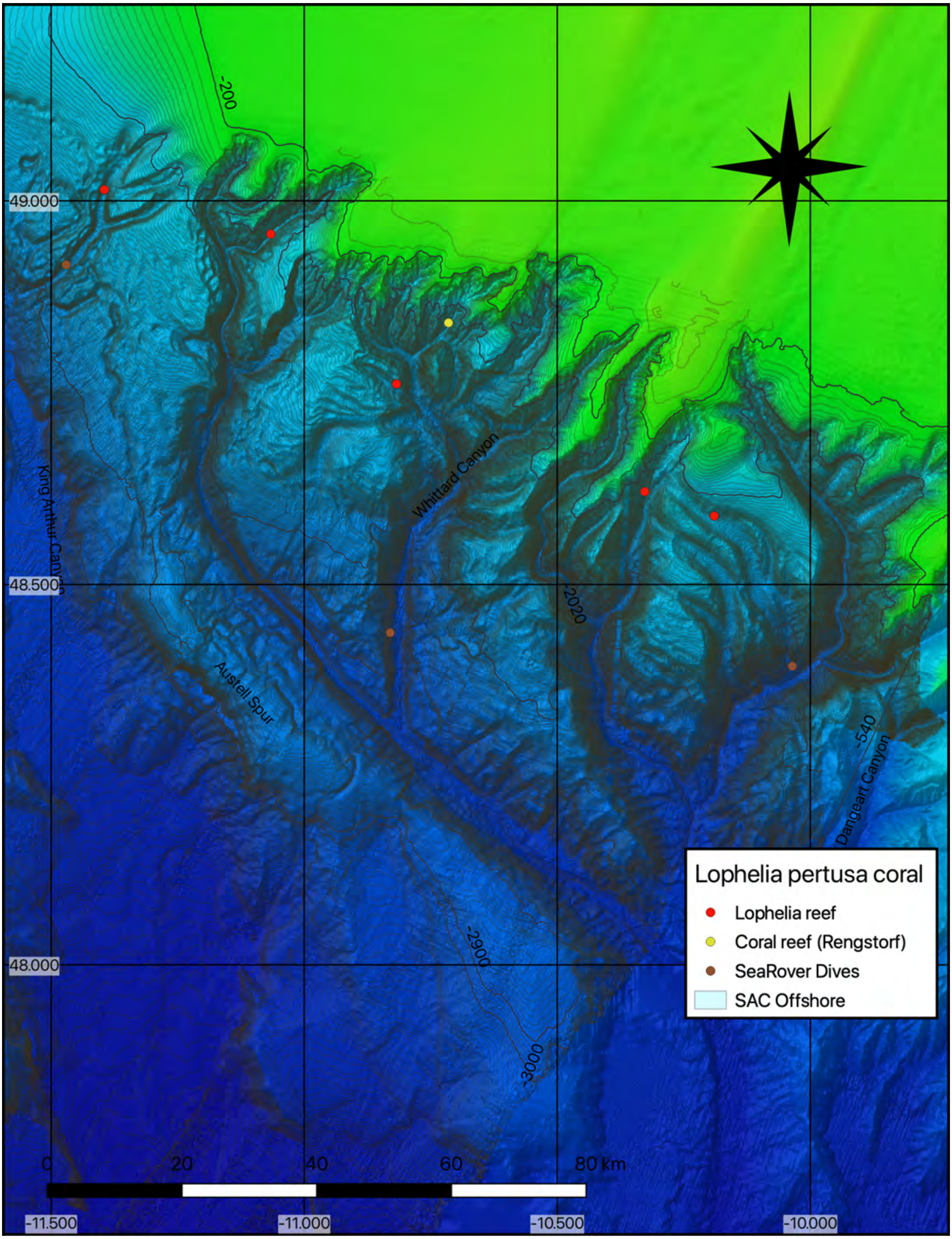


Figure 3. The Whittard canyon, SW Ireland with SeaRover dives and previous records of Lophelia *reef. Imagery of the canyon system and bathymetry from EMODnet multibeam bathymetry gathered by INFOMAR.*

In 2010 the National Parks and Wildlife Service commissioned a survey to map the occurrence of Ireland's offshore geogenic reefs and to carry out monitoring surveys of the candidate SACs (Guinan & Leahy, 2009). In response to the need for detailed knowledge of the distribution of cold water coral reefs and vulnerable marine ecosystems in Irish waters a study was carried out to create a habitat suitability model for *Lophelia* reefs (Rengstorf, 2013). Sites identified by this study are shown on the cold water coral reef maps in this report.

Under Article 17 of the directive, member states are required to report every six years on the conservation status of Annex I habitats and Annex II species and on the measures that have been implemented to ensure their protection. In 2013 Ireland's Department of Arts, Heritage and the Gaeltacht (now department of Arts, Heritage, Regional, rural and Gaeltacht Affairs) submitted the second Article 17 Assessment (NPWS, 2013). This report noted that there were significant knowledge gaps with regard to offshore reef habitat distribution, extent and ecology and the potential pressures affecting the conservation of reef species and associated communities and assessed the overall status of reefs as Unfavourable/Bad with on-going decline. The report also identified significant gaps relating to the area, range, structure & functions and potential pressures within the assessment.

In 2017 NPWS commissioned a review on the distribution, ecological requirements and resilience of offshore geogenic and biogenic cold-water coral reef habitat in the Irish offshore waters greater than 200 m depth. This included a supporting GIS database of known records. This report was a synthesis of data from previous cruises. Under recommendations it suggested: Additional surveys to the north, west and south of the existing SACs as well as surveys of the Fangorn Bank and Edoras Bank (to the west of Rockall bank) to assess their conservation potential and possible addition to the Natura network of SACs (Forde et al., 2017).

Figure 4. Cover of the 2017 SeaRover cruise report.

For areas of future study it made the following recommendations: that the identity of many structure-forming species is poorly known and further work is needed on the taxonomy of these groups; studies to investigate the genetic connectivity between *Lophelia* reefs, studies on age, reproduction and ecology of black corals and soft corals; survey of geogenic reefs.

1.3 Aims and objectives

The requirement to quantify the quality and distribution of offshore reef habitat in Irish waters to fulfil Ireland's legal mandate and generate baseline data for subsequent monitoring was identified as high priority by NPWS. In response to this the Sensitive Ecosystem Assessment and ROV Exploration of Reef (SeaRover) survey was commissioned by the Marine Institute in partnership with NPWS and funded by EMFF, Department of

Agriculture, Food and the Marine (AFM). This three year project was coordinated and led by Ireland's Marine Institute and INFOMAR (Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (funded by the European Maritime Fisheries Fund (EMFF) Marine Biodiversity Scheme and the NPWS. Survey operations were led by scientists from the Marine Institute, INFOMAR and NPWS, accompanied by scientists from NUI Galway and University of Plymouth with support from scientists from the Geological Survey Ireland and the Norwegian Marine Institute. The primary aim of the survey was to map the distribution and abundance of Ireland's biogenic and geogenic offshore reef habitat within Ireland's EEZ with a view to protecting them from deterioration due to fishing pressures. The project aligns with sub-article 6.2 of the Habitats Directive (EC 92/43/EEC) which requires member states to ensure listed habitats are maintained in a favourable state. Secondary objectives of the SeaRover survey included the collection of biological samples for genetic and population analysis and the collection of sediment cores for ground-truthing seabed mapping data and analysis of microplastics within the sediment.

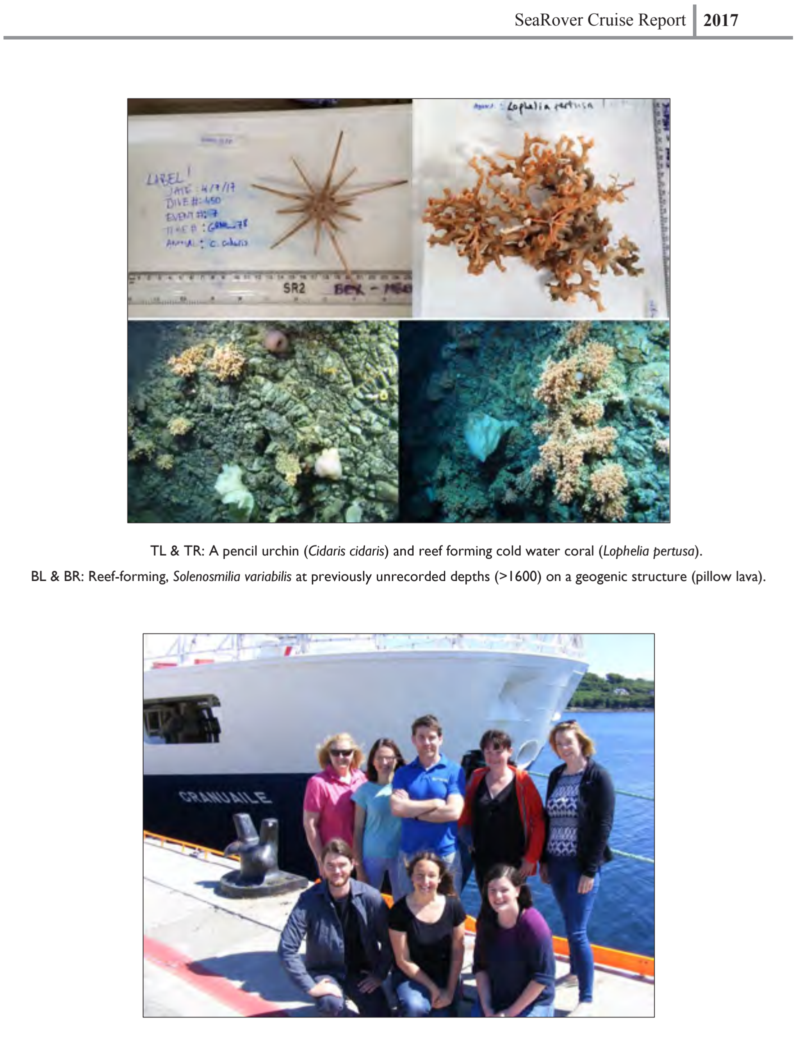


Figure 5. Page from the 2017 SeaRover cruise report showing two collected samples, two underwater images of biotopes and the shipboard party from 2017.

The survey spanned 2017–2019 and comprised three cruises.

The first two cruises (2017, 2018) took place aboard the ILV *Granuaile* whilst the Marine Institute's RV *Celtic Explorer* was used for the 2019 cruise. For each of the cruises the Marine Institute's remotely operated vehicle (ROV) *Holland I* was employed. The ROV was equipped with high definition cameras and video which were used to record and map the distribution and abundance of biogenic and geogenic reefs and associated fauna along the northwest continental shelf. The ROV was fitted with a robotic arm to facilitate sample collection. The survey transects were selected following consultation between the Marine Institute and NPWS using the following criteria: depth range; areas of highly sloping terrain, geographical spatial discreteness, historical fishing activity, historical scientific studies and the presence or absence of certain target geomorphological features which included canyons and canyon walls, gullies, escarpments, ridges, carbonate mounds and cobble fields. The data collected will be used to set site specific conservation objectives, monitor existing SACs and evaluate change due to anthropogenic activities.

The first cruise took place from 3rd July–23rd July during which a total of 50 transects were surveyed, 147 biological specimens and 49 sediment samples were collected. The ship travelled 1900 km, 127 hours and 77 km of seabed were spent sampling and recording video. The survey found biologically sensitive Annex I cold-water coral reefs (*Lophelia pertusa* and *Madrepora oculata*) at multiple sites and discovered new Vulnerable Marine Ecosystems (VMEs) listed under the UN Charter consisting of xenophyophores (large unicellular organisms) and sea-pens.

The second leg of the survey was from 2nd – 22nd July 2018 and surveyed 52 transects. The vessels travelled 2173 km, 119 hours were spent sampling and recording HD video on the seabed. The ROV surveyed 119.75 km of seafloor and collected 34 biological and 44 sediment samples. In addition to finding more sites for Annex I cold-water coral reef species (*Lophelia pertusa* and *Madrepora oculata*) the survey also recorded the following: a potentially new species of black coral *Stauropathes* sp. at three separate locations and species of octocoral and black coral that were recorded for the first time from Irish waters; hydroids and relicanthids that were previously unrecorded from the northeast Atlantic; a blackmouth shark *Galeus melastomus* nursery within the Hovland Mound Province SAC.

The final leg of the survey was 1st – 21st August 2019. The objective of this cruise was to map the distribution and of geogenic and biogenic reef habitat at spatially discreet locations along the southern Porcupine Bank, Porcupine Seabight, Goban Spur, Southwest Approaches and other areas of interest. A total of 52 transects were surveyed with a combined 87 hours sampling and recording HD video on the seabed. The ROV surveyed 104 km of seafloor and collected 27 biological and 48 sediment samples. The survey identified additional Annex I cold-water corals (*Lophelia pertusa* and *Madrepora oculata*). The survey also found a previously unknown aggregation of the bird's nest sponge *Pheronema carpenteri*.

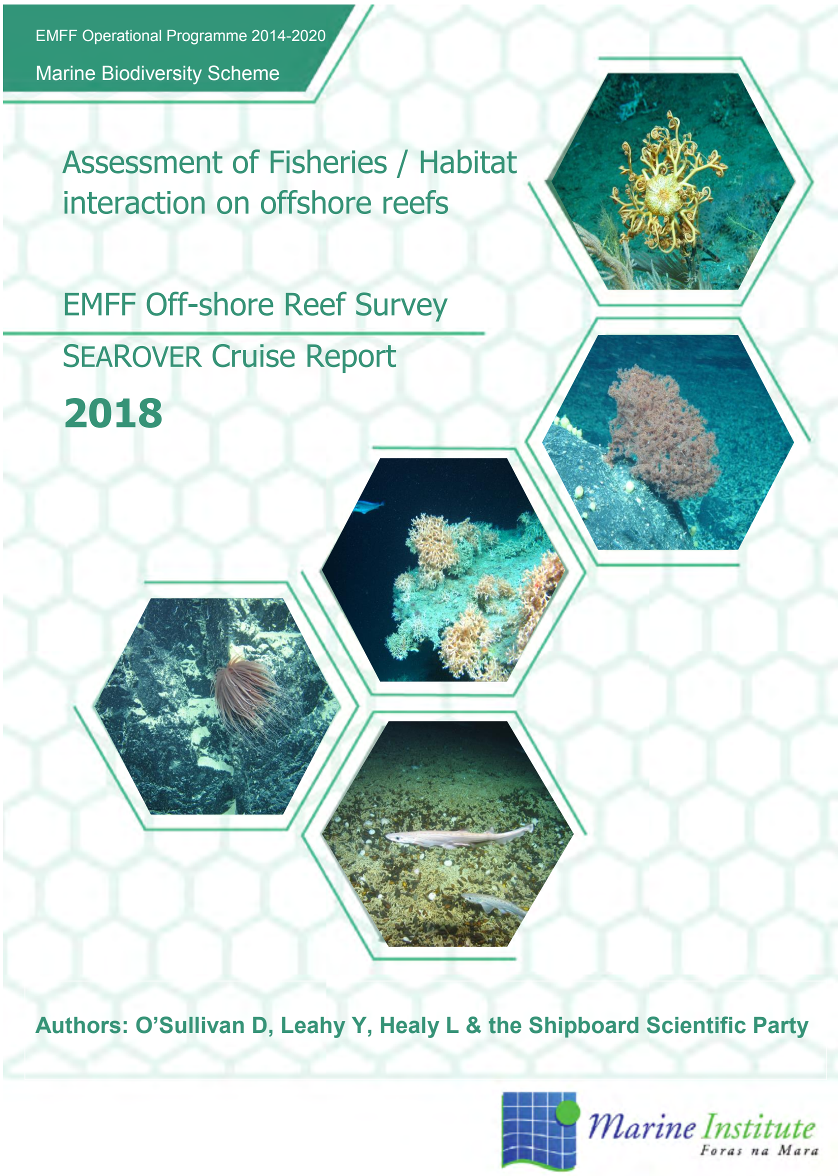


Figure 6. Cover of the 2018 SeaRover cruise report.

2. Methods

2.1 Survey Vessel

In 2017 and 2018 the ILV *Granuaile* was used the map the distribution of biogenic and geogenic reefs along Ireland's northwest continental slope. The vessel was equipped with Class 1 dynamic positioning linked to a satellite based navigation system. The back deck of the vessel housed two storage containers fitted out as wet labs for sample processing and two containers for the ROV control centre and workshop and also the launch and recovery platform for the ROV itself including hydraulic A-frame & winch. In 2018 additional cable was added to extend the operational depth of the ROV to 3000 m.

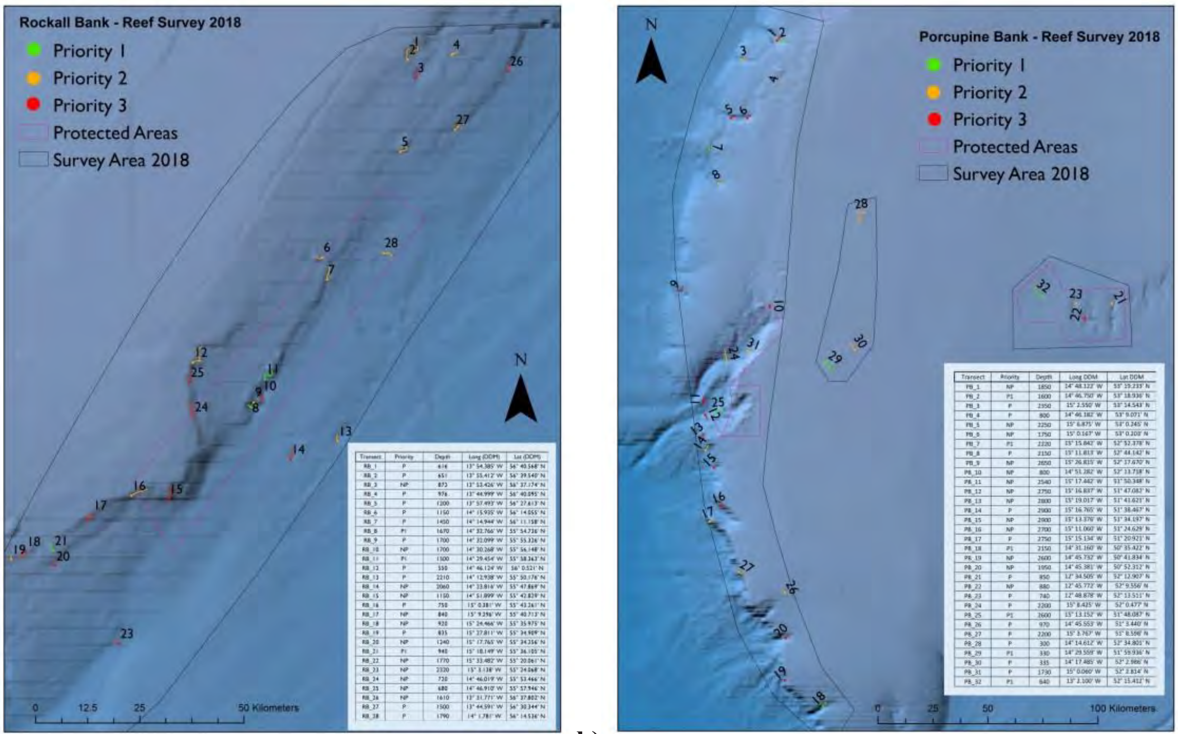
In 2019 the Marine Institute's RV *Celtic Explorer* was chartered for the survey. For the duration of the survey the back deck housed containers for the ROV control centre and workshop and a bespoke launch and recovery platform including hydraulic A-frame & winch.

2.2 Site selection

Ireland's continental margin is characterised by steep slopes and canyon systems incising the shelf at ~150 m extending down-slope to the floor of the Rockall Trough in the west at ~2500 m and the Porcupine Abyssal plain in the south at ~4000 m.

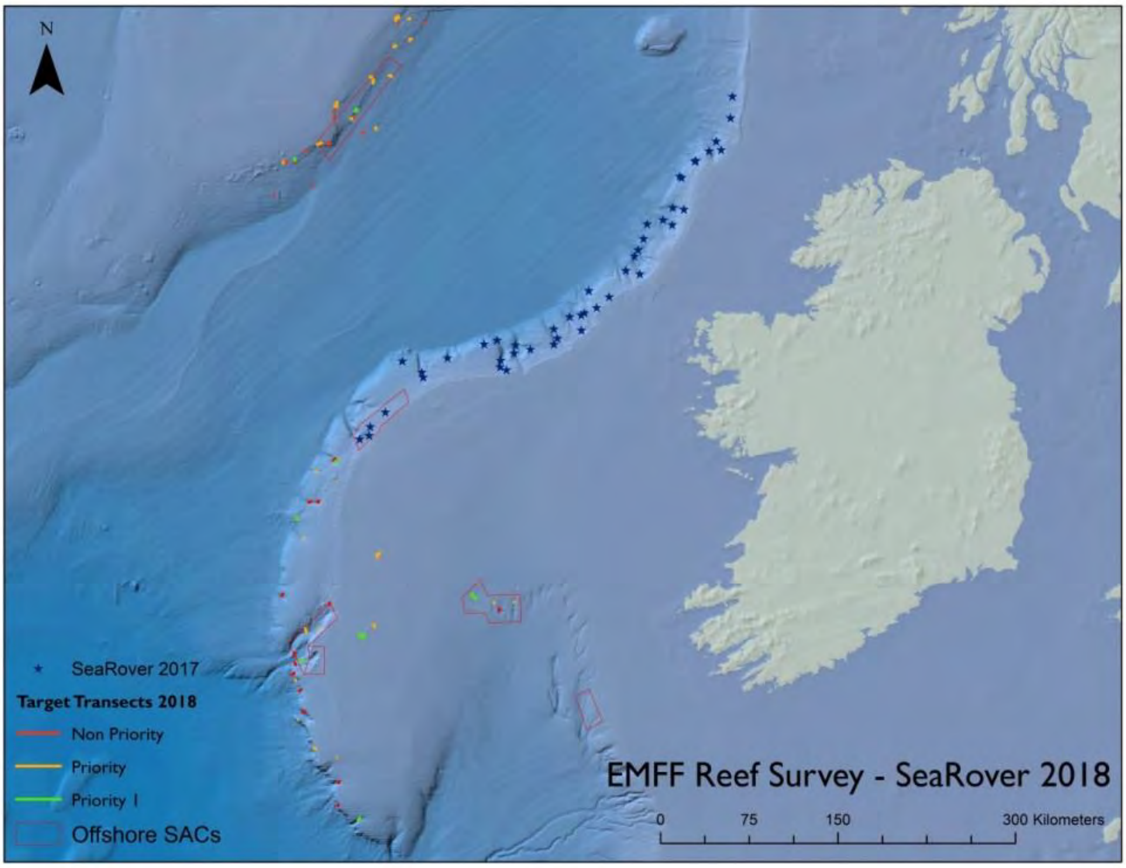
The 2017 survey area extended approximately 560 km from the Porcupine Bank to south of the Hebrides Terrace Seamount (Figure 7).

The 2018 survey focused on two distinct areas (Figure 7), the first leg explored the South-east Porcupine Bank SAC and the eastern slope of the Rockall Bank within Ireland's EEZ. The Rockall Bank rises along the western flank of the Rockall Trough from ~2500 m to 500 m. Bathymetric data suggests the presence of geomorphological features of interest including canyons and carbonate mounds. Guinan & Leahy (2009) recorded biogenic and geogenic reef formations on the bank which were used to guide the 2018 survey. The second leg extended the 2017 survey area south along the Porcupine Bank at the continental margin. This



a) b)

Pre-survey SeaRover 2018 target transects on a) the Rockall Bank & b) Porcupine Bank.



Location of completed 2017 survey transects (navy stars) and proposed 2018 transects within the northeast Atlantic.

Figure 7. Figures from EMFF Offshore Reef Survey SeaRover Cruise Report 2018 showing planned transects and completed transects from 2017.

area is characterised by steep slopes and canyon systems incising the shelf at ~150 m extending down-slope to the floor of the Rockall Trough at ~2500 – 4000 m (Sacchetti et al. 2011). In addition, features of interest evident in the bathymetric data were surveyed on the continental shelf extending eastward into the Hovland Mound Province SAC within which four transects were carried out.

The 2019 survey area included the southern extent of the Porcupine Bank, the Porcupine Seabight, the Goban Spur and the Southwest Approaches including the Whittard Canyon system and other areas of interest specific to the survey objectives (Figure 10). Bathymetric data indicated the presence of small canyon systems along the southern extent of the continental margin of the Porcupine Bank and around its southern tip.

The varied topography along Ireland's continental margin is ideal for cold-water coral reef habitat as the canyons and spurs offer suitable terrain for attachment while up-wellings, a feature of these systems, ensure a rich food source. In order to survey such a large geographical area systematically certain criteria were employed to identify smaller survey units or transects.

These are listed as follows:

- steeply sloping terrain
- historically low fishing effort in canyons which are more likely to be ecologically preserved
- historically low scientific studies or surveys to increase geographical coverage

Additionally target areas would:

- be spatially discrete along the shelf-edge giving a full geographic spread
- contain the presence of one or more target morphological features identified with reef habitat including terraces, gullies, steep-sided canyon walls of canyon systems, escarpments, ridges, mounds and cobble fields

A Geographic Information (GIS) database was created using ArcMap 10.2 and populated with spatial records from the following sources:

- NPWS - In order to increase the knowledge base for the national assessment of offshore reef required under Article 17 of the Habitats Directive an extensive desktop report and supporting GIS was commissioned by NPWS (Forde et al. 2017). The report collated existing spatial data on offshore reef habitat and included scientific data from previous surveys. It was extensively consulted for the current survey.
- INFOMAR - The national seabed mapping programme INFOMAR and the Irish National Seabed Survey (INSS) provided the offshore bathymetry data to help target seabed features associated with reef habitat.
- Atlas of the deep-water seabed: Ireland (Dorschel et al. 2010).
- Fisheries Ecosystem Advisory Services (FEAS) at the MI - Historical fisheries data comprised of electronic Vessel Monitoring System (VMS) logbook data from all boats fishing in Irish waters from 2005 to 2015. The data indicates where fishing effort is concentrated and reveals those areas in which no fishing is evident.

Plymouth University – Predictive modelling of species distributions has indicated the possible presence of various vulnerable ecosystems (*Lophelia pertusa* reefs, *Pheronema carpenteri* aggregations, xenophyophore aggregations) at a variety of scales within the survey area (Ross & Howell 2013; Ross et al. 2015). Some of these areas were chosen in order to validate the predictive models and assess their performance.

Using the above criteria, the 2017 leg of the cruise identified 30 priority target areas and 15 non-priority areas (T01 – T45). Seven additional areas were also surveyed (T46 – T52). The transects and their locations are shown in Figure 10.

In 2018 28 target areas (RB01 – RB28) were identified on the Rockall Bank (22 of which were surveyed (Figure 7). During the second leg on the Porcupine Bank, 30 sites from a list of 32 sites of interest (PB01 – PB32) were surveyed (Figure 10).

In 2019 fifty target transects were identified and prioritised based on the above criteria. In addition, 4 transects were chosen during the cruise in response to survey progress and favourable environmental conditions (T51 – T54). The survey area, with the locations of individual transects is illustrated in Figure 10.

For each targeted area a depth profile, deployment position, planned transect length and transect attributes were provided along with a GIS chart showing planned route in relation to the targeted features (presence of carbonate mounds, canyons, ridges, escarpments, SACs etc.) (Keogh & O'Sullivan, 2018; Oliver & O'Sullivan, 2019).

2.3 Remotely Operated Vehicle

The Marine Institute's ROV *Holland I* is a SMD Quasar Hydraulic work-class 100 hp hydraulic vehicle. The vehicle is operated from a dedicated launch and recovery system consisting of a winch carrying 4000 m of main lift wire plus an A frame (Figure 8).

In 2018 an additional 1000 m of cable was fitted increasing the maximum depth range to 3000 m. The ROV descends at ~ 30 m/min and is flown along a pre-determined transect line 1-2m above the seabed. A range of sensors, including sonar, altimeter, depth, gyrocompass and doppler log are also fitted.

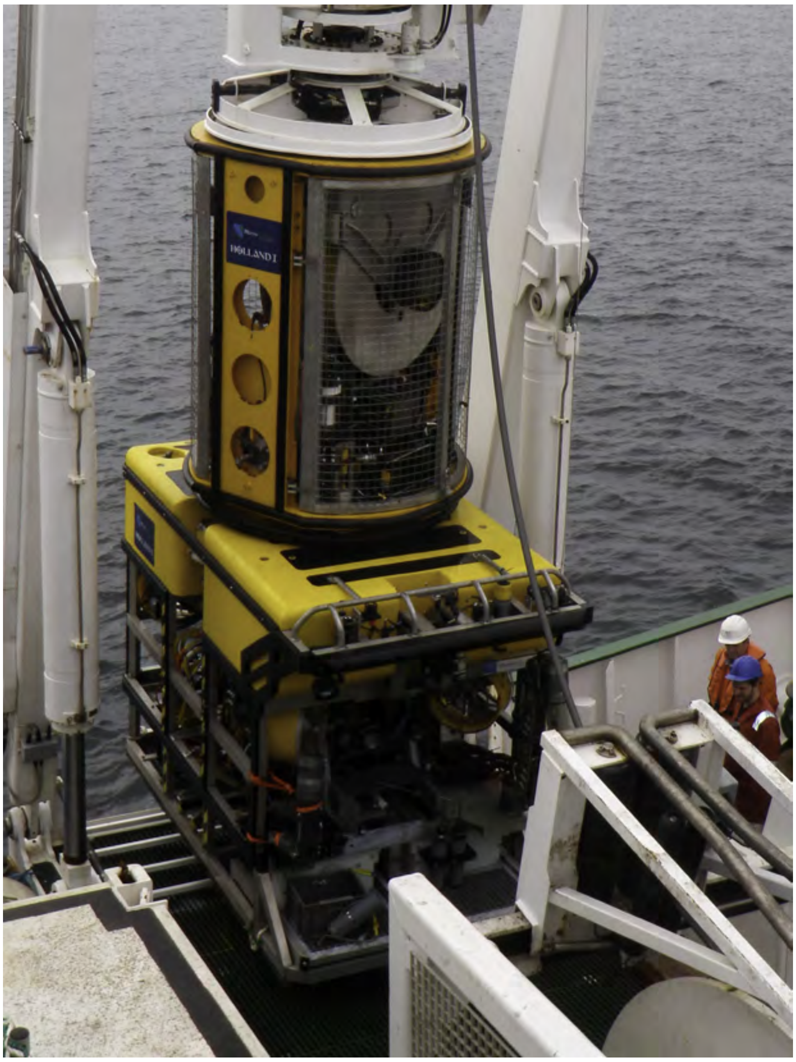


Figure 8. ROV Holland I with tether management system above, being recovered onto Celtic Explorer.

The ROV has two manipulator arms for sample collection and a retractable tool sled carries sample drawers for stowage and sampling tools (push-cores and scoops). The vehicle is fitted with a high-definition television camera (recording in 1080i resolution), up to 7 phase alternating line video cameras plus a 5 mega-pixel digital stills camera fitted with a flash. Illumination for the cameras is primarily provided by two 400 W hydrargyrum medium-arc iodide lights.

The ROV underwater positional information is recorded using an Ultra Short Baseline (USBL) system with a transponder/responder fitted onto the ROV frame. The USBL system calculates the position of the ROV by measuring the range and bearing from a vessel-mounted transceiver to an acoustic transponder. In addition to an acoustic transceiver and in-water transponders, the USBL system includes attitude sensors for the accurate determination of vessel pitch, roll and heading.

Real-time video data acquisition and processing

Ocean Floor Observation Protocol (OFOP) is a software package developed to facilitate real-time visual observations of video data acquired during the deployment of ROVs and TV-sled tows (http://ofop.texel.com). OFOP reads a variety of position data and formats including data from the Global Acoustic Positioning System (GAPS) underwater navigation system. The software was installed on a PC in the ROV container and observations logged to individual dive protocols during ROV operations.

To allow the logging of information in real time OFOP requires the creation of button files. Button Files provide the user with a list of geomorphological and biological groupings as well as species which can be used to identify and characterise habitat types from the video footage. OFOP 'button files' were edited to account for survey knowledge and practise acquired during the 2009 and 2017 surveys (Guinan & Leahy 2009, O'Sullivan et al. 2017). Faunal groupings were left at high taxonomic level to achieve more consistent identification throughout the cruise and only those species which were likely to be present and accurately identified were included. A number of descriptors indicating anthropogenic disturbance were also employed.

Sediment Sampling

Sediment samples were gathered opportunistically by the ROV but generally at the beginning of each dive. A 30 cm long hollow tube with a diameter of 8 cm was used to extract a sediment core which can be recovered to the surface. Cores could only be successfully extracted in areas of primarily muddy sediment. Coarse sand was not retained in the core whilst areas of harder ground prevent penetration of the core into the seafloor.

Duplicate samples were taken where possible. A sample from each transect was used to ground-truth acoustic backscatter data collected by INFOMAR. It is not necessary to retain any layers within the sediment core and instead the entire sample was analysed onboard (colour, sorting, clade, biogenics composition) and retained for Particle Size Analysis (PSA) at a later date.

A second duplicate core was taken with only the top 5 cm layer of sediment retained. The samples were carefully recovered with a clean metal trowel and stored in a glass jar to avoid contamination. These samples will be analysed as part of a study to assess the proliferation of micro-plastics within benthic sediments by a scientific group based at Galway / Mayo Institute of Technology (GMIT).

CTD Sampling

Conductivity, temperature and depth (CTD) measurements were acquired directly from the ROV using SBE Data Processing software which consists of modular, menu-driven routines for converting, editing, processing, and plotting of oceanographic data acquired with Sea-Bird profiling CTD's and thermosalinographs.

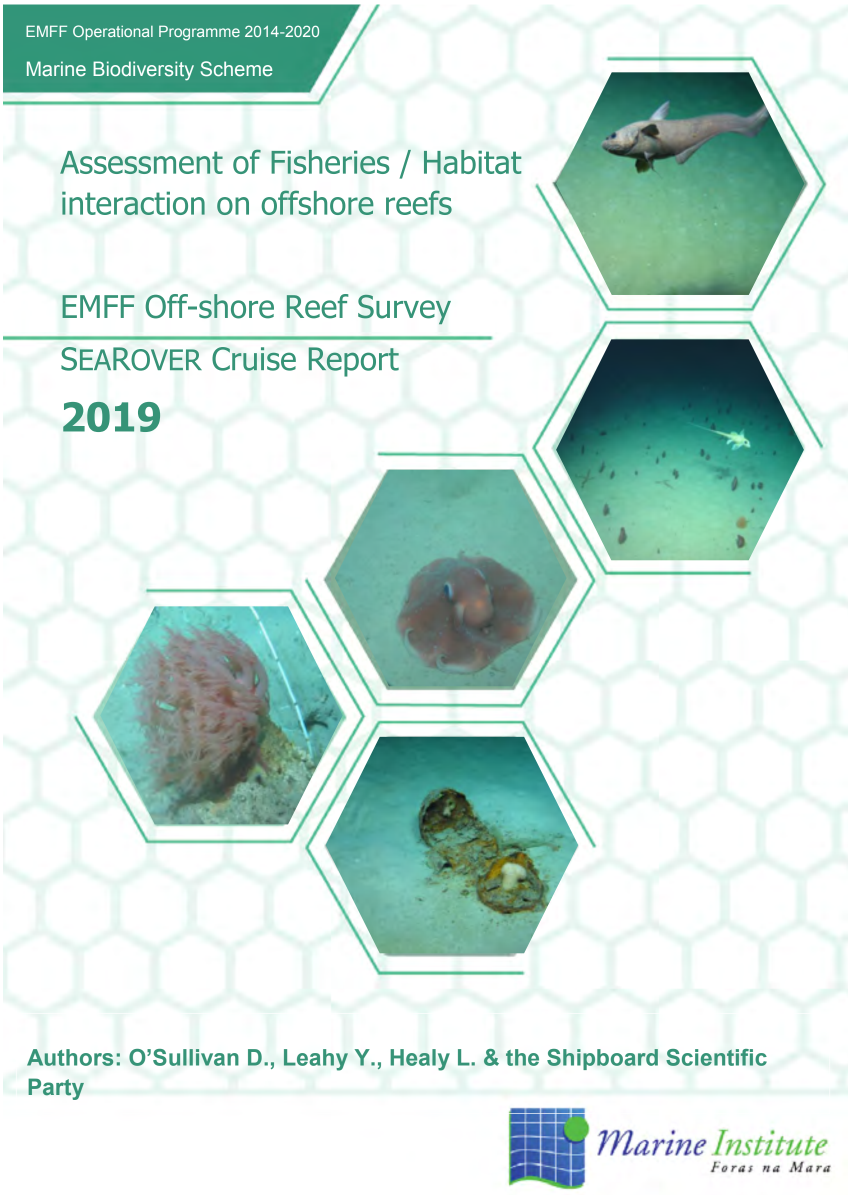


Figure 9. Cover of cruise report for 2019 SeaRover expedition.

Data Analysis

Detailed analyses of the deep-water reef habitats and their associated fauna was carried out by scientists at the University of Plymouth (Ross et al. 2018; Bianca et al. 2018 & Bianca et al. 2020) using the HD video footage and stills images captured by the ROV. The following is a breakdown of the methods employed to achieve this:

Physical Data

All data was generated after review of transect HD video. This was supplemented by high resolution digistills and standard definition composite video if necessary. Each HD video was reviewed at least twice at up to 4x speed depending on the complexity of content. The first viewing was used to create the enhanced OFOP files, characterising substrate, geomorphologies and features, reef presence, Annex I reef type, biotopes, their dominant species, and the presence of listed species and biotopes. The second viewing was used to create a species list with the benefit of a priori SACFOR abundance estimates (see table 3, p.27) having previously reviewed the whole dive. This viewing also allowed for any amendments to the enhanced OFOP file data after a complete review of the transect.

Substrate characterisation

This analysis aimed to record the substratum at a level relevant to the fauna and biotopes being observed, with data resolution tempered by the resolution of HD video and stills imagery. An adapted Wentworth grain size scale was used. Primary and secondary substrata were logged where necessary, representing either mixed or mosaicked substrate areas. (e.g. boulders on sand, or frequently alternating patches of exposed carbonate protruding through mud). Some areas displayed a complex mixed substrate. Here either a primary and secondary substrate from the perspective of the dominant fauna were recorded.

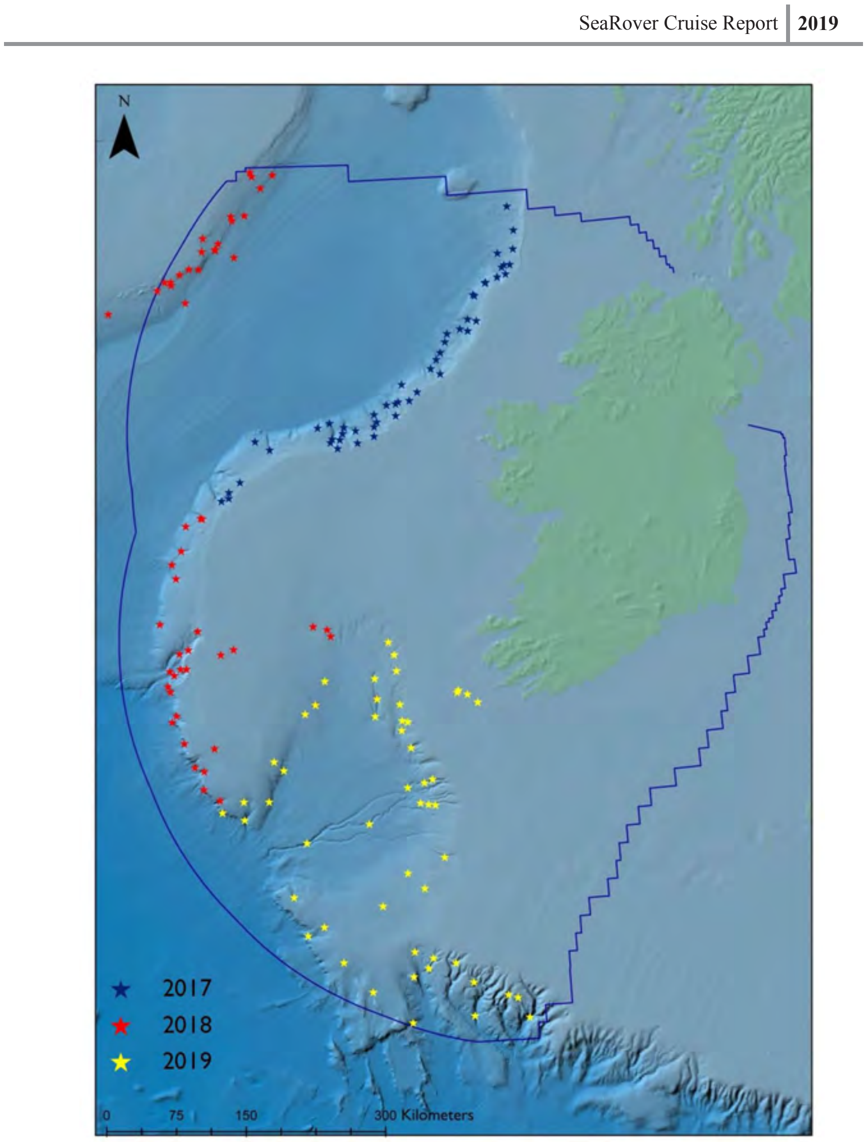


Figure 10. Figure from 2019 Cruise report showing areas surveyed.

Geomorphology, Features and Annex I habitat types

Geomorphological features were logged, primarily referring to the Annex I habitat list of geogenic and biogenic morphologies, but supplemented by additional descriptors where necessary (e.g. soft sediment slope). Over-arching geomorphologies were assigned on the basis of transect locations, and larger landscape features targeted during transect planning. The features category highlighted any notable interesting landscapes observed (e.g. pinnacles, depressions). Strictly Annex I habitat categories were also recorded allowing these to be located and highlighted easily in the future.

Reef presence

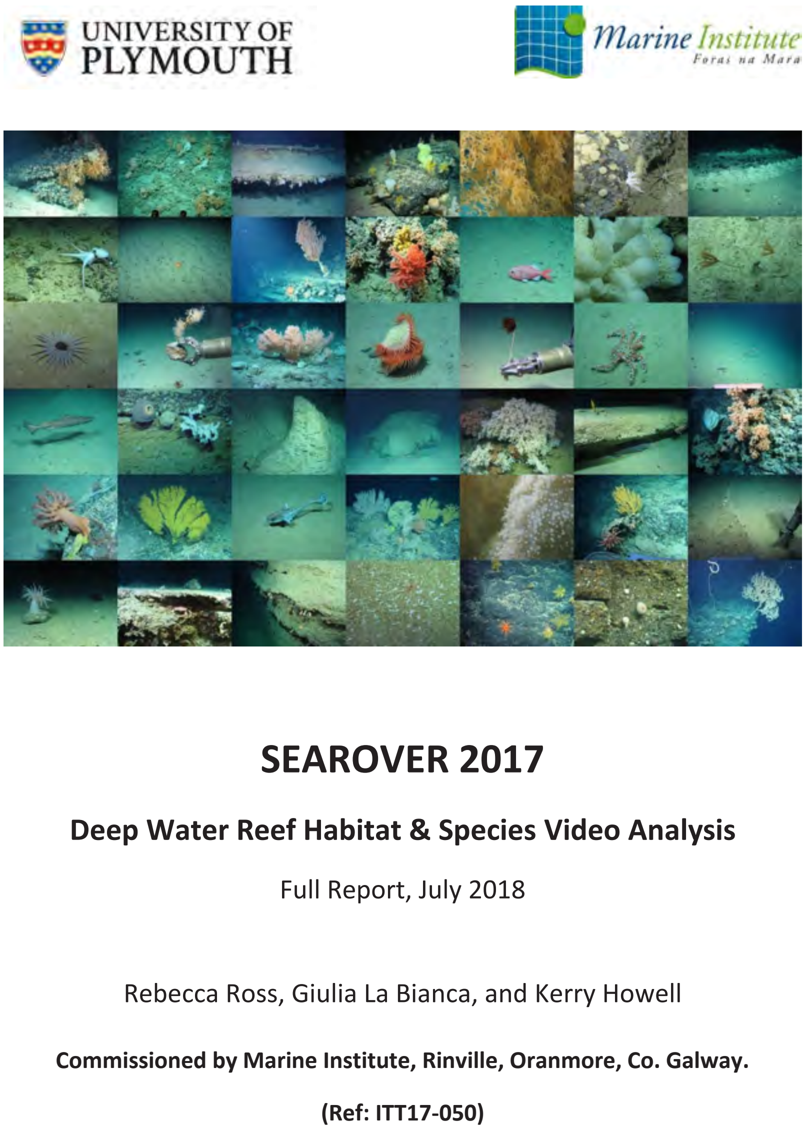
Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.

Clarifications:

- "Hard compact substrata" are: rocks (including soft rock, e.g. chalk), boulders and cobbles (generally >64 mm in diameter).
- "Biogenic concretions" are defined as: concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species.
- "Geogenic origin" means: reefs formed by non biogenic substrata. - "Arise from the sea floor" means: the reef is topographically distinct from the surrounding seafloor.
- "Sublittoral and littoral zone" means: the reefs may extend from the sublittoral uninterrupted into the intertidal (littoral) zone or may only occur in the sublittoral zone, including deep water areas such as the bathyal.
- Such hard substrata that are covered by a thin and mobile veneer of sediment are classed as reefs if the associated biota are dependent on the hard substratum rather than the overlying sediment.

- Where an uninterrupted zonation of sublittoral and littoral communities exist, the integrity of the ecological unit should be respected in the selection of sites.
- A variety of subtidal topographic features are included in this habitat complex such as: Hydrothermal vent habitats, sea mounts, vertical rock walls, horizontal ledges, overhangs, pinnacles, gullies, ridges, sloping or flat bed rock, broken rock and boulder and cobble fields.

Where biogenic or geogenic reef was encountered this was logged. There was an assumed minimum patch size of 5m x 5m (this is a standard minimum area used for biotope classification). The percentage of reef present per transect is summarised as a proportion of cells marked as reef in the enhanced OFOP file when compared with the length of the dive. This means that the reef presence estimate is based on time, so may be skewed when there have been lots of stops for sampling or beauty shots.



UNIVERSITY OF PLYMOUTH

Marine Institute
Foras na Mara

SEAROVER 2017

Deep Water Reef Habitat & Species Video Analysis

Full Report, July 2018

Rebecca Ross, Giulia La Bianca, and Kerry Howell

Commissioned by Marine Institute, Rinville, Oranmore, Co. Galway.

(Ref: ITT17-050)

Figure 11. Cover from 2017 analysis report.

If biogenic reef was present then an estimate of percentage living and dead reef forming coral was provided. However, it should be recognised that a healthy reef rarely has more than 50% living colonies; the dead framework or parts of colonies providing the main habitat for other species. The GIS Dives layer provides details of all transects, what percentage was reef, and if biogenic, what percentage was living reef. An additional note is provided as a provisional assessment of reef health and should be considered in tandem with the percentage data. For example, a 99% dead reef at the base of a cliff is likely to be a sign of healthy living colonies attached to the cliffs above rather than an unhealthy reef.

Percentages of living reef were estimated by eye, and therefore are roughly categorised as: <1%, <10%, <25%, 25-50%, >50%.

2.4 Biological Data

Biotopes

All biotopes were logged in line with the *Marine Habitat Classification for Britain and Ireland* (v.15.03) (MHCBI) new deep-sea section where possible. Some new biotopes encountered were clear extensions of existing categories recorded at new depths. These were marked as a variant for future consideration (Table 1).

Table 1. Example of procedure adopted in relation to biotopes which do not fit the MHCBI definitions.

Existing Biotope:	Variant Logged in SeaRover 2017:	Potential future biotope:
M.AtUB.Ro.DeeSpo	(var) M.AtUB.Ro.DeeSpo	M.AtLB.Ro.DeeSpo
Deep sponge aggregation on Atlantic upper bathyal rock and other hard substrata	(**lower** bathyal variant) Deep sponge aggregation on Atlantic **upper** bathyal rock and other hard substrata	Deep sponge aggregation on Atlantic **lower** bathyal rock and other hard substrata
If the biotope appeared entirely new then the nearest appropriate parent biotope was identified and the biotope marked as a variant with new child label indicated in brackets. (See also Figure 15, page 11.)		
M.AtUB.Ro.SpaEnc	(var) M.AtUB.Ro.SpaEnc(.HydBry)	M.AtUB.Ro.SpaEnc.HydBry
Sparse encrusting community on Atlantic upper bathyal rock and other hard substrata	(variant) Sparse encrusting community on Atlantic upper bathyal rock and other hard substrata (dominated by Hydrozoans [e.g. *Stylaster*/*Pliobothrus*] and Bryozoans [e.g. *Reteporella*])	Sparse encrusting community with Stylasterid hydrozoans and bryozoans on Atlantic upper bathyal rock and other hard substrata

Biotope changes were logged when patch size was assumed to be 5m x 5m or greater. Primary and secondary biotopes, like sediments, are logged to represent either concurrent or mosaicked biotopes. For example*,* burrowing anemones are only associated with the mud in an area that also presents with dropstone boulders hosting mixed corals. Transitions or overlapping biotopes may also be encountered e.g. an echinoid dominated sediment bottom may also present patchy juvenile elpiidid holothurian aggregations. Where two biotopes are present, one is always assigned as dominant.

Dominant Species

The dominant species were logged per biotope transition, as judged by eye. These are often intrinsically linked with the biotope description e.g. If “M.AtLB.Mx.SurOph.OphCer, *Ophiomusium lymani* and cerianthid anemone assemblage on Atlantic lower bathyal mixed sediment” is logged as the dominant biotope, it is likely that *Ophiomuseum lymani* that is the dominant species. However the biotope can be more vague in description e.g. M.AtLB.Ro.MixCor, Mixed cold water coral community on Atlantic lower bathyal rock and other hard substrata so the dominant species may indicate whether it was e.g. a *Solenosmilia variabilis*, Chrysogorgiidae sp, or *Stichopathes* sp dominated coral garden. Some of these more generic biotopes may warrant further subdivision in the future in line with reoccurring dominant species.

Occasionally no dominant species were apparent and this is logged accordingly. “No dominant species” usually occurs on soft sediment (which is not the main target of this survey) and is more indicative of the need to undertake infaunal sampling in these regions to better characterise the biotopes present.

Conservation Listed Species & Habitats

While the main purpose of the SeaRover survey was to identify the occurrence of Annex I Reefs habitat [1170] in Irish waters, any habitats or species known to be listed by OSPAR or ICES were highlighted, with species counted where appropriate. Table 2 is an overview of the potential listed habitats (VMEs) (OSPAR/ ICES Type combinations) with the potential to be encountered in Irish offshore waters.

There are only four OSPAR listed species likely to be encountered at depth in Irish waters, all of which are fish.

- Portuguese Dogfish (*Centroscymnus coelolepis*, IUCN Near threatened)
- Gulper Shark (*Centrophorus granulosus*, IUCN Data Deficient)

- Leafscale Gulper Shark (*Centrophorus squamosus*, IUCN Endangered)
- Orange Roughy (*Hoplostethus atlanticus*, IUCN Vulnerable)

Table 2. OSPAR and ICES categories and subcategories, aligned to show where overlaps occur.

OSPAR	ICES	ICES subcategory
Lophelia pertusa reefs	Cold-water coral reef	*Lophelia pertusa*/*Madrepora oculata* reef
(*Lophelia pertusa* reefs)	Cold-water coral reef	*Solenosmilia variabilis* reef
Coral gardens	Coral garden	Hard-bottom coral garden
Coral gardens	Coral garden	Hard-bottom coral garden: Hard-bottom gorgonian and black coral gardens
Coral gardens	Coral garden	Hard-bottom coral garden: Colonial scleractinians on rocky outcrops
Coral gardens	Coral garden	Hard-bottom coral garden: Non-reef scleractinian aggregations
Coral gardens	Coral garden	Hard-bottom coral garden: Stylasterid corals on hard substrata
Coral gardens	Coral garden	Soft-bottom coral garden
Coral gardens	Coral garden	Soft-bottom coral garden: Soft-bottom gorgonian and black coral gardens
Coral gardens	Coral garden	Soft-bottom coral garden: Cup-coral fields
Coral gardens	Coral garden	Soft-bottom coral garden: Cauliflower Coral Fields
Deep-sea sponge aggregations	Deep-sea sponge aggregations	Soft-bottom sponge aggregations
Deep-sea sponge aggregations	Deep-sea sponge aggregations	Hard-bottom sponge aggregations
Sea-pen and burrowing megafauna communities	Sea-pen fields	-
	Anemone aggregations	Soft-bottom anemone aggregations
	Anemone aggregations	Hard-bottom anemone aggregations
	Mud and sand emergent fauna	-
	Bryozoan patches	-
	Hydrothermal vents/fields	-
	Cold seeps	-

Species Lists & SACFOR

Species lists were compiled on a second viewing of the video. All species were identified in line with Howell et al. (2017), (available online at http://www.deepseacatalogue.fr/) and supplemented with taxonomic literature. Expert advice was also sought from Kerry Howell, Louise Allcock, and known experts on twitter (e.g. Chris Bird (CEFAS, @SharkDevocean), Graham Johnston (MI, @GJShark), and Brit Finucci (NIWA, @BritFinucci) helped with fish identifications).

All identifications were made to the highest taxonomic resolution possible from the footage and images available, and operational taxonomic units assigned to aid tracking future identifications (in line with & supplementary to Howel et al., 2017).

Species abundance measures were recorded using the MNCR SACFOR method (see Table 3). This method categorises abundances into six categories (Super-abundant, Abundant, Common, Frequent, Occasional, Rare) allowing faster approximation of abundance than more accurate count data, while allowing better agreement between observers than un-categorised count estimates.

Table 3. A SACFOR Table of abundance measures adapted from JNCC's online table to give corresponding counts/ densities per average 2hr/2km transect length for SeaRover.

	Growth form		Size of Individuals/Colonies			COUNTS (1st col Based on 2hr/2km transect)	
	EncrSponge	Barnacles	S	M	L		
% cover	Crust/meadow	Massive/Turf	1-3 cm	3-15 cm	>15 cm	Density measures	
>80%	S						
40-79%	A	S	S			>	1000-9999 / m2
20-39%	C	A	A	S		>	100-999 / m2
10-19%	F	C	C	A	S	>	10-99 / m2
5-9%	O	F	F	C	A	1-9 per 1m	1-9 / m2
1-5% or density	R	O	O	F	C	1-9 per 10m	1-9 / 10m2
<1% or density		R	R	O	F	1-9 per 100m	1-9 / 100 m2
				R	O	2-20 per transect	1-9 / 1000 m2
					R	1-2 per transect	<1/1000 m2

Quality Assurance

To ensure the standard of identifications of animals, 5% of transects (3 transects) were independently analysed by Dr Kerry Howell. Transects were selected to cover a range of habitats and depths and were as follows: T5, T22, T42. Each transect was reviewed and all taxa observed were noted. Taxa were identified using the species catalogue produced for the project. Taxon lists produced by Drs Ross and Howell were then compared for consistency. The results of the QA analysis show minor differences in the number of OTU's recorded between observers (Table 4). These differences are primarily a result of missed OTUs rather than discrepancies in identification (where observers disagreed on the identification of an animal). In many cases the missed OTU's resulted from differences in taxonomic resolution between observers. For example where one observer distinguished different forms of Bathycrinidae the other had identified all forms at the family level thus giving the impression of 'missed' taxa. In only a limited number of cases, the missed OTU's were taxa that the observer had overlooked. For all transects the combined number of OTU's observed on any one transect was consistently higher than that recorded by a single observer. This suggests lists of OTU's provided in this project are under-estimates of the number of taxa present rather than over estimates.

Table 4. Quality assurance of species identification between expert analysers.

Transect	Total No. O.T.U		No. O.T.U. in common	Inter-observer agreement	No of disgreements	No. missed OTU		Combined total no. O.T.U.	Accuracy	
	KH	RR				KH	RR		KH	RR
T5	80	76	73	88%	1	3	6	83	96%	92%
T22	69	70	58	73%	3	9	6	79	87%	87%
T45	56	62	51	77%	1	10	4	66	85%	94%

Trends in the number of species between transects remained consistent between observers, as well as when considering only those OTU's in common, or the combined total number of OTU's. With inter-observer agreement at >73%, this analysis is at a high quality level relative to published averages of 67-83% self-consistency, and 43-72% inter-observer agreement (MacLeod et al., 2010).

2.5 Deliverables

Enhanced OFOP Files

Enhanced OFOP files are designed to combine the outputs of USBL and CTD data, initial OFOP observations, and detailed analysis recordings in such a way that is compatible with GIS data projections. In order to combine these data types:

- Times were synchronised in the ROV shack as much as possible at time of recording to ensure alignment of CTD and USBL/OFOP data
- CTD data was converted into cnv text files for ease of manipulation using “SBE Data Processing” software (a Sea-Bird CTD Software which is part of the CTD recording used by Holland I).
- All data types were aligned using time as a common variable
- Quicktime video player allows the display of either recorded time or media time elapsed when reviewing footage, so both time values are provided to improve compatibility for future viewings.
- USBL data was retained as 1 second recordings to ensure consistency of position throughout the transect. All datatypes were aligned to this.
- Additional analysis variables (substrates, geomorphologies, reef types and percentages, Annex I habitats, biotopes, dominant species, and the presence of listed species and biotopes) were recorded into the final combined excel file and are aligned to the timestamps and positions.
- Sampling events were also recorded for ease of location in the future
- Image EXIF data for all dives was obtained using ExifTool for windows (freely available from https://www.sno.phy.queensu.ca/~phil/exiftool/), allowing an easy alignment of digistills image filenames by timestamp.

Dive Summaries

In each analysis report dive summary reports are provided per dive. A template was set up to ensure consistency of reporting. All dive summaries contain:

Time/location/image/sampling/planning metadata.

- Maps showing actual track with substrata transitions, biotope transitions and reef, if present (derived from the enhanced OFOP file) (Figure 12).
- Four annotated representative images per dive displaying biotopes, substrates, species, and geomorphologies considered to be representative of the dive (Figure 13).
- A summary description detailing timings of biotope transitions and the progress/general observations of the dive.

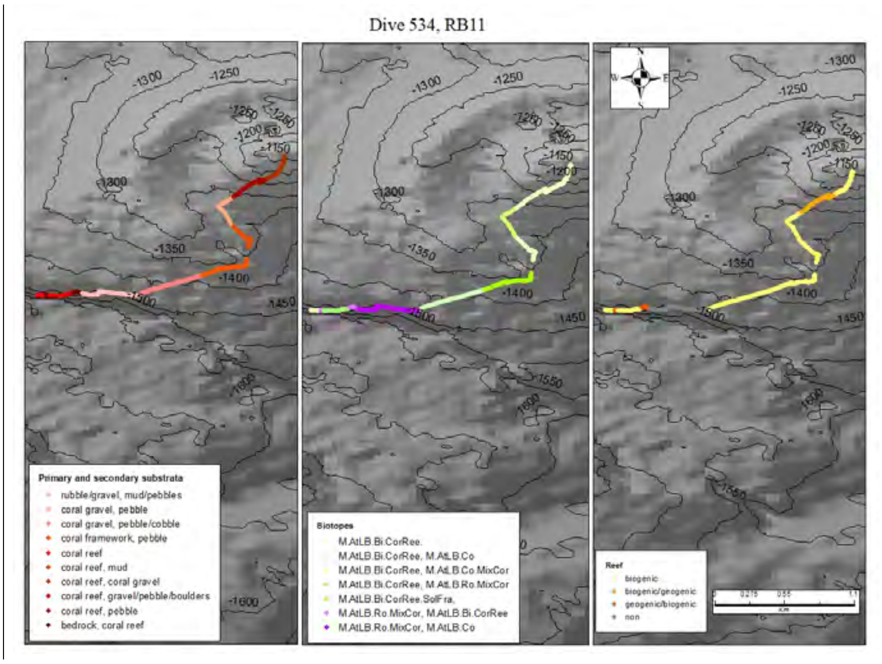
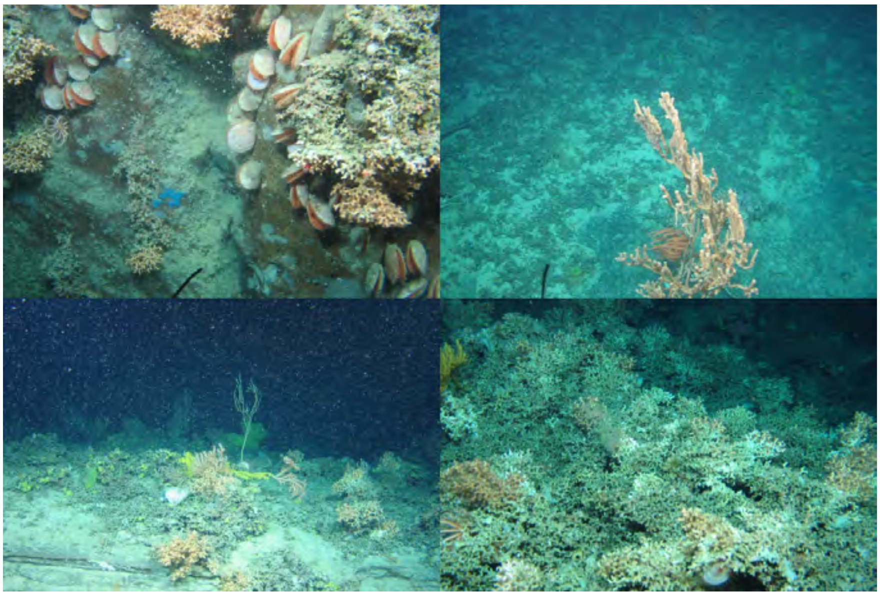


Figure 12. Typical maps from a dive summary showing biotope and substrata transitions and track of ROV.

- A physical data summary showing reef percentages, a list of substrates (dominant substrates for the dive are shown in bold), geomorphologies, features, Annex I types and pressures encountered per dive.
- A biological data summary showing number of species, species list and SACFOR abundance measures, biotope list and their conservation status, biotope progression with dominant species (numbers aligning to the dive summary numbers in square brackets), and a summary list of the

conservation listed habitats and species encountered.

- An area for additional comments regarding the dive if necessary.



Top L. *Acesta excavata* OTU106 and *Solenosmilia variabilis* OTU700 colonies co-habit on vertical hard substrata (M.AtLB.Ro.MixCor).

Top R. *S.variabilis* OTU700 reefs on slope with closed up imagery of large Eknomisis sp OTU640 (M.AtLB.Bi.CorRee.SolFra).

Bottom L. Biogenic reefs on *S.variabilis* OTU700 on slope, hosting many epifauna species incluging Eknomisis sp OTU640 and Zoanthidae sp2 OTU586 (M.AtLB.Bi.CorRee.SolFra).

Bottom R. Extensive *S.variabilis* reefs (M.AtLB.Bi.CorRee.SolFra).

Figure 13. Page from analysis report showing biotopes from a single dive.

2.6 Synthesis of 2017-2019 data

We combined Excel spreadsheets for 149 dives into an MS Access database. Five dives from 2018 were missing OFOP data and we reconstructed transect positions based on the start and finish positions in the cruise report and biotope records from the video analysis conducted by the Plymouth team. Species/OTU records for each dive were imported to a records table and cleaned to create a consistent OTU list. OTUs were checked and higher classification attached from World Register of Marine Species (WoRMS). The final database contained 1125806 observations (GPS positions at 1 second intervals for all dives), 476 OTUs, 154 dives and 7570 species records. 259 OTUs were additional to the 2017 catalogue of Howell et al., (2017) and 217 were already assigned OTU numbers.

We reduced the observations to 19432 unique observations for convenient use in GIS software, providing sufficient resolution to track the position of the ROV at 1 minute intervals and retaining all biotope changes.

We catalogued 25,000 still images by importing to Adobe Lightroom and selected a set of 750 by attributing the best images with 5 star ratings. We added GPS positions for start of dive to these images, which were already sorted into a single folder per dive by Marine Institute. Lightroom's ability to gather metadata from images and to look at all images in subfolders then made it simple to look at our selected images as a single group and selectively keyword these with OTU and species names, fishing activity, rubbish, etc..

We evaluated the video from one dive to assess the difficulties of analysing the 310 hours of video generated during SeaRover dives. We tested the option of splitting this video using Batch Video Splitter on a 2013 21.5 inch screen iMac with 2.7 GHz quad-Core Intel Core i5 processor, 8 GB of 1600 MHz DDR3 RAM and 1TB SSD partitioned to boot either into MS Windows or macOS Catalina v. 10.15.7. We split the video into 3 minute segments and recoded the segments to MP4 using Hijack version 1.3.3. For dive 669 this resulted in 49 files of 250-300 MB size which were then easy to access and catalogue using Adobe Bridge and Quicktime. We envisaged a scenario where video segments could be catalogued against observations of each OTU for further refinement of the taxonomic investigation of the species present.

Potential New Escarpment biotope

Example image of the potential new escarpment biotope (IMG_8254 from D492/T50)

Noted in the analysis as:

- (var) M.AtMB.Ro.MixCor.DisLop: (Escarpment variant of) Discrete *Lophelia pertusa* colonies on Atlantic mid bathyal rock and other hard substrata
- (var) M.AtUB.Ro.MixCor: (Escarpment variant of) Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata
- Seen in transects 19, 42, 50, 51

This potential new biotope is associated with vertical walls, and notably is dominated by *Desmophyllum sp* solitary scleractinians, purple anemones (*Actiniaria sp13*, OTU478), *Ceremaster sp* sea stars, *Cidaris cidaris* echinids, and encrusting fauna. This may occur with or without discrete *Lophelia pertusa* colonies.

Figure 14. Figure from 2017 analysis report describing a potential new biotope.

For map generation we received a set of 2450 files from Marine Institute which included shapefiles for all aspects of the Forde et al. (2017) review plus associated shapefiles for many aspects of the SeaRover cruise planning. We used the open source GIS software QGIS version 3.16.0-Hannover to create layers from .csv files exported from the MS Access database and saved these as ESRI shapefiles and in a Spatialite database file. To map species/OTU distributions we exported a .csv file from the Records table of the MS Access database joined to the classified OTU table. To map species individually or by higher taxon, categorised, we set a filter on the species layer, for example for Order Pennatulacea, and then categorised by OTU name within QGIS. To map biotopes we generated a start and finish observation from the MS Access observations table which resulted in a biotopes table containing 1151 segments classified into 162 biotopes, 101 of which matched previously described biotopes in the MHCBI classification with the others being variants or new biotopes with different characterising species and depth ranges.

3. Results

3.1 Survey coverage

Figure 16 shows the location of the SeaRover transects from 2017–2019. The locations of the offshore SACs are also highlighted. The 2017 survey focused on the NW continental slope, the 2018 leg included the outer Porcupine Bank and the Rockall Bank area. The 2019 cruise covered the Porcupine Seabight, the Goban Spur and the south-western canyons. Table 5 analyses the number of transects conducted within each of the major depth zones.

Table 5 The distribution of transects by depth zones.

Zone	DepthRange	Number of transects	2017	2018	2019
Circalittoral	-30 to -200 m	4	0	0	4
Upper Bathyal	-200 to -600 m	10	3	4	3
Mid Bathyal	-600 to -1300 m	57	18	18	21
Lower Bathyal	-1300 to -2000 m	51	21	15	15
Upper Abyssal	-2000 to -3000 m	32	8	15	9

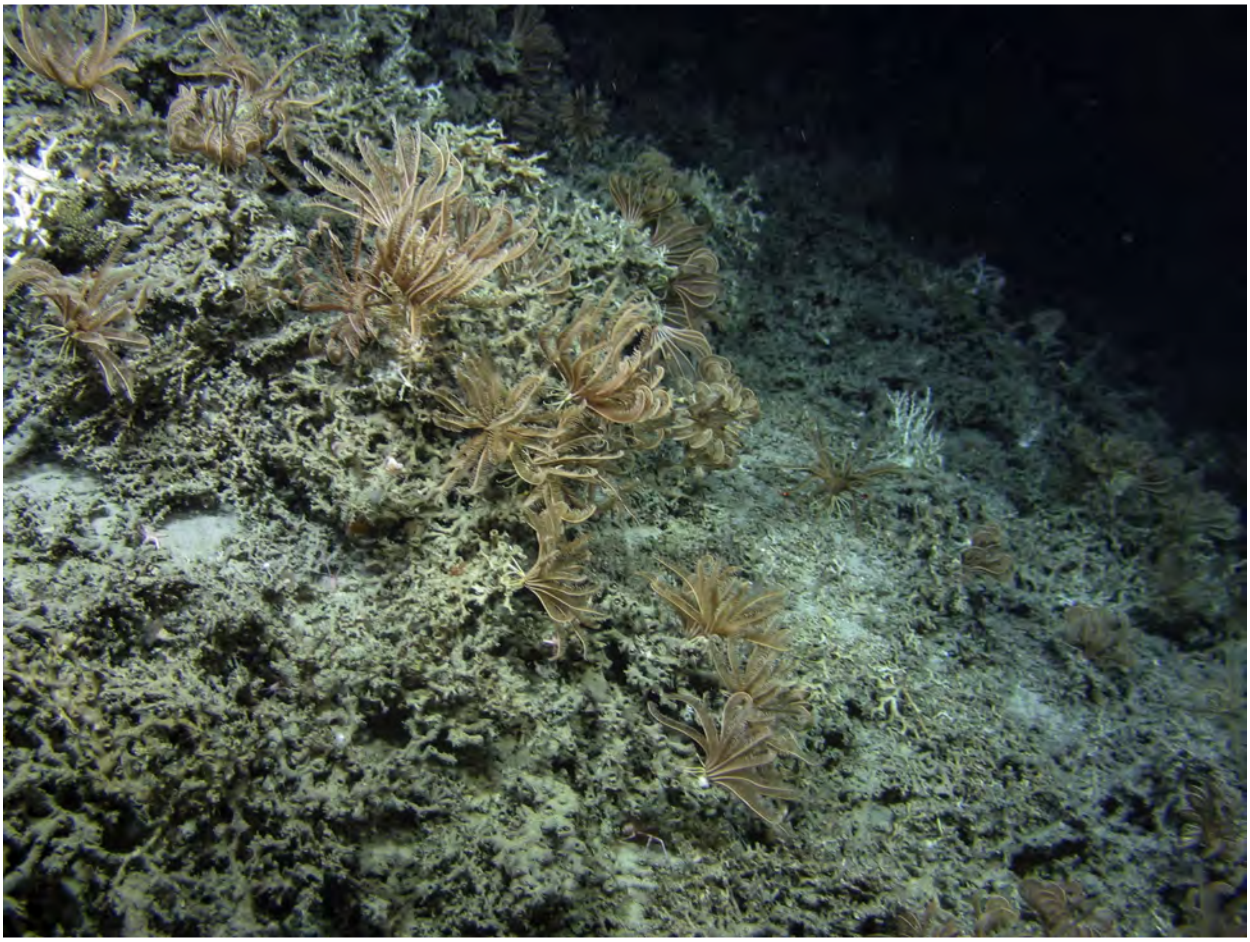


Figure 15. Coral rubble slope with the crinoid Koehlermetra porrecta*.*

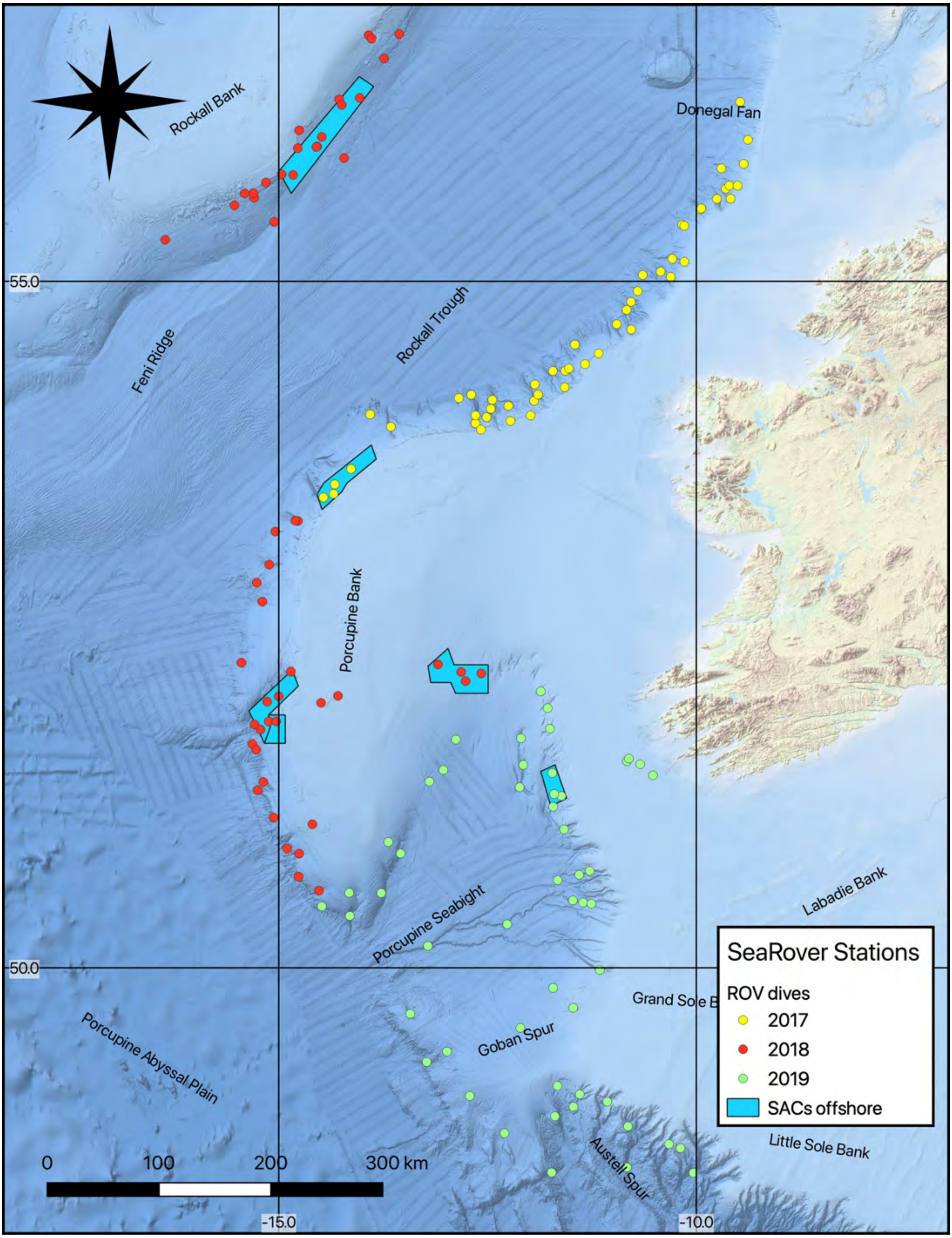


Figure 16. Map showing positions of SeaRover ROV transects, 2017-2019.

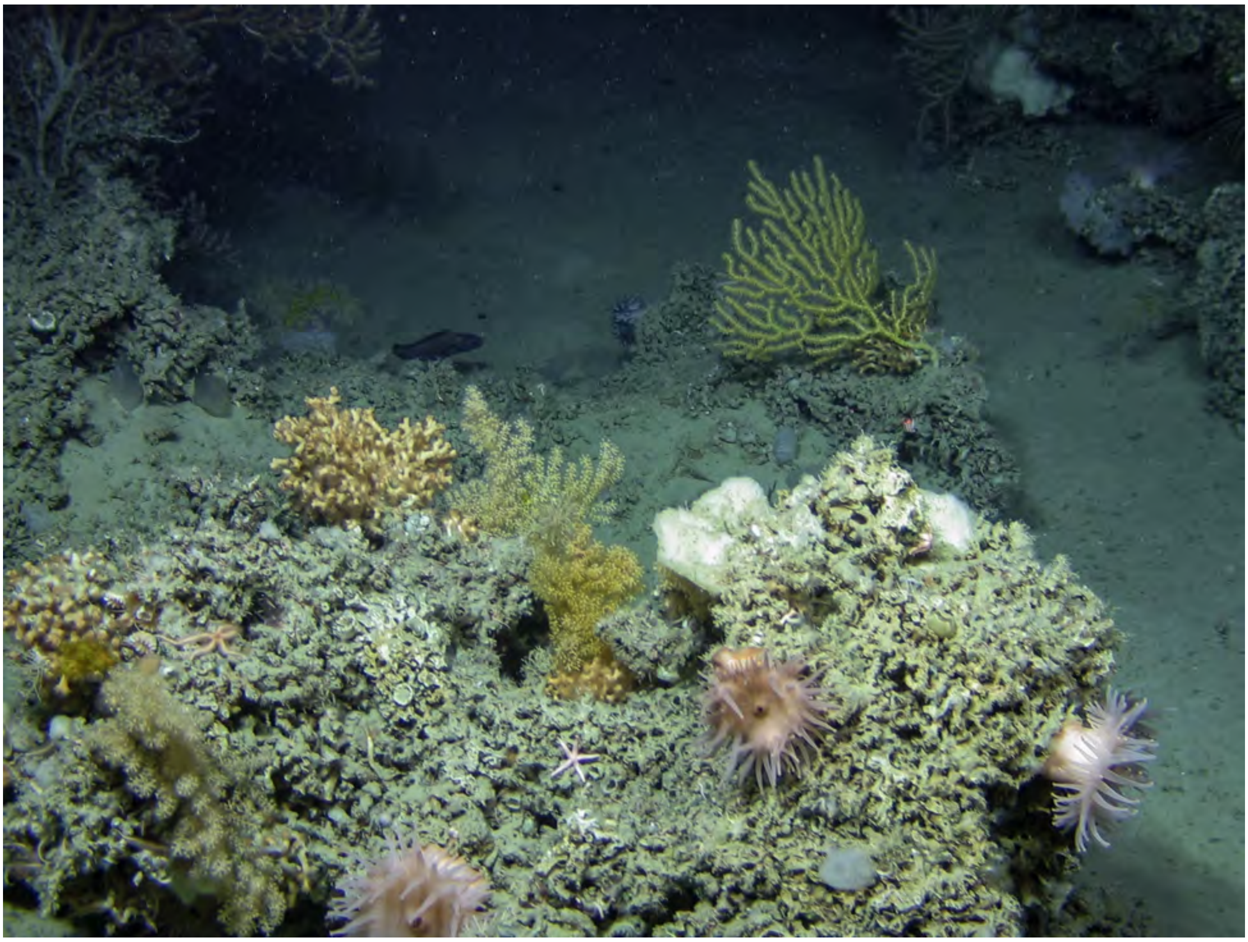


Figure 17. Reef with anemones, soft and hard corals and sponges.

3.2 Diversity of OTUs

For many of the species that were encountered by SeaRover it was not possible to attribute identifications to the species level and an operational taxonomic unit (OTU) system was used. A list of the OTUs recorded by SeaRover is given in Appendix III.

Figure 18 shows the locations of the transects surveyed by SeaRover scaled by number of OTUs recorded at each site. The diversity was highest in the shallow and middle depths of the canyons and also high on escarpments with hard reef habitats. The observed diversity was lowest on extended plains with sediment habitats. As previously noted, infaunal sampling would be required to establish associated diversity. Sediment habitats which were undisturbed clearly supported many species buried beneath the surface and often had characteristic emergent communities, especially of sea-pens and burrowing anemones. A section of continental slope where the Porcupine Bank meets the Rockall Trough appears to be a biodiversity hotspot for black corals and soft corals (Figures 19–24).

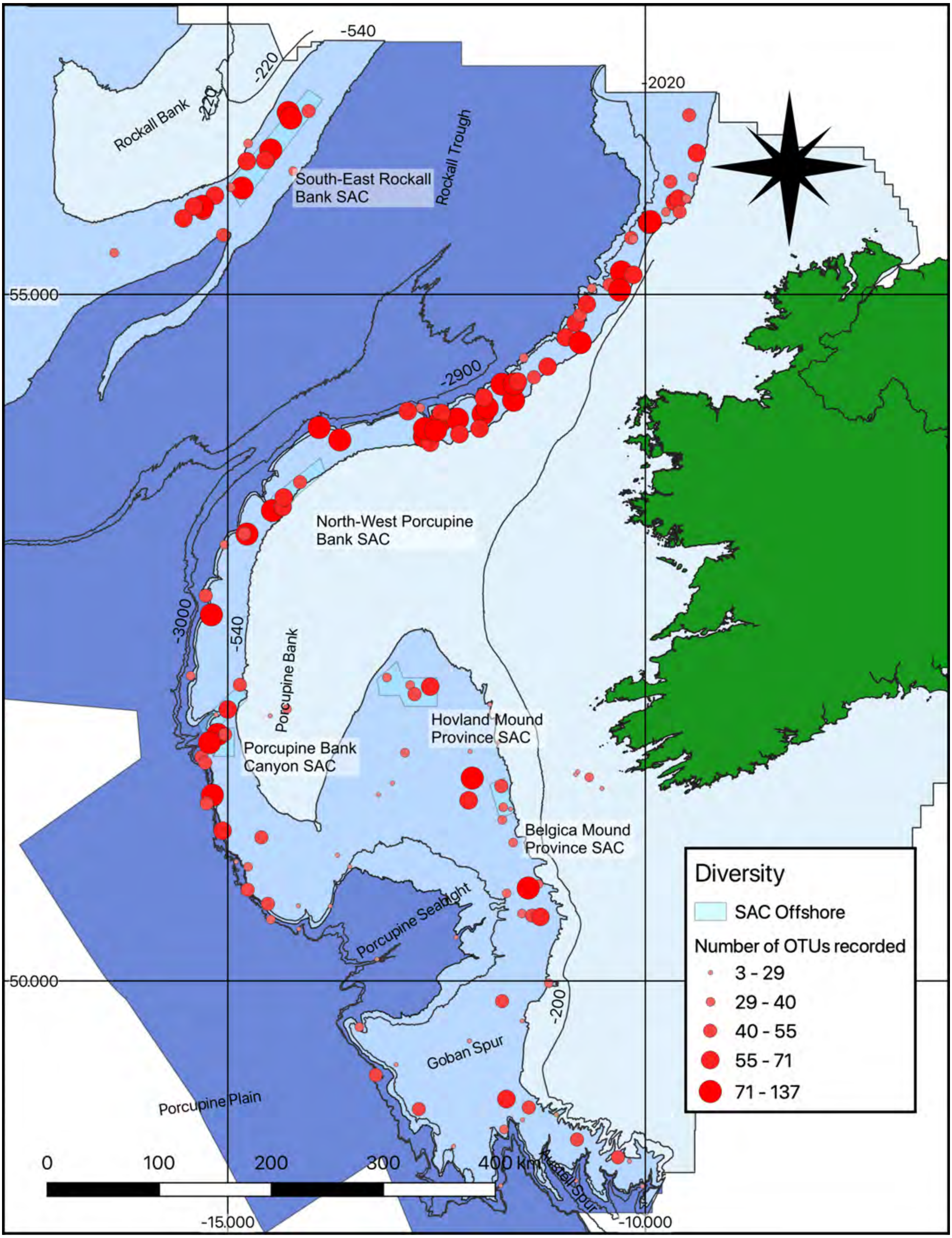


Figure 18. Diversity of the species recorded was highest in shallow and middle depths in canyons and on escarpments with hard reef habitats and lowest on extended plains with sediment habitats. Sediment habitats which were undisturbed clearly supported many species buried beneath the surface and often had characteristic communities, especially of sea-pens and burrowing anemones.

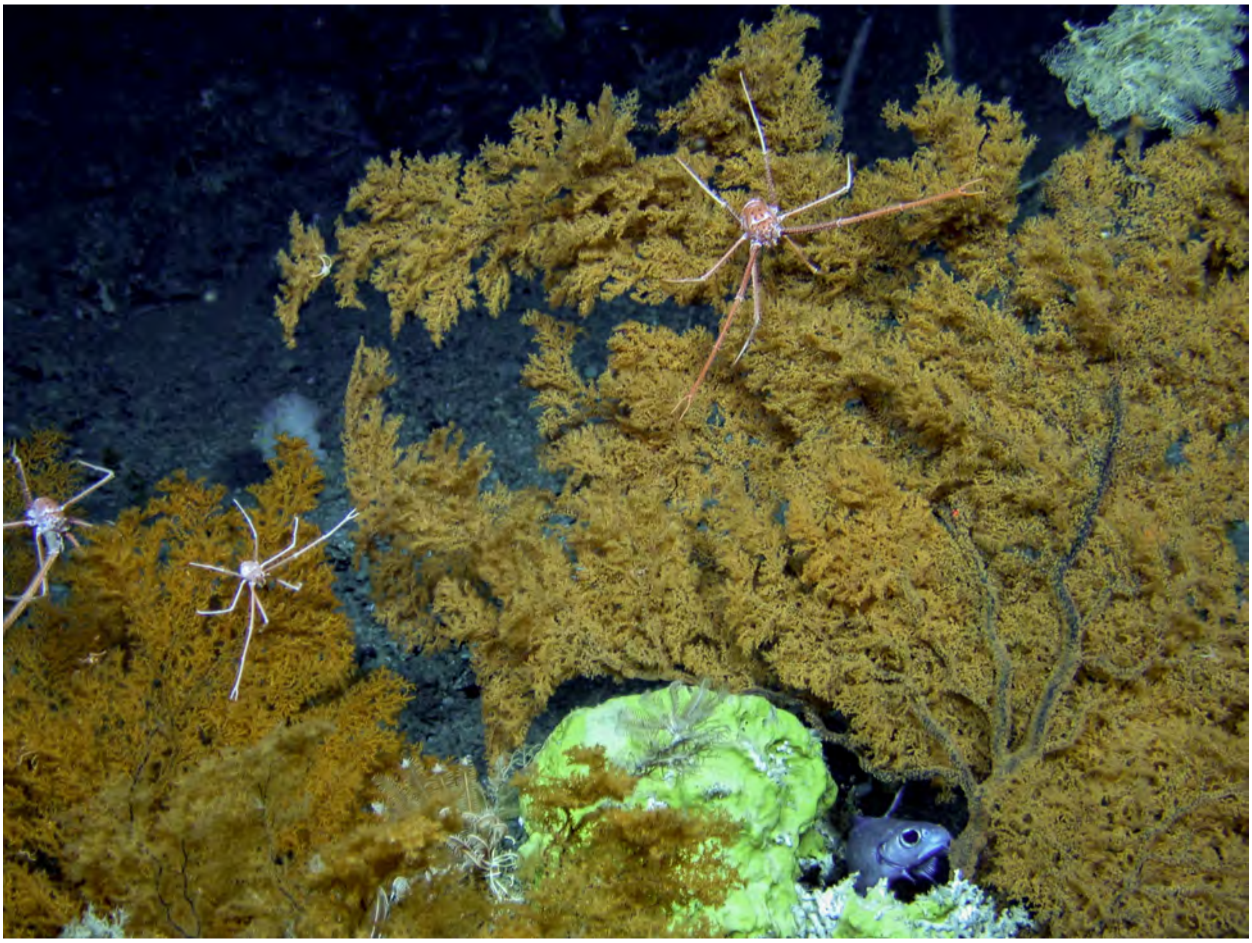


Figure 19. Large black coral on geogenic reef (dive 543).

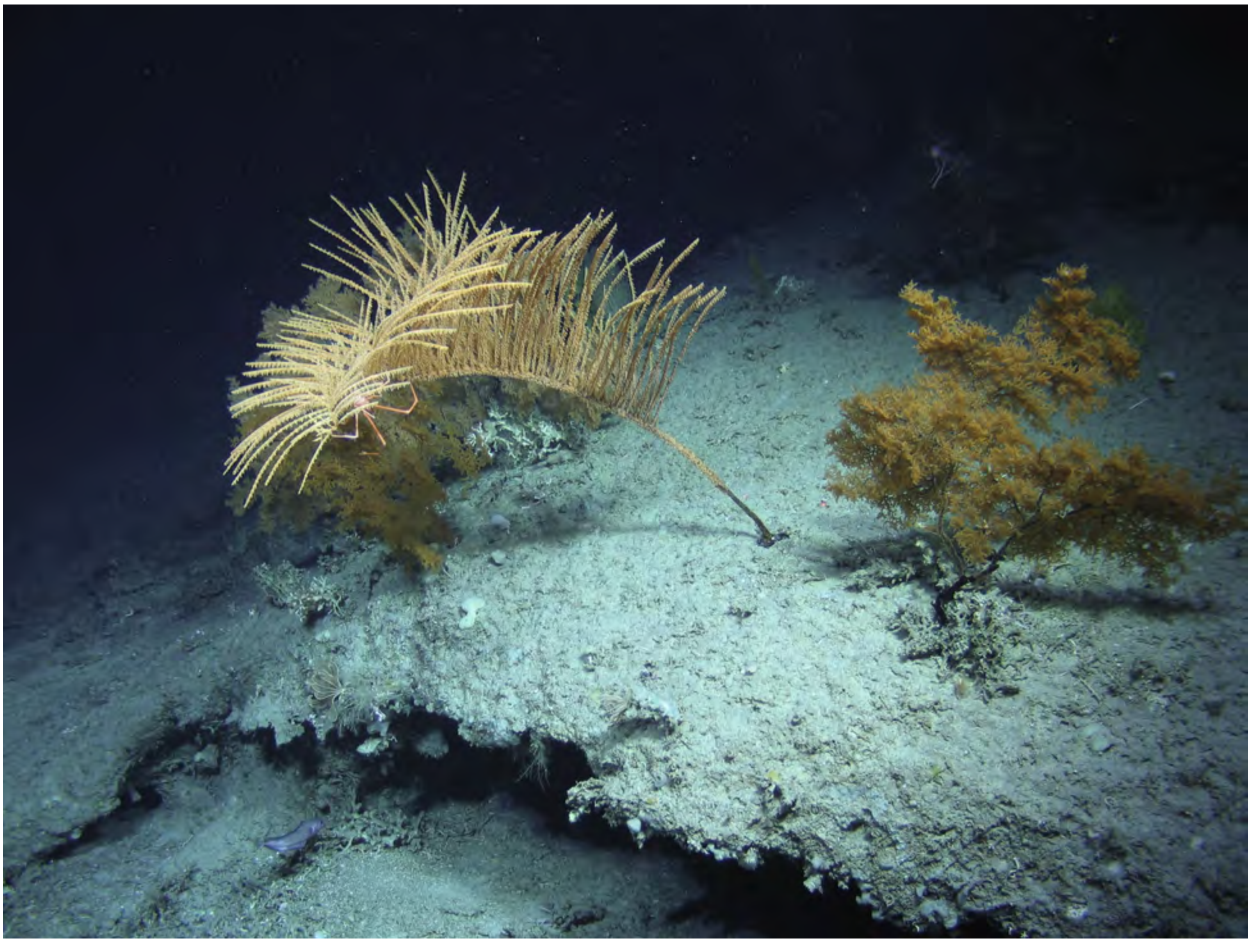


Figure 20. A variety of black corals on geogenic reef (dive 543).

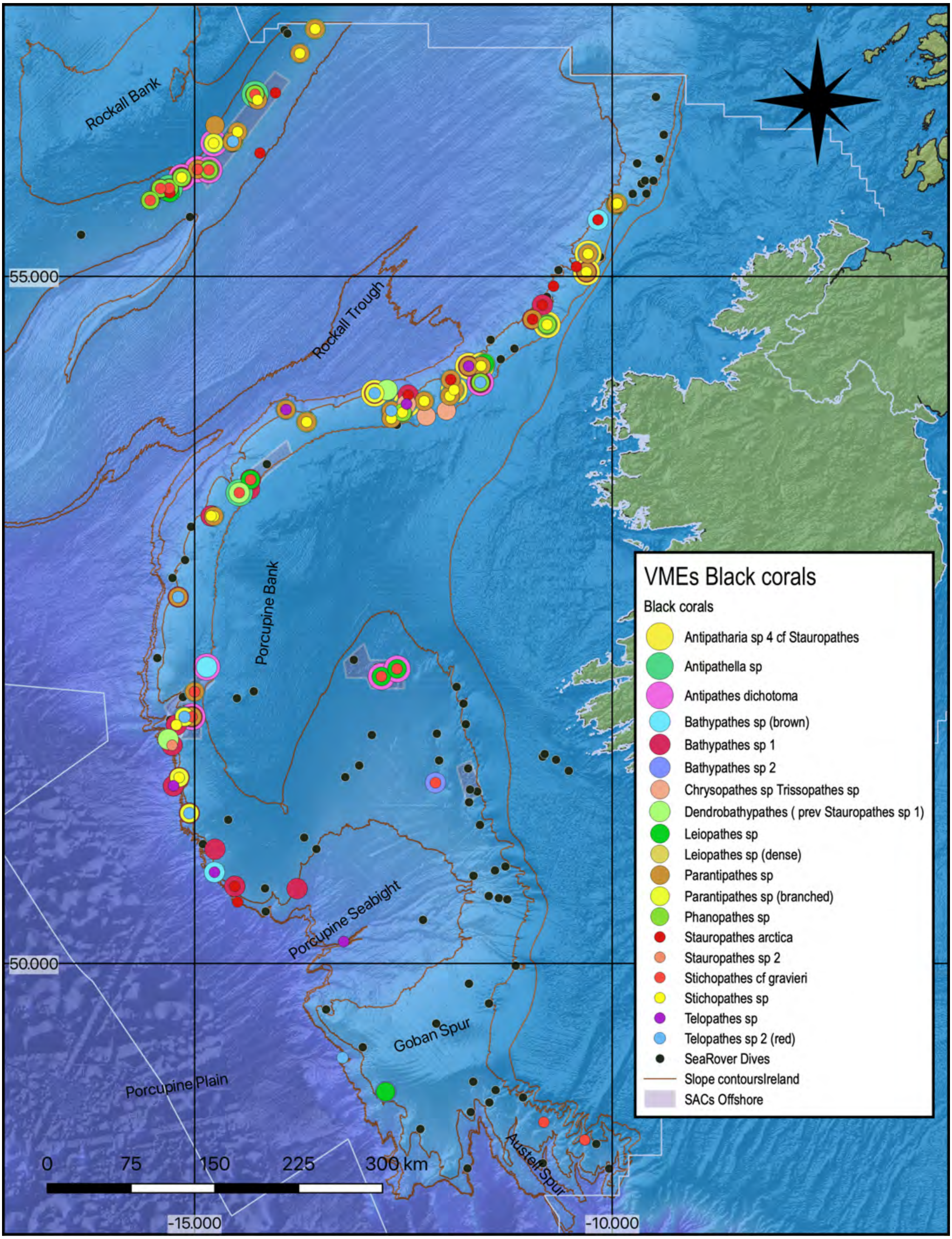


Figure 21. Distribution of the species of black coral recorded by SeaRover. An area of high diversity is apparent on the north west continental slope.

Figure 22. Large pink sea fan with brisingid starfish and the scleractinian coral Solenosmilia variabilis *(dive 535).*

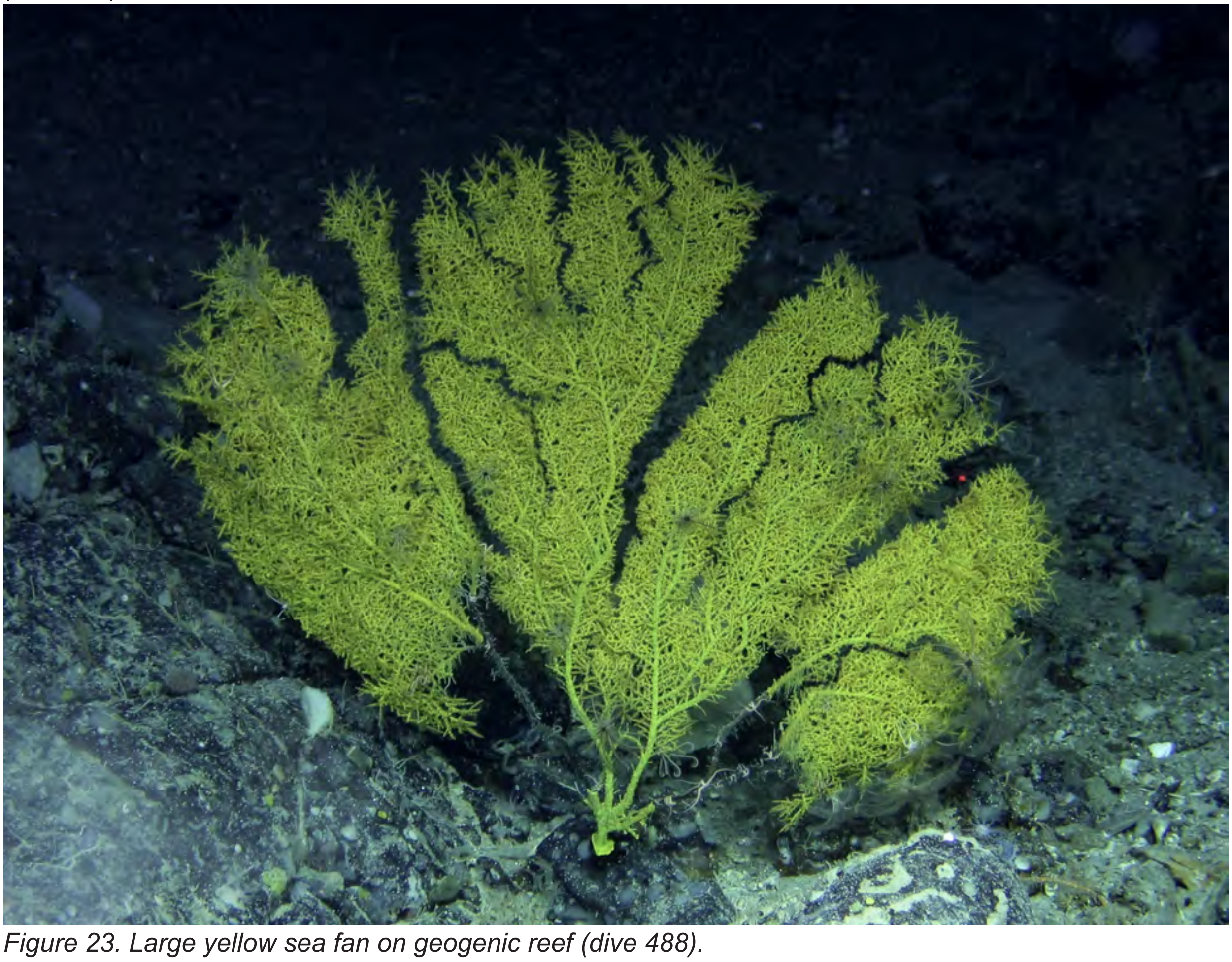


Figure 23. Large yellow sea fan on geogenic reef (dive 488).

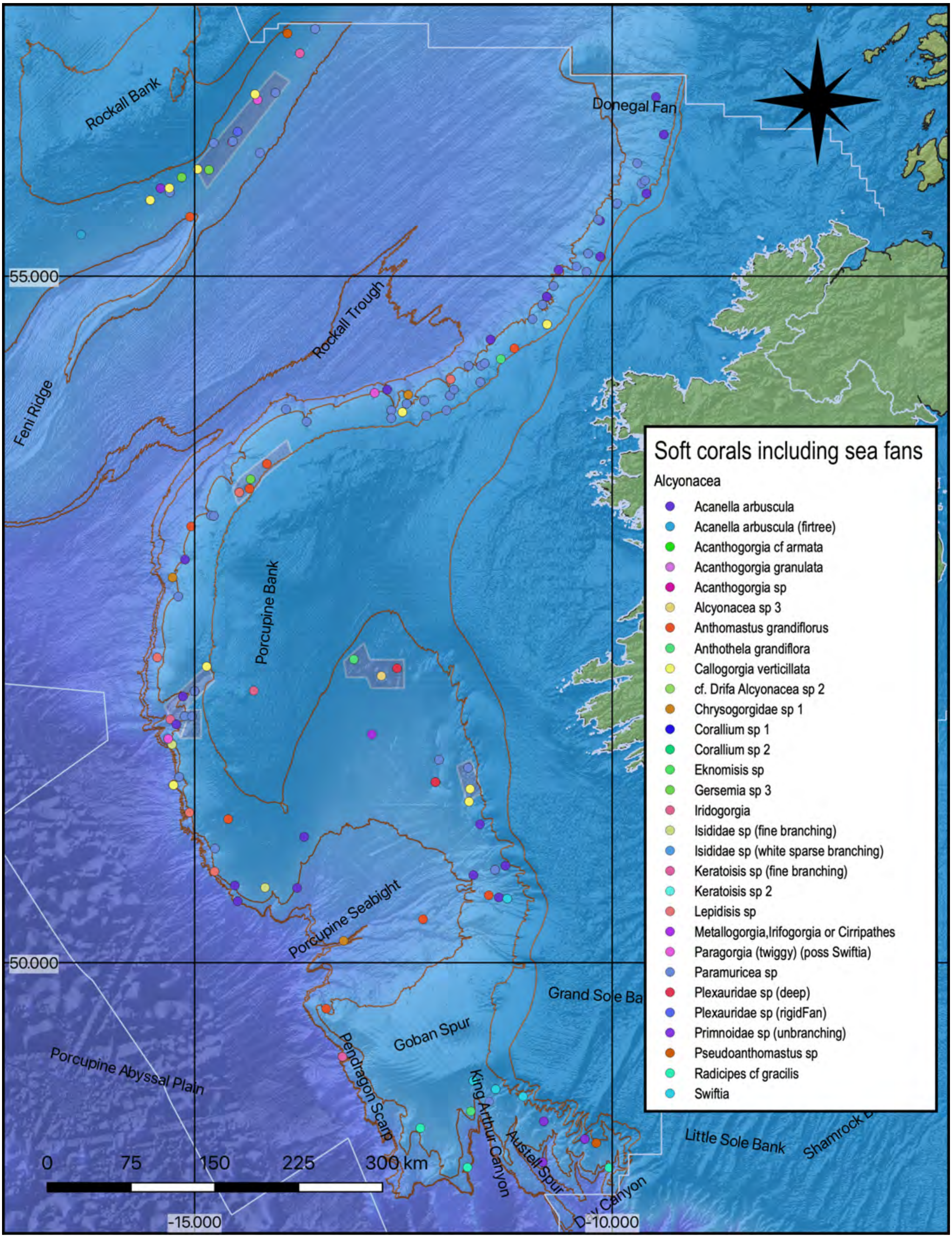


Figure 24. Distribution of the species of soft coral recorded by SeaRover. An area of high diversity is apparent on the north-west continental slope.

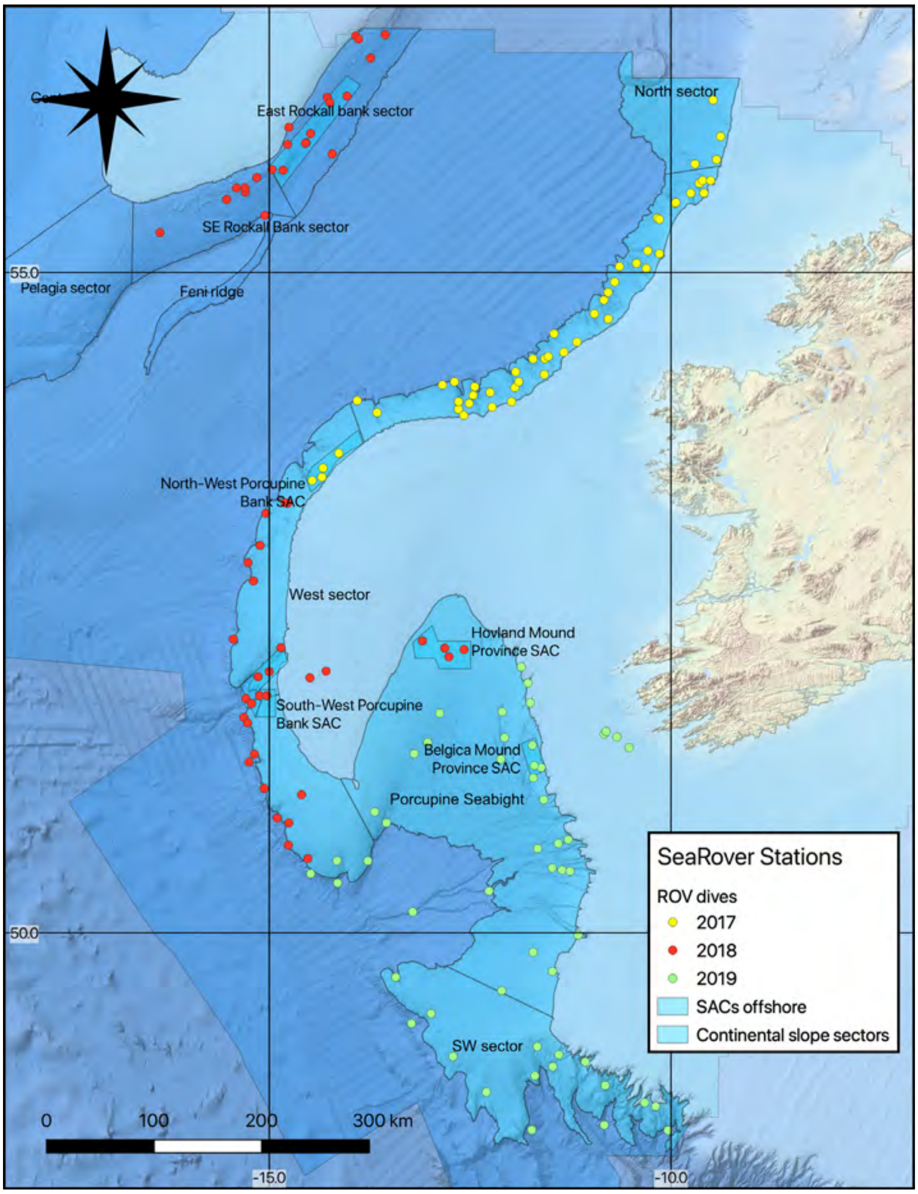


Figure 25. Sectors used to calculate the area of sectors for estimating amount of lost fishing gear on the seabed of Ireland's continental slope.

Table 6. The area of seabed for different sectors of Ireland's continental slope based on Figure 25 above. The area covered by SeaRover and number of encounters with lost fishing gear are used here to estimate the abundance of discarded fishing gear on Ireland's continental slope.

Explanation	Name	Area km^2	Area m^2	Dives as % of Continental slope	
	North sector	5352	5352000000		
	NW Sector	9288	9288000000		
	West sector	8537	8537000000		
	Porcupine Bank sector	8527	8527000000		
	Porcupine Seabight	38537	38537000000		
	SW sector	18026	18026000000		
Total area of adjacent slope between -540 and -2600 m	Continental slope total	88267	88267000000		
Area surveyed by SeaRover		0.76	761811	0.0009%	
Number of dives where fishing gear was encountered					42

3.3 Seabed pressures from marine litter, trawl marks and fishing gear

Marine litter (non-fishing gear)

Marine litter is defined as 'any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine or coastal environment. It consists mainly of very slowly degrading waste items such as plastic, metals and glass. It can have damaging ecological and economic effects on the seabed, in the water column and on the seashore' (Marine Institute, 2013). According to the Marine Institute Report (2013), the main sources of sea-based litter are fishing and shipping (Figure 26).

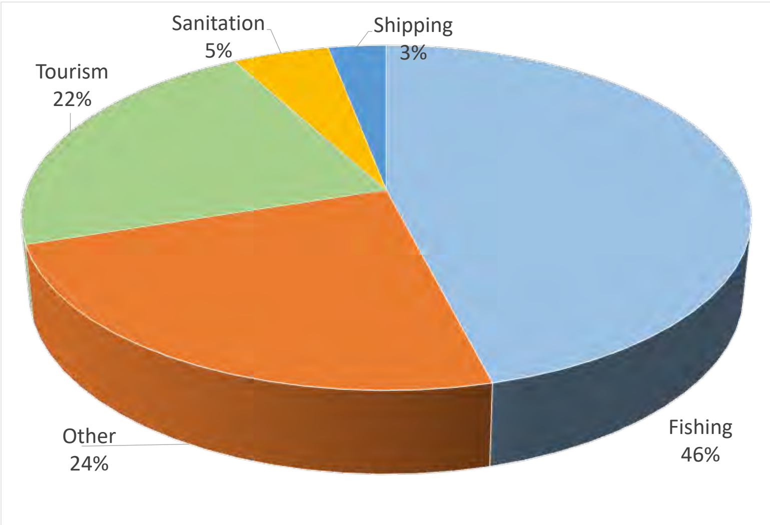


Figure 26. Based on Figure 9 (Marine Institute, 2013) Proportions of beach litter collected on surveys of four beaches in 2011 and assigned to broad source categories.

Figure 27. Marine litter: plastic bag caught under a ledge, fishing line in the foreground and a dead bamboo coral (white with black joints).

One of the aims of the SeaRover survey was to record the frequency and type of marine litter encountered on the seabed. Figure 27 shows a plastic bag caught under a ledge, there is also fishing line in foreground and broken bamboo coral. Figure 28 shows a black plastic bag caught on a large sea fan. Figure 29 is a distribution map showing the areas of seabed where SeaRover encountered marine litter that was non-fishing gear. The majority of this litter was found in the NW sector of the continental slope.

Trawl marks

Figure 32 shows the SeaRover transects where trawl marks were encountered, the majority of these were also in the NW sector of the continental slope. Trawl marks were not often recorded but areas which were partly flattened to dead rubble were observed in some places including the NW Porcupine Bank SAC.

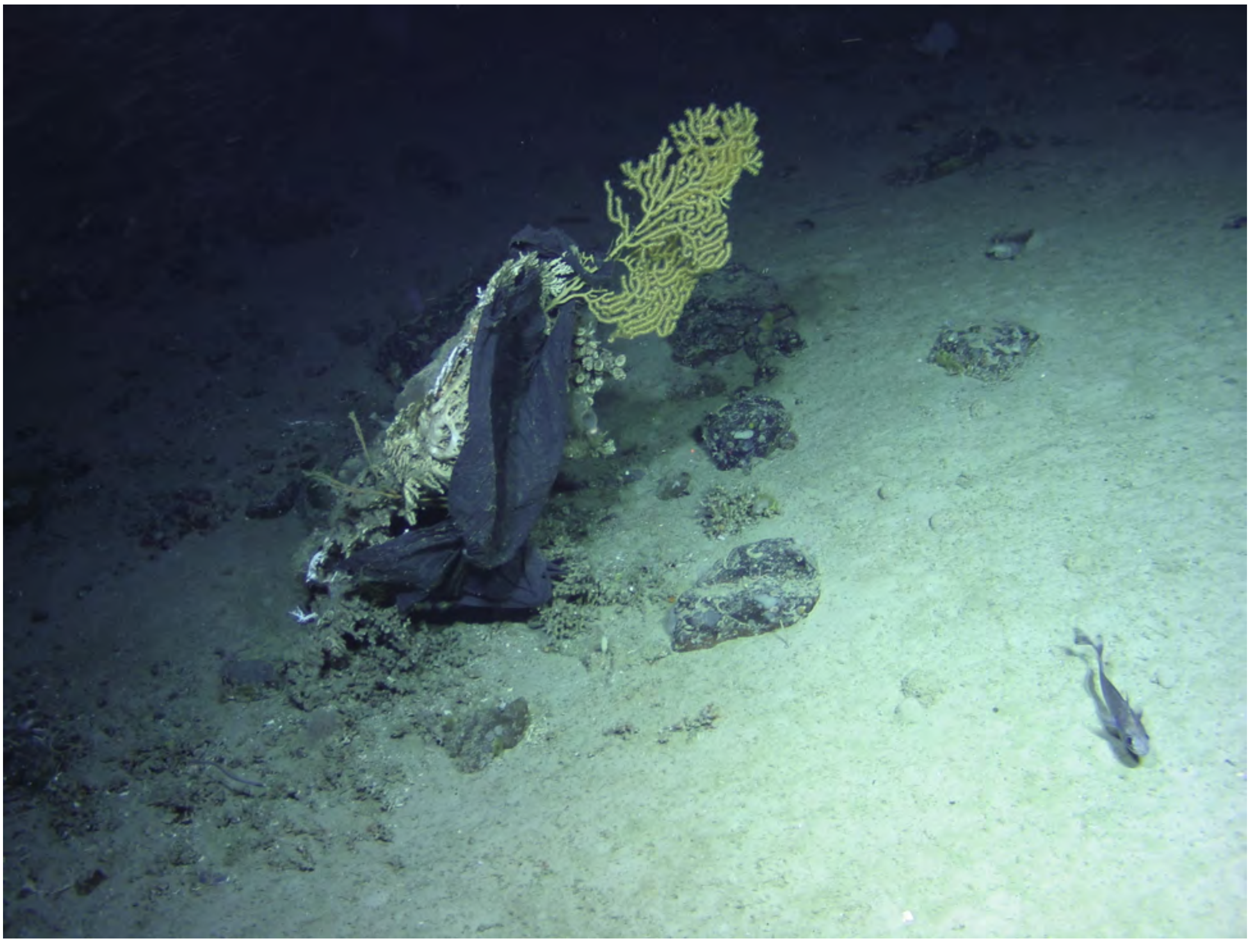


Figure 28. Marine litter was frequently observed. This included plastic bags caught on corals and even a neatly tied black plastic bag, upright on the seabed.

Lost fishing gear

Figure 31 shows a range of discarded fishing gear as well as plastic litter caught up on an isolated rocky reef. Figure 33 shows a lost gill net in which a blackbelly rosefish (*Helicolenus dactylopterus*) has become entangled, this illustrates the problem that ghost fishing poses in the deep sea. In Figure 34 fishing line is entangled on an escarpment and is entangled around a piece of detached coral. Figure 35 shows the transects where lost fishing gear was encountered. The most commonly recorded gear was nylon gill nets and long lines, but trawl nets were also observed. Escarpments where fishing lines were caught on the protruding rock and corals were broken off on the adjacent seabed were also recorded. Table 6 calculated that the SeaRover survey covered approximately 761811 m^2 of seabed within the adjacent continental slope (excluding Rockall Bank). The area of continental slope between -540 to -2600 m (Figure 25) was calculated to be 88267 km^2 (just over 0.0009% was surveyed visually by SeaRover). SeaRover observed discarded fishing gear on 42 dives within this area.

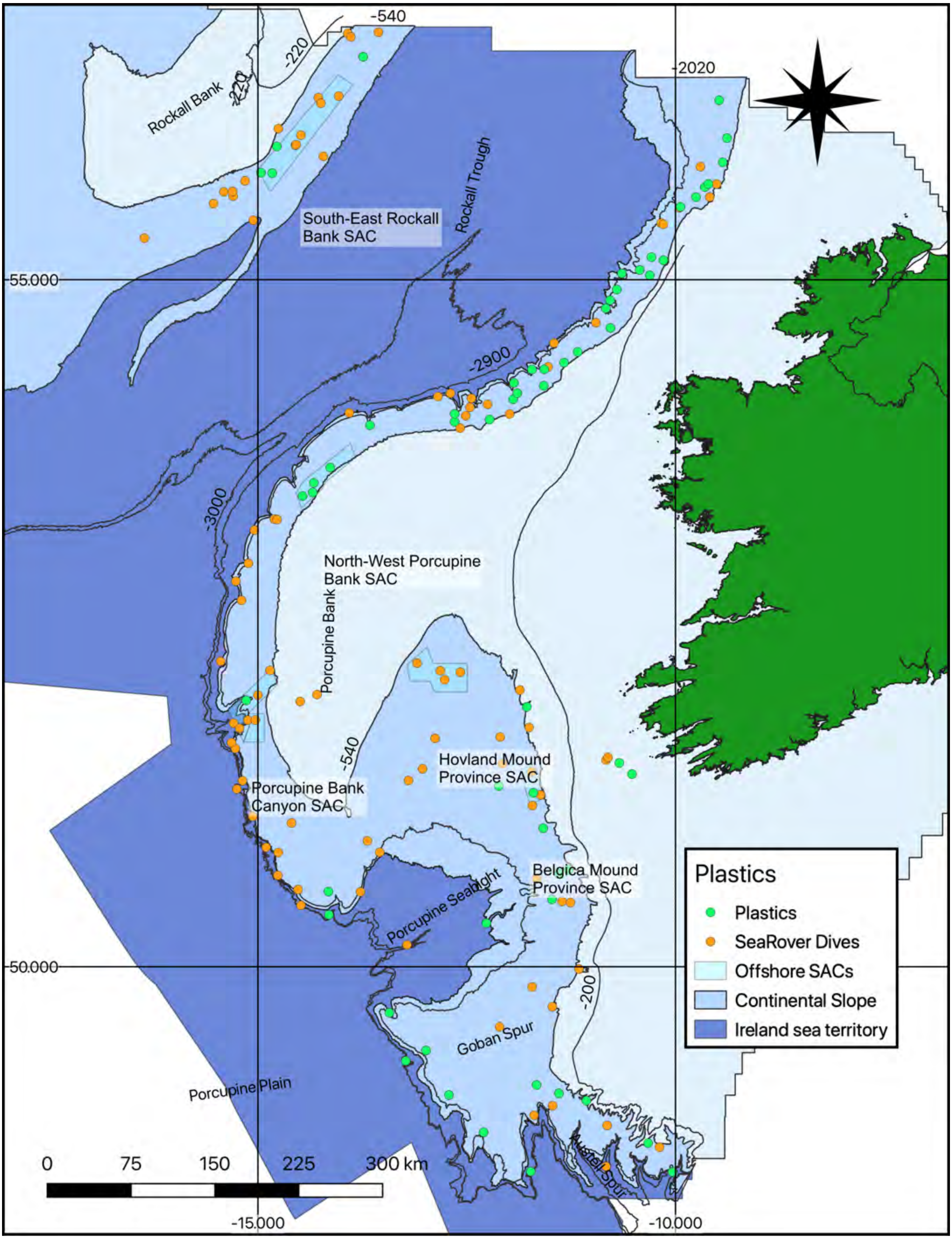


Figure 29. Distribution of SeaRover dives with observations of marine litter marked in green. The NW sector of the continental slope had the most litter.

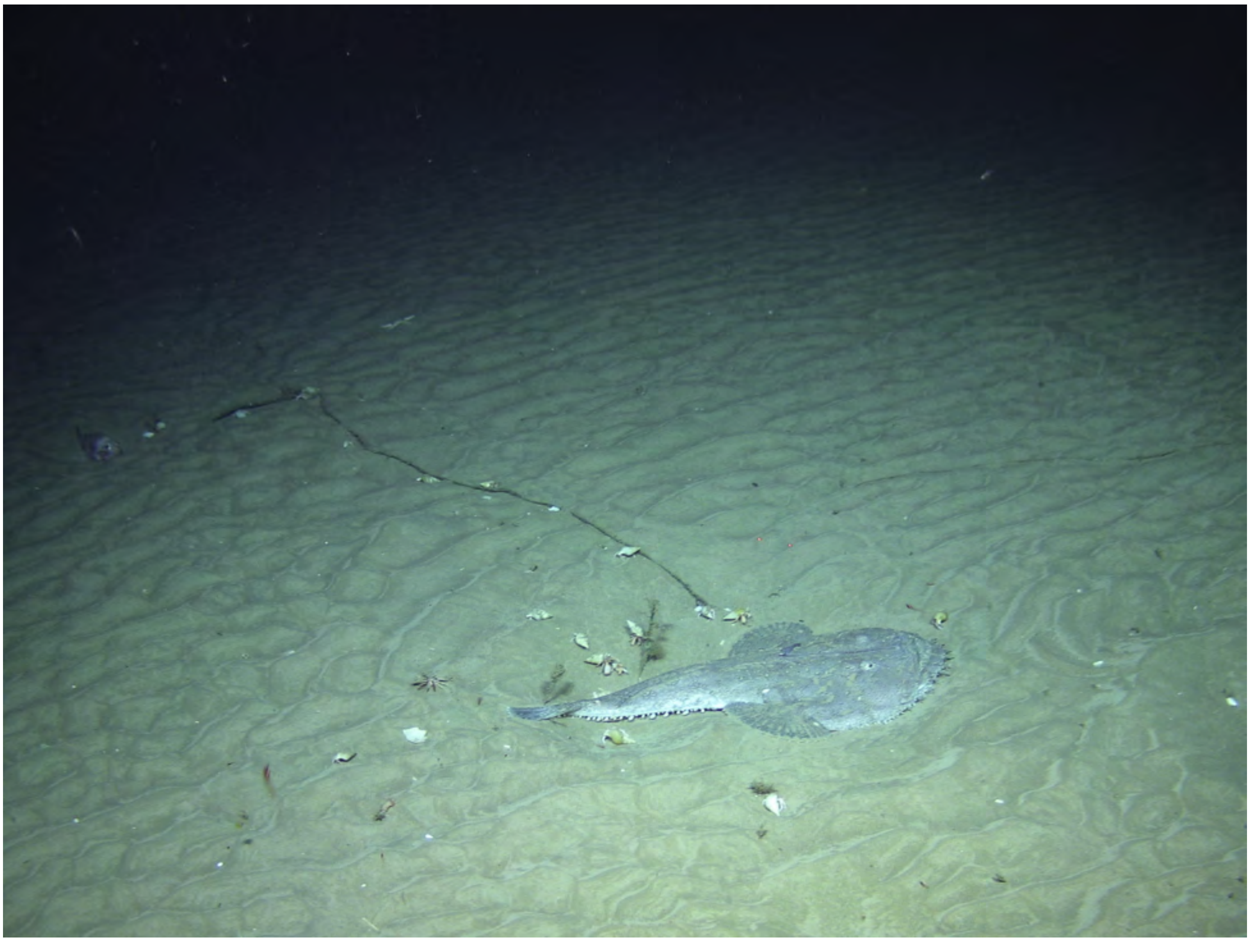


Figure 30. Lophius piscatorius*, the monkfish or anglerfish is the target of a substantial fishery on the Porcupine Bank. They were frequently observed in areas of coral rubble.*

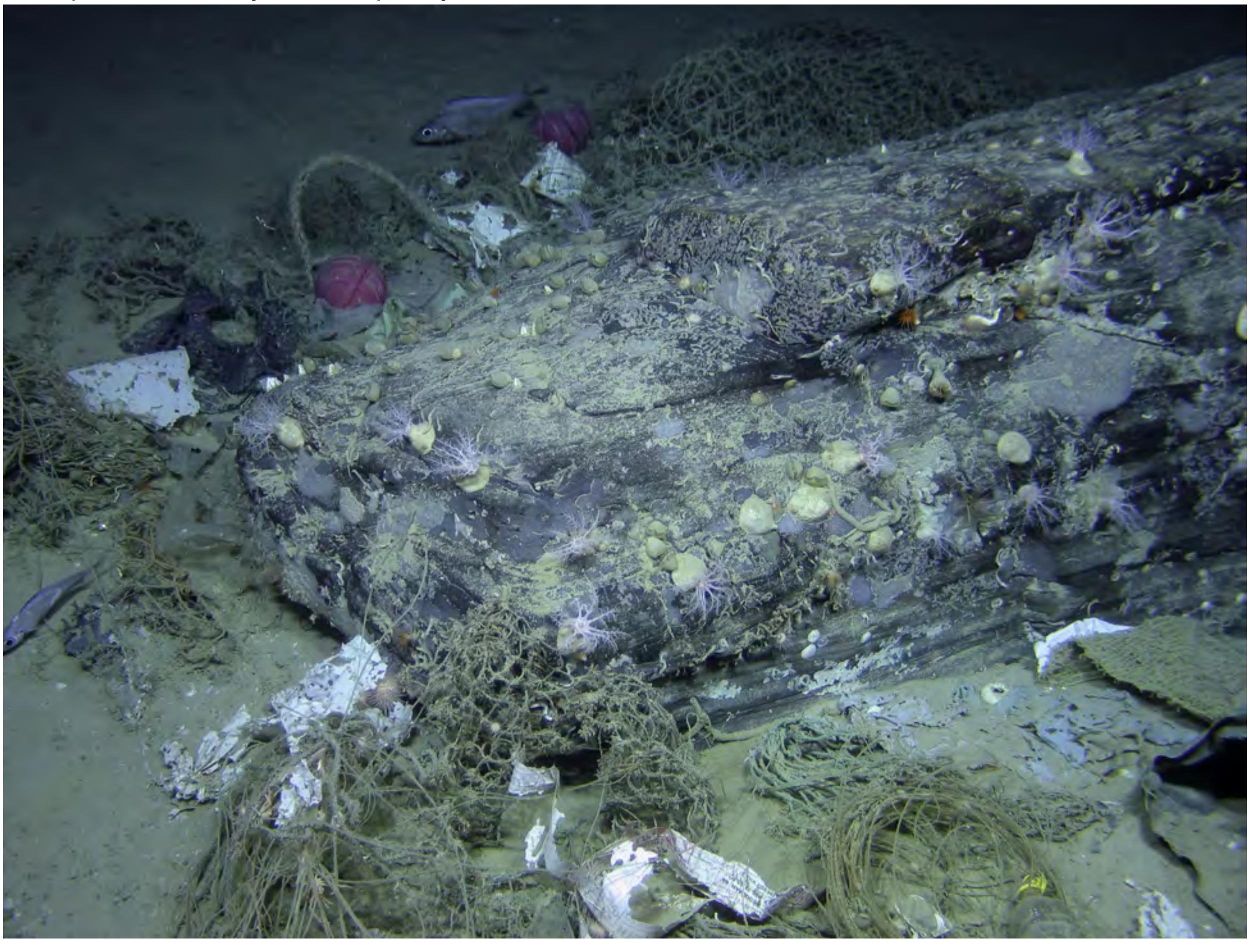


Figure 31. Plastics and fishing gear accumulating in the scour pit around a large isolated rock.

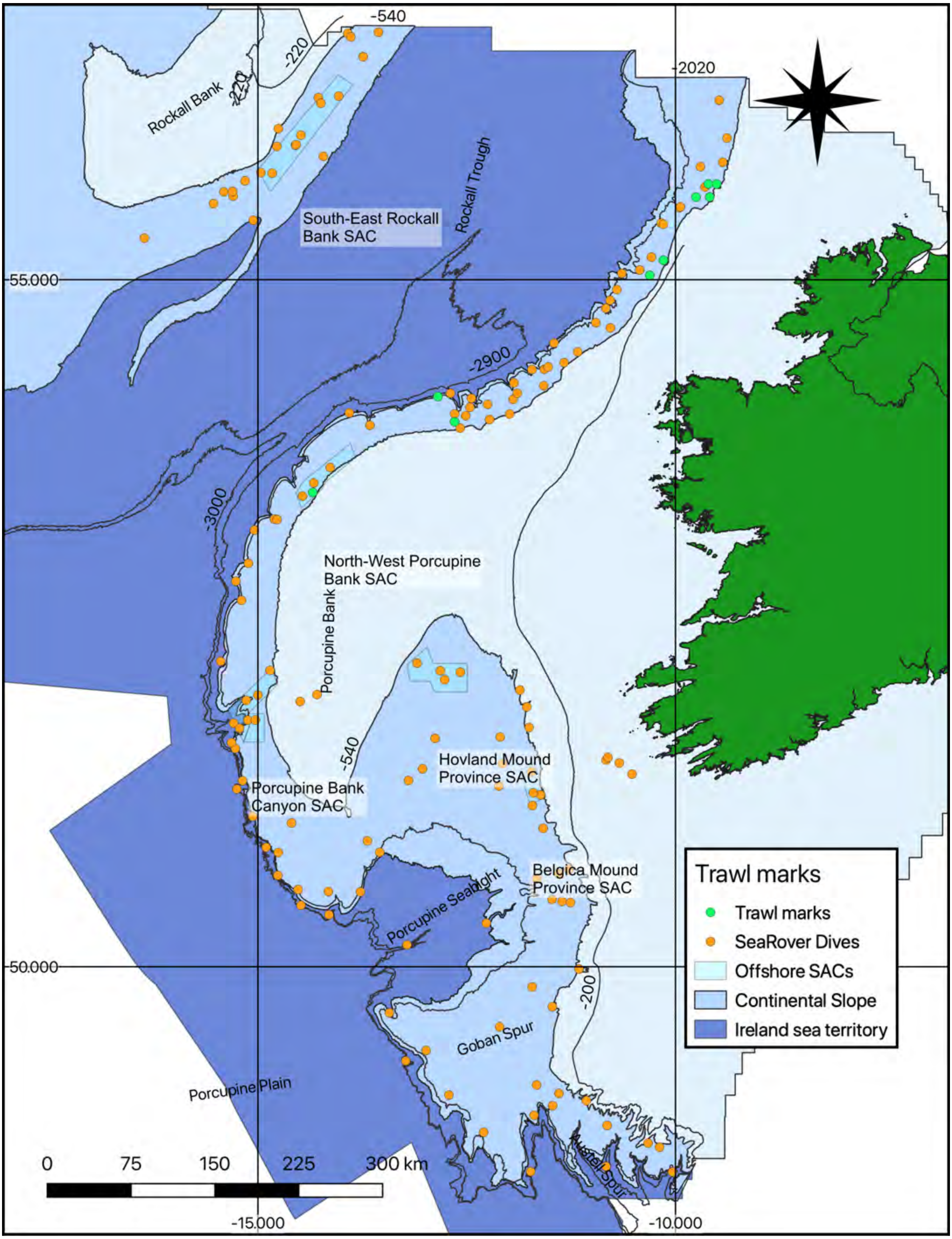


Figure 32. Trawl marks were not often observed, but areas of coral which were partly flattened to dead rubble were seen in some places, including the NW Porcupine Bank SAC.

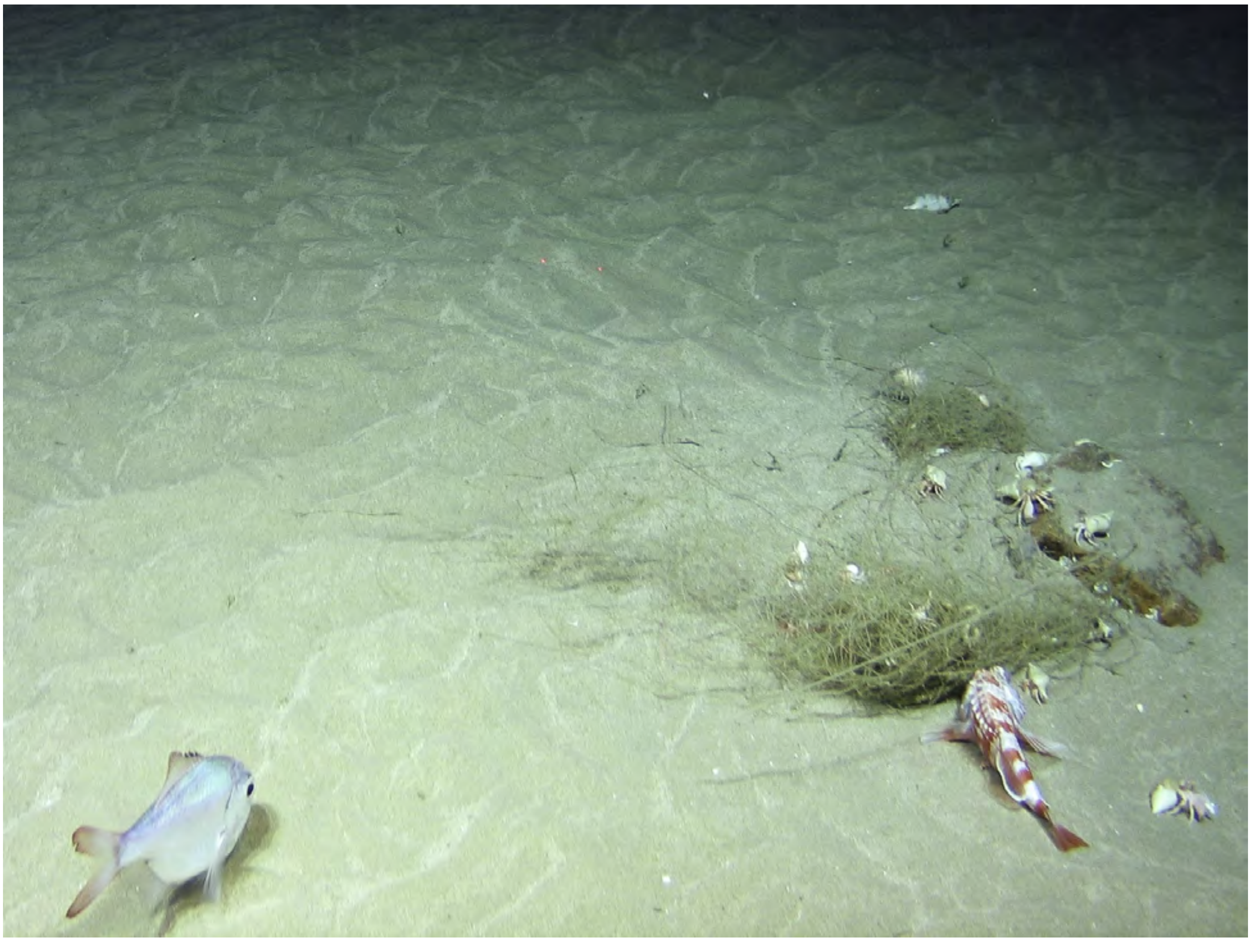


Figure 33. Lost gill net entangled on a rock and ghost fishing. Hermit crabs are numerous.

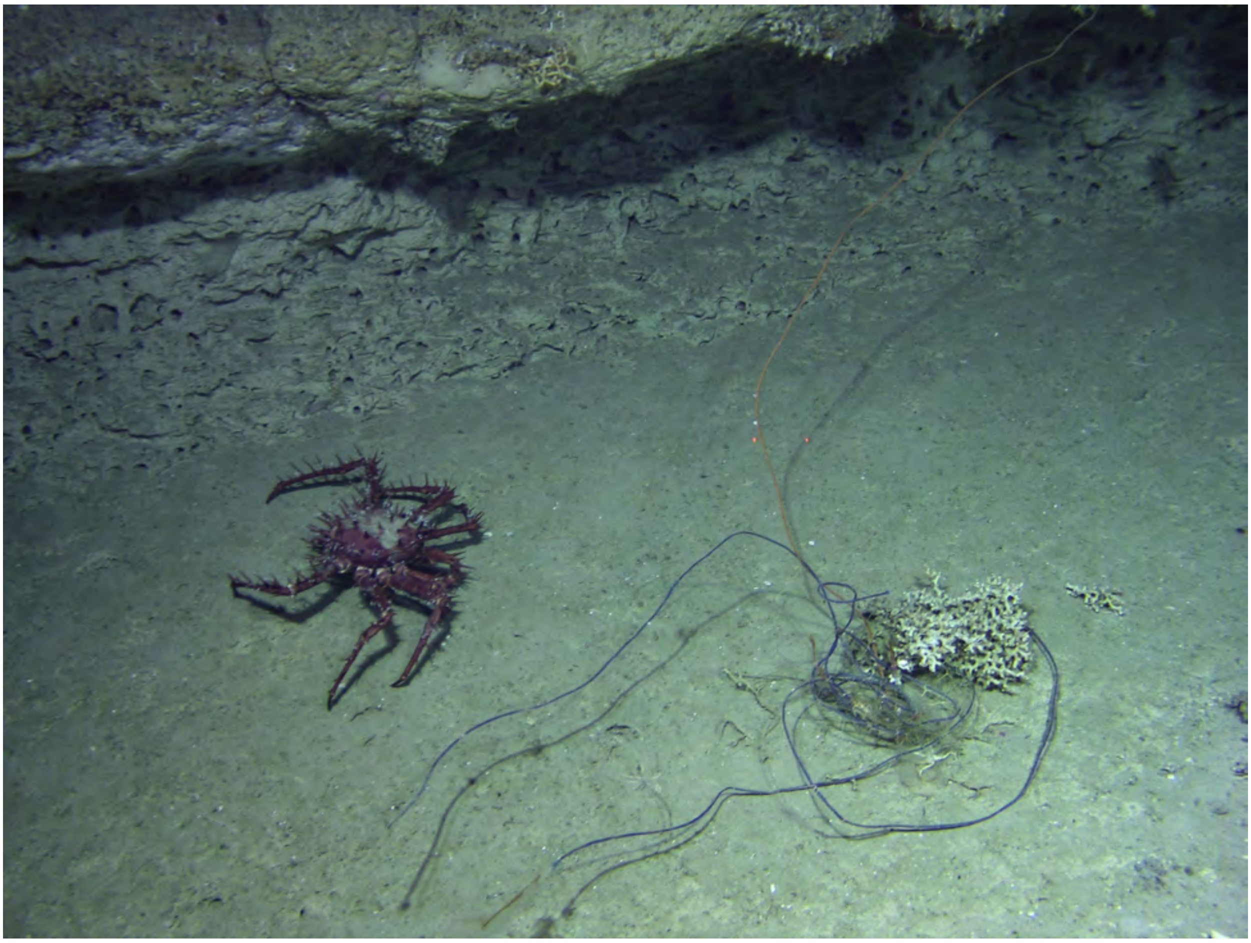


Figure 34. Fishing lines entangled on an escarpment and around a detached piece of coral.

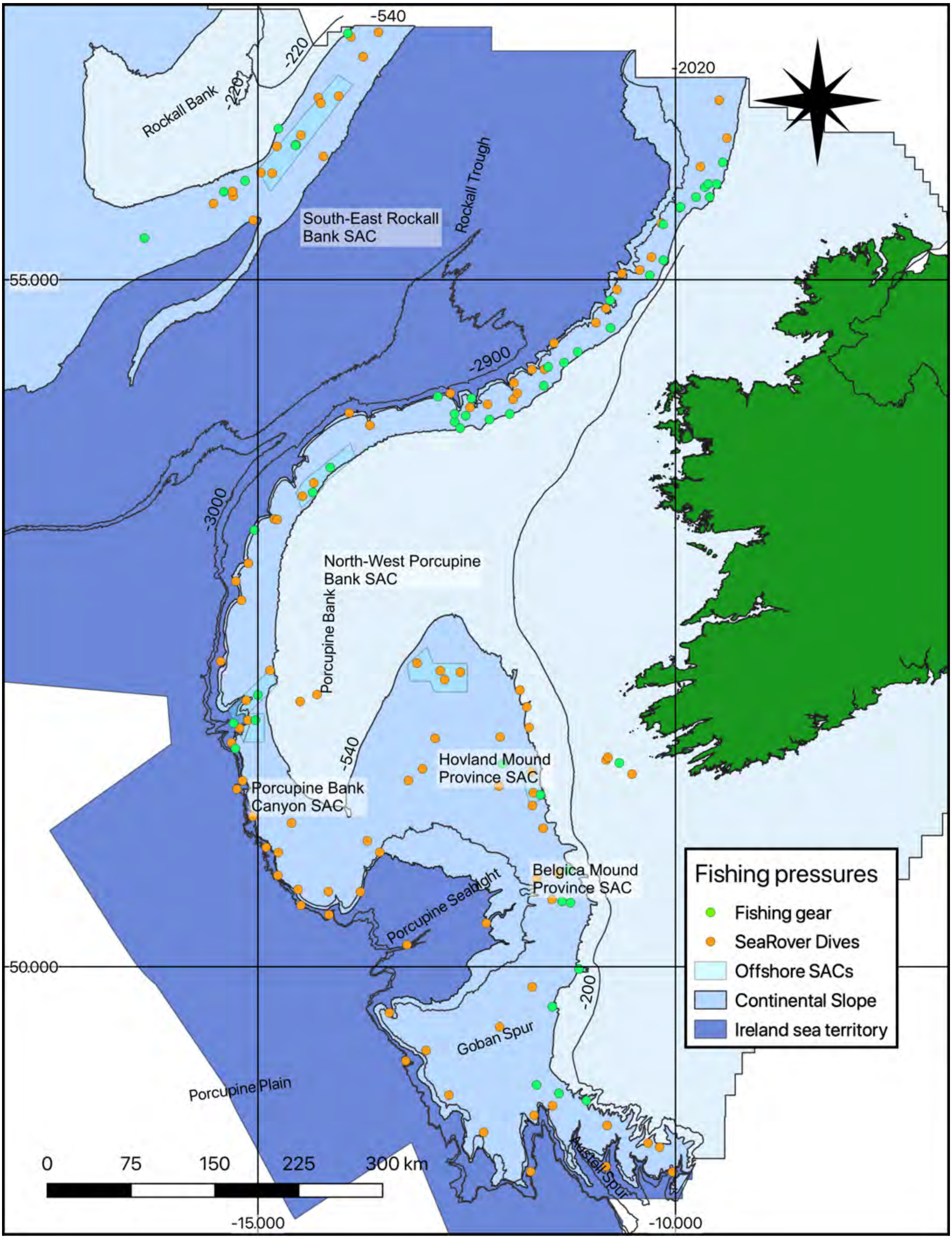


Figure 35. Lost fishing gear, most commonly nylon gill nets and long lines, but also trawl nets, were frequently observed. Escarpments were seen where lines were caught on the protruding rock and corals were broken off on the adjacent seabed.

Role of the continental shelf in fisheries

The most productive fisheries in the world are associated with continental slopes (Huang et al., 1991, Carr & Kearns, 2003, Jacobs et al., 2020). Surface waters receive sunlight and are the start of the food chain, with planktonic algae combining nutrients, carbon dioxide and water to grow and reproduce at a fast pace when conditions are not limited by nutrient availability. These planktonic algae are consumed by planktonic animals, predominantly copepod crustaceans. These animals are then eaten by larger animals, especially fish and fish larvae. Copepods are the major food of fish from sardines to basking sharks.

Surface waters quickly become nutrient poor as nitrogen and phosphorous are taken up by the plant plankton and this limits food production in most parts of the ocean. Near to shore these nutrients are replenished by run off from the land during periods of rainfall, which in the north east Atlantic is mostly in the winter, when light is the limiting factor for plant growth. Offshore, at the continental margin these nutrients are replenished due to upwelling from deep ocean water, sustaining plankton production and fisheries throughout the year.

Figure 36 demonstrates the fact that high levels of productivity for fish living in the water column are in the waters above the continental slope, where high productivity occurs due to upwelling and the habitats on the seabed and in the canyons which provide food and shelter larvae.

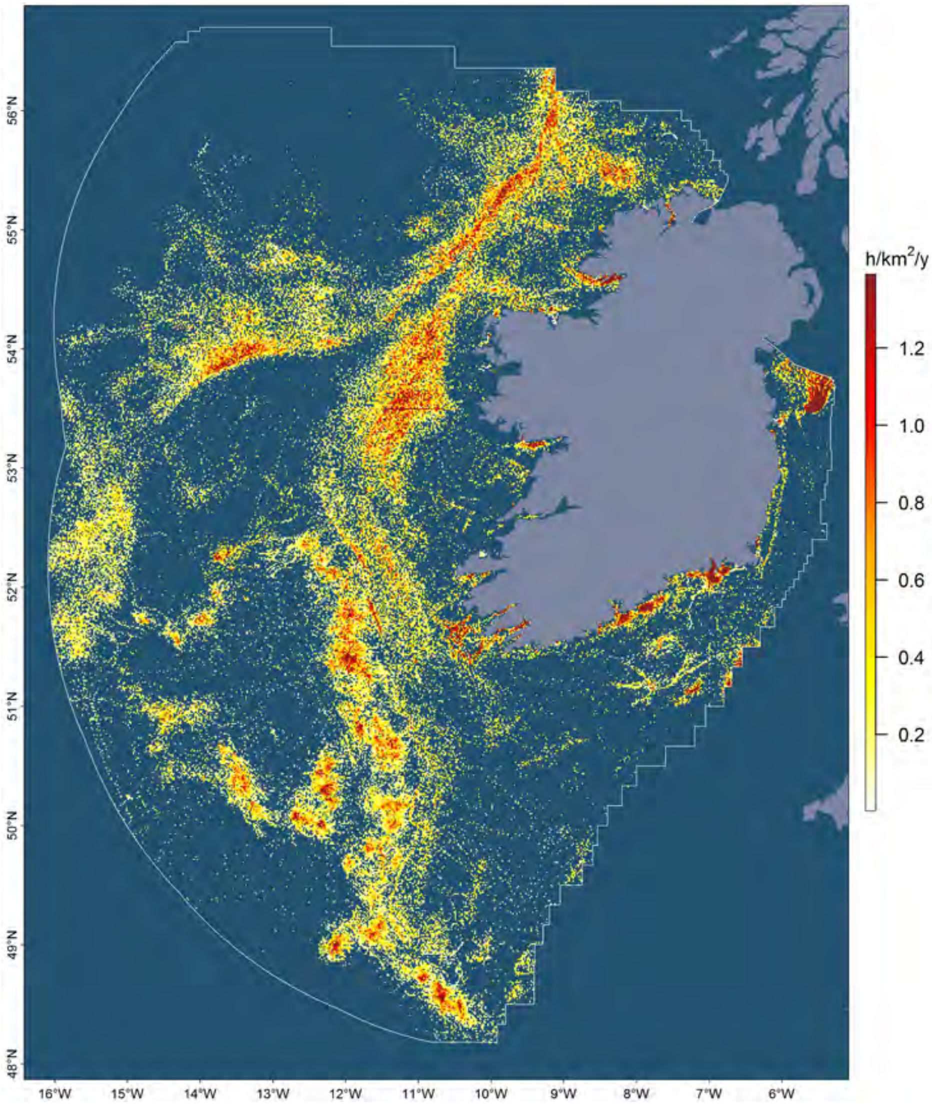


Figure 36. (Figure 35: Distribution of international pelagic trawl effort in the Irish EEZ in 2014-18, page 39 from Gerritsen & Kelly, 2019 Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.)

On an average day, approximately 500 fishing vessels are active in the waters of Ireland Exclusive Economic Zone (EEZ), clocking up more than 1.8 million fishing hours per year. Much of the seabed near Ireland is trawled at least once per year and some regions are trawled more than 10 times per year. Fishing is one of the most significant ocean uses in the waters around Ireland. (Gerritsen & Kelly, 2019)

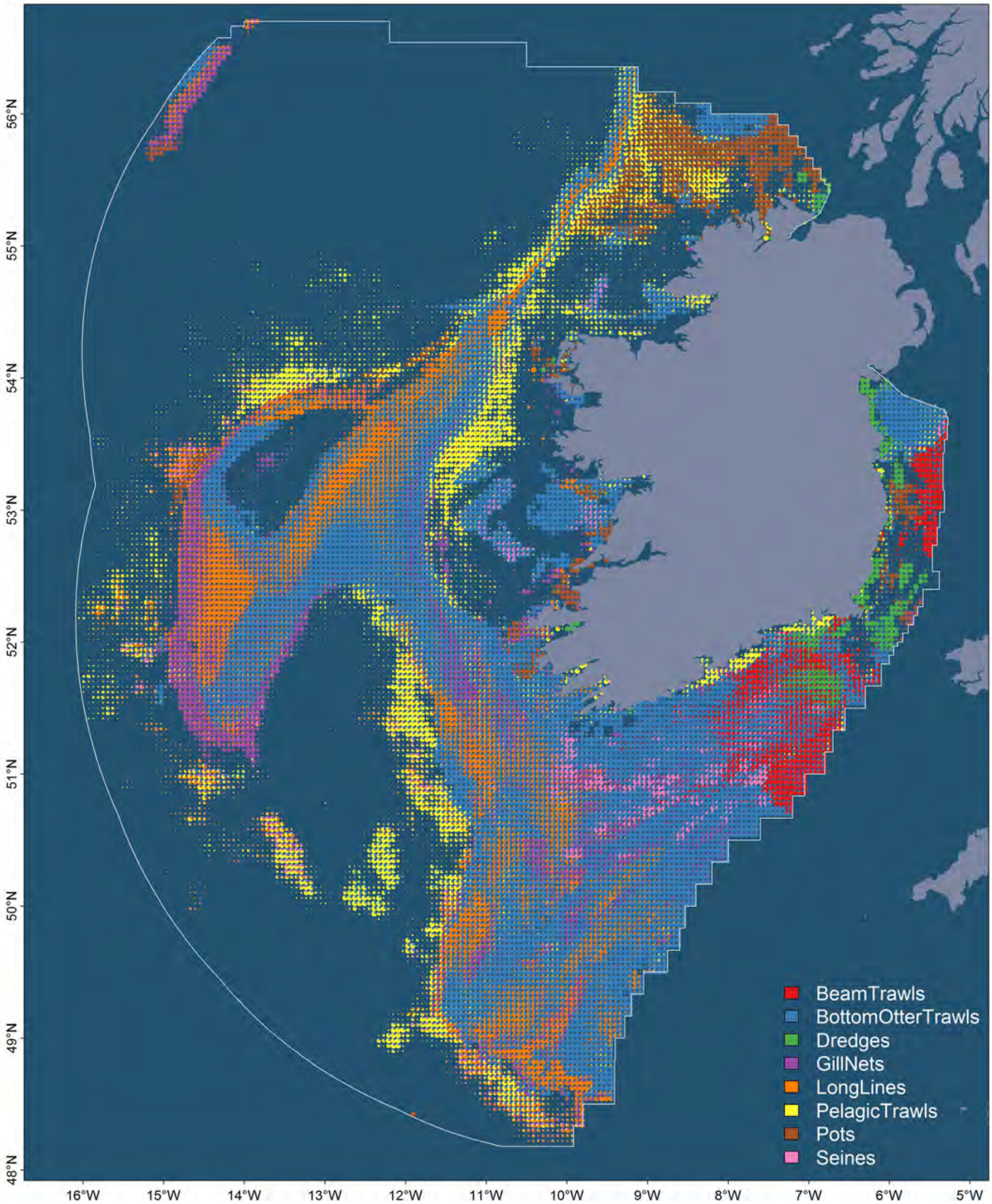


Figure 37. (Figure 5: Distribution of international fishing effort in Irish EEZ by gear 2014-18, page 8 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.)

The fisheries in Irish waters are highly diverse. The Irish otter trawl fleet alone can be divided into 33 distinct fisheries, each using a different fishing technique or targeting different species or groups of species. A large part of this heterogeneity in the fisheries can be explained by spatial patterns in the availability of the target species. Figure 37 demonstrates the fact that the continental slope is mainly fished by otter trawls, gill nets and long lines. Most of the lost fishing gear seen by SeaRover consisted of long lines and gill nets with occasional trawl nets and warps.

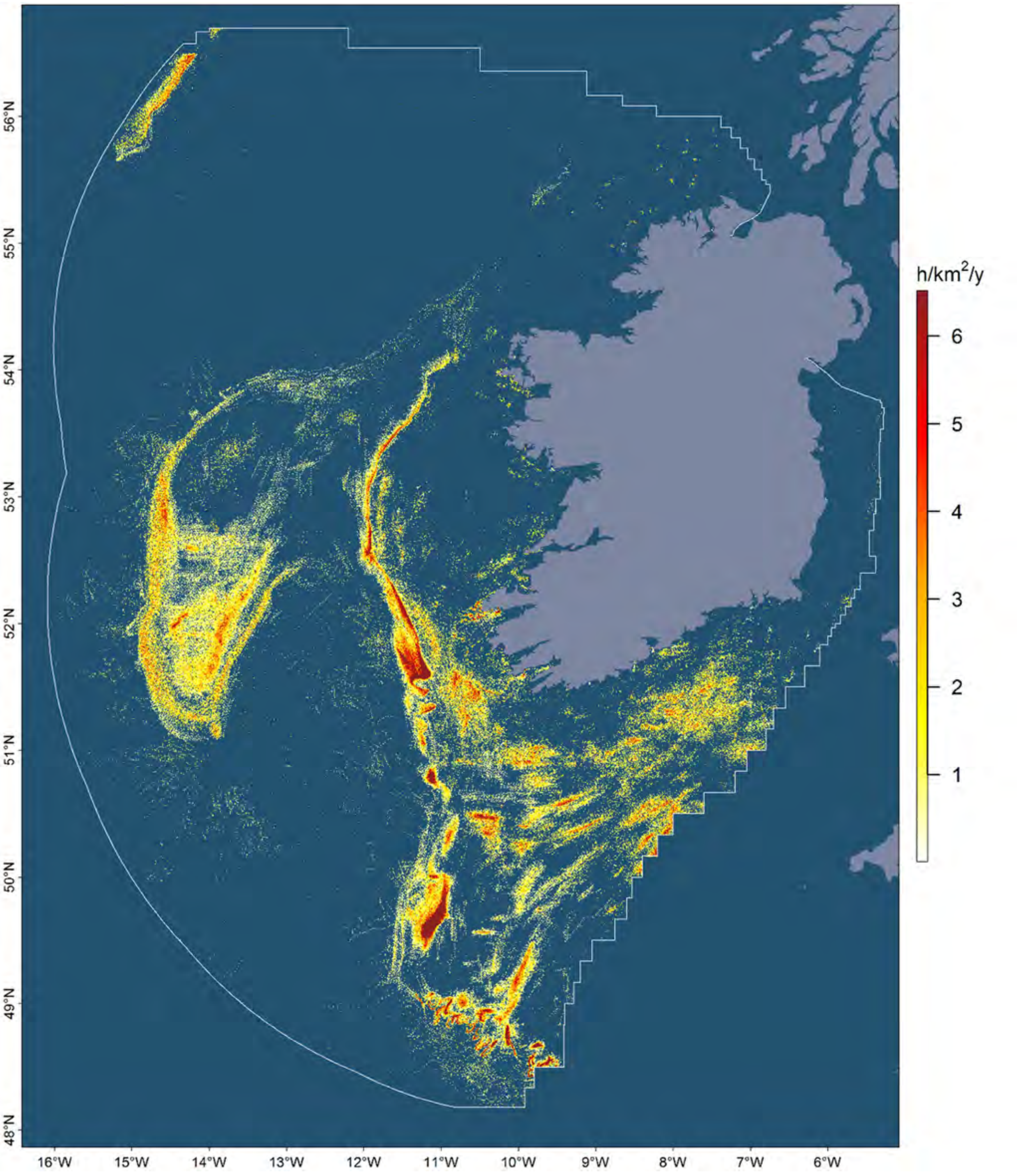


Figure 38. (Figure 19: Distribution of international gill net effort in the Irish EEZ in 2014-18, page 23 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.) International gill net effort is high in the SW and the outer part of the Porcupine Bank. Areas of high fishing effort are noticeable along the continental shelf edge.

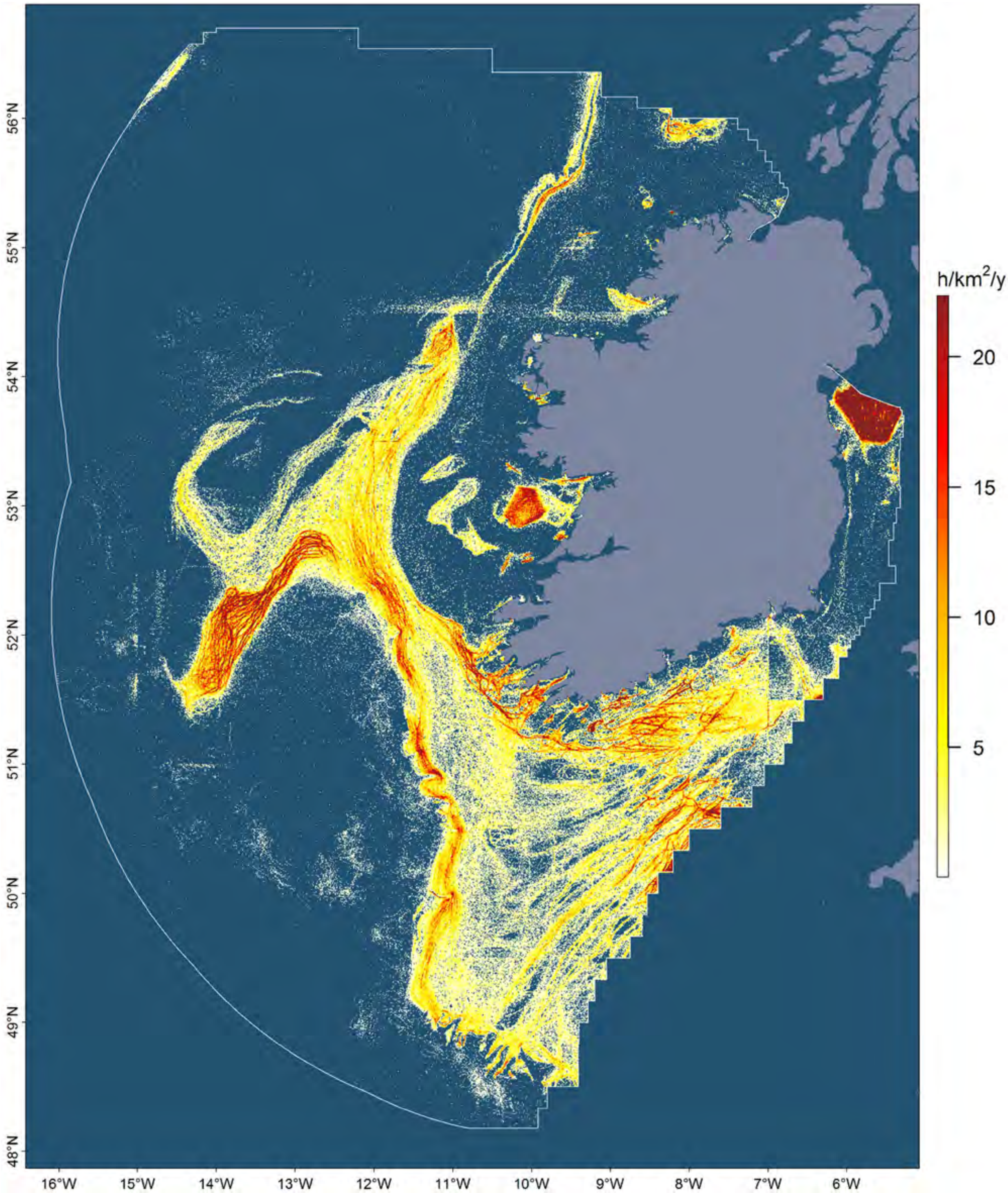


Figure 39. (Figure 7: Distribution of international demersal otter trawl effort in the Irish EEZ in 2014-18, page 11 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.) International trawl effort is concentrated on the slopes around the Porcupine Seabight and edge of the continental shelf in the south-west, with highly concentrated effort on the steep slope in the north-west.

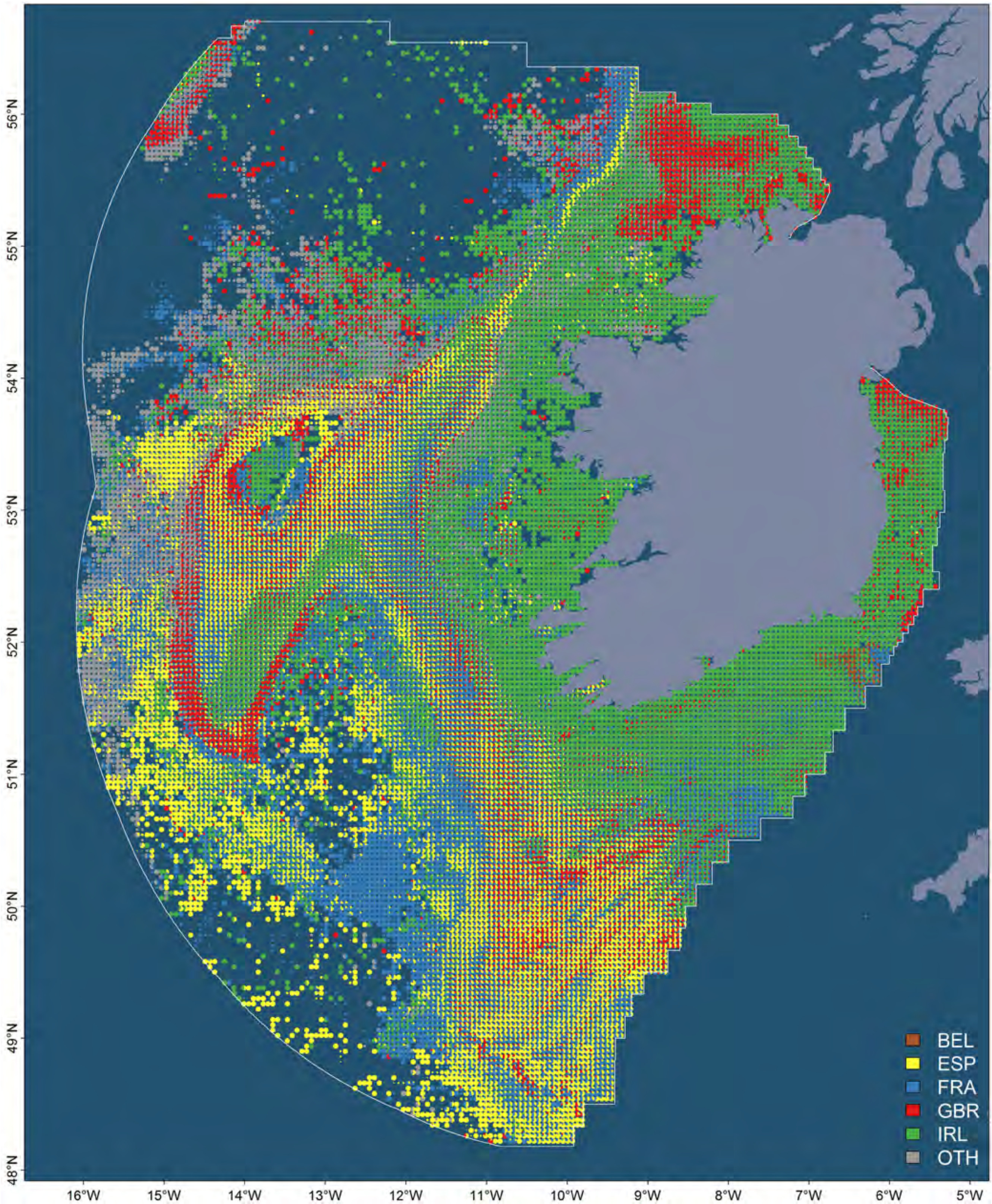


Figure 40. (Figure 6: Distribution of international fishing effort in the Irish EEZ by country 2014-18, page 9 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019). Points of note include the fact that most of the Irish fishing effort is relatively close to shore whilst Spanish and British boats tend to work the continental slope.

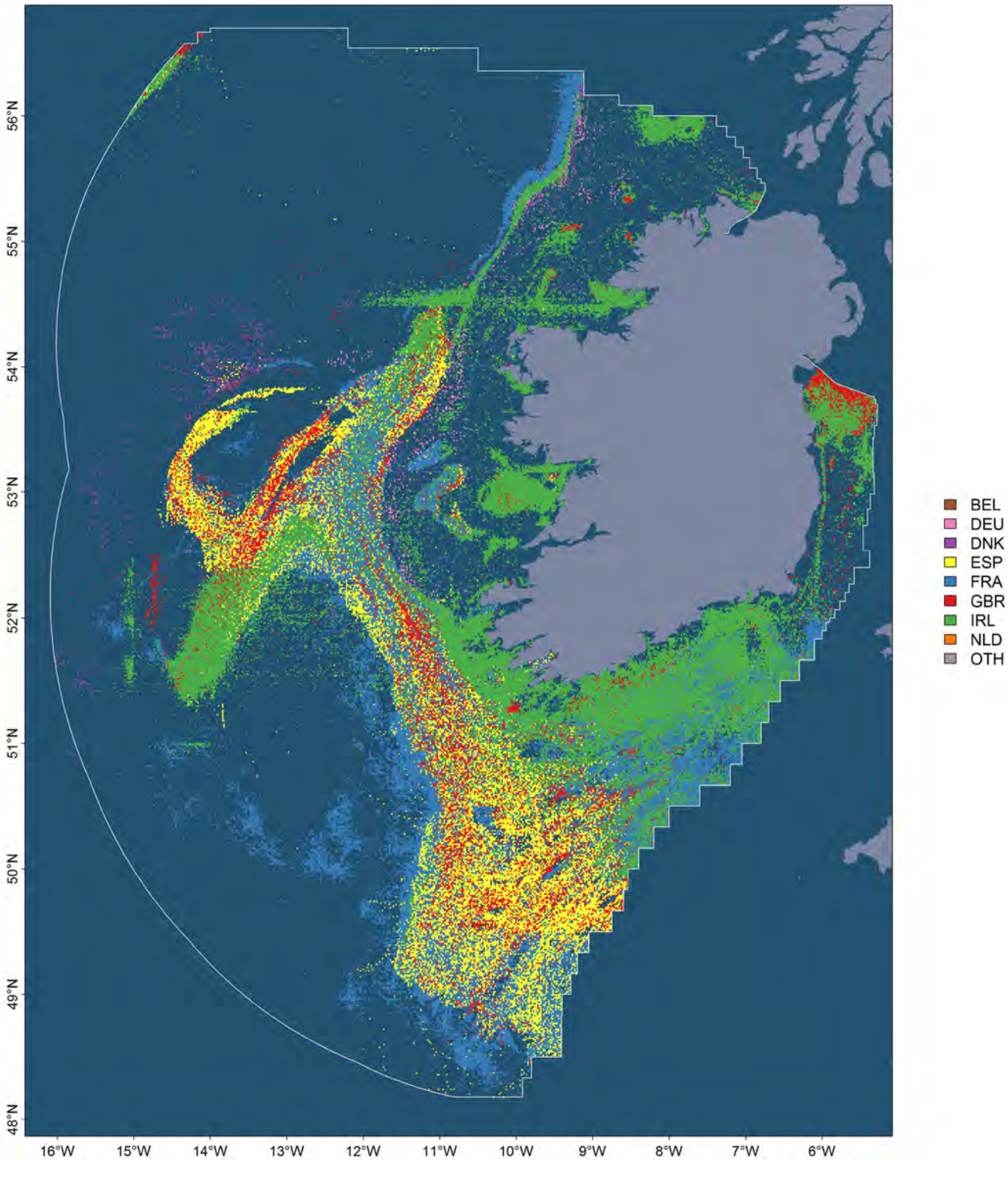


Figure 41. (Figure 8: Distribution of international demersal otter trawl effort in the Irish EEZ by country in 2014-18, page 12 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.) Note that Irish otter trawling effort is mostly conducted on the extensive relatively flat areas of the continental shelf whilst much of the international effort is further offshore in deeper water.

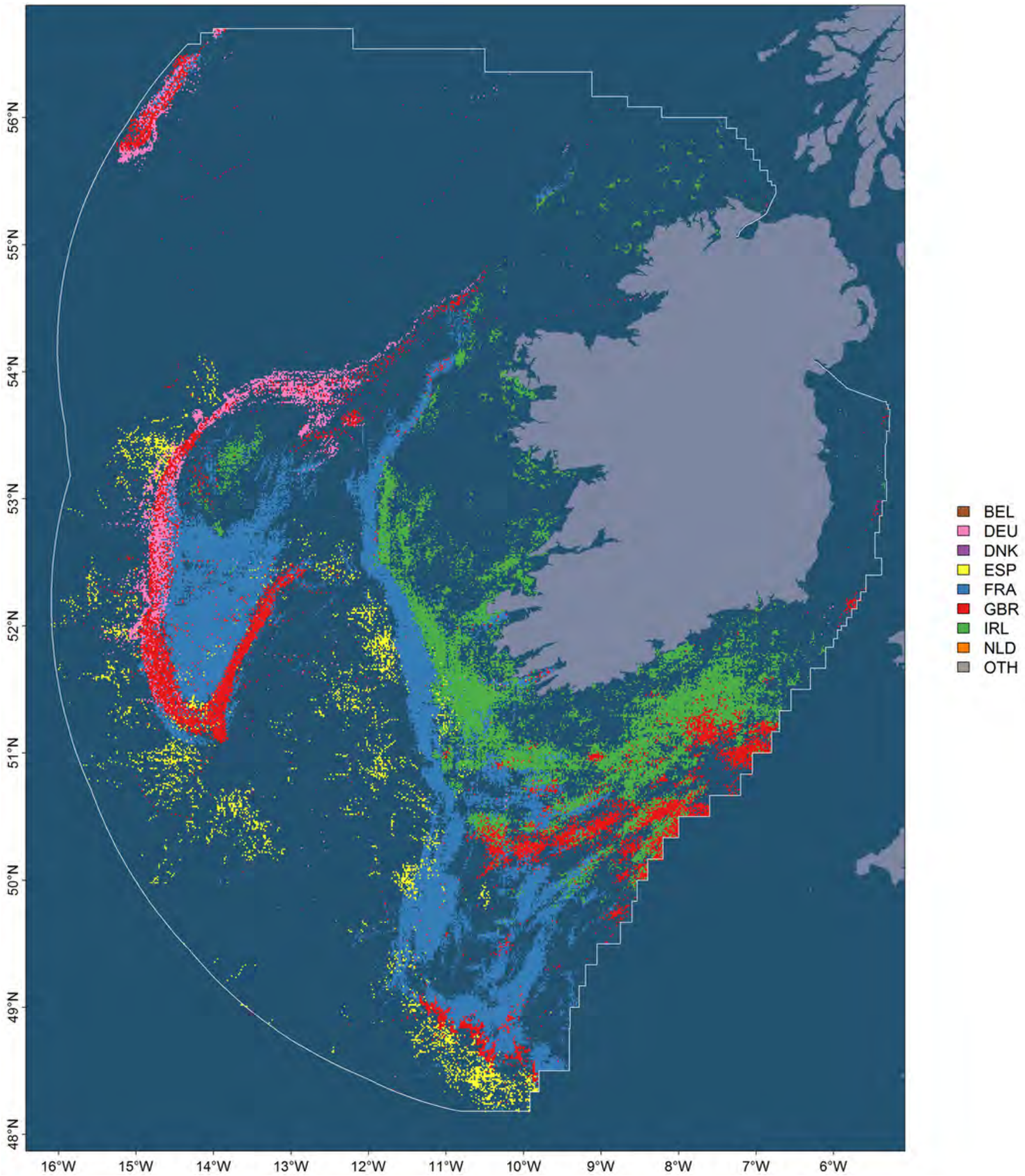


Figure 42. (Figure 20: Distribution of international gill net effort in the Irish EEZ by country in 2014-18, page 24 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.)

Note the prevalence of gill netting by British boats on the continental slope on the outside of the Porcupine Bank and in the Canyons of the south-west and German boats in the hotspot area (page 17) to the north of the Porcupine Trough.

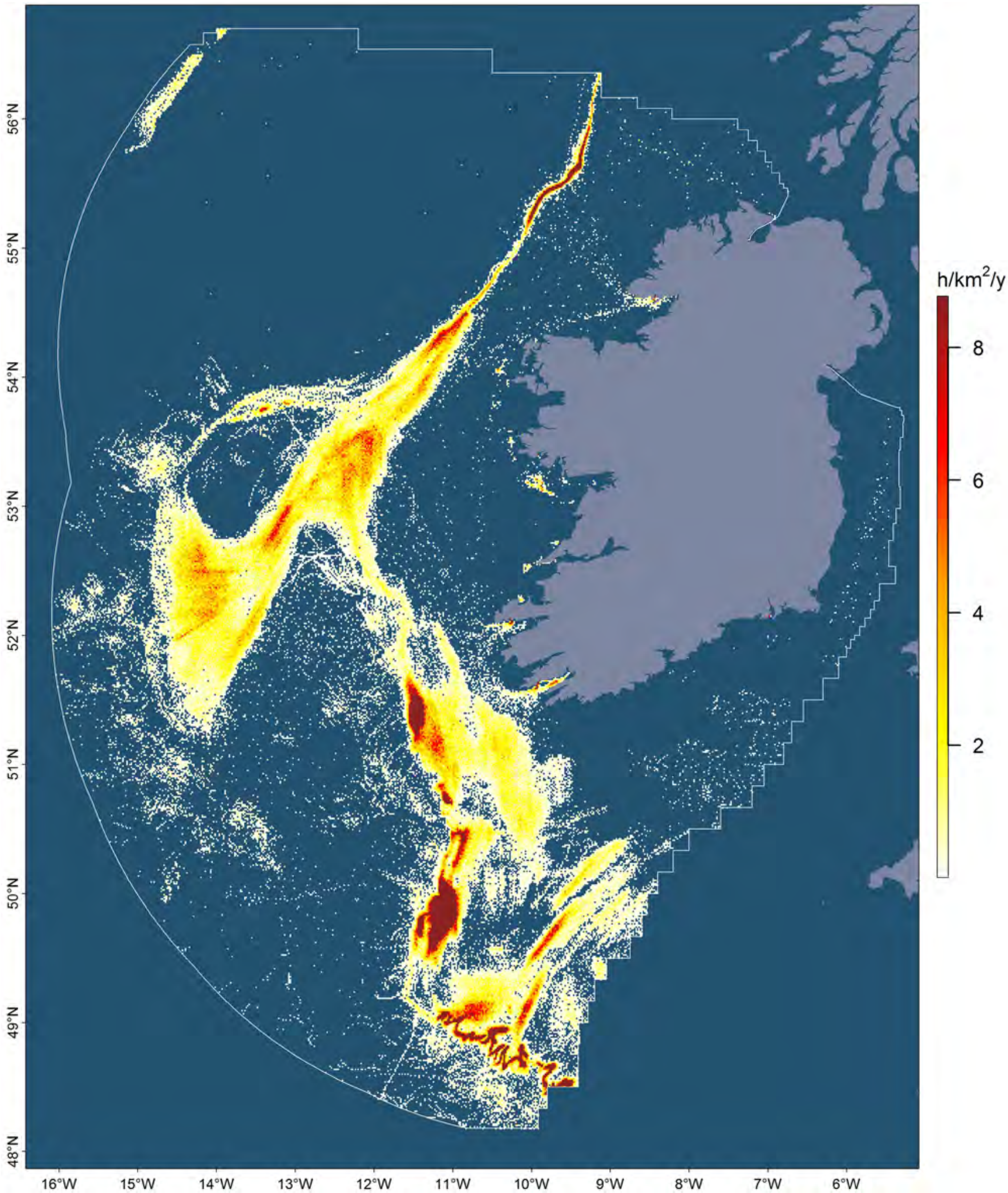


Figure 43. (Figure 23: Distribution of international longline effort in the Irish EEZ, page 27 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.) The canyons and steep slopes in the south-west and the north-west are the focus of a lot of long line fishing.

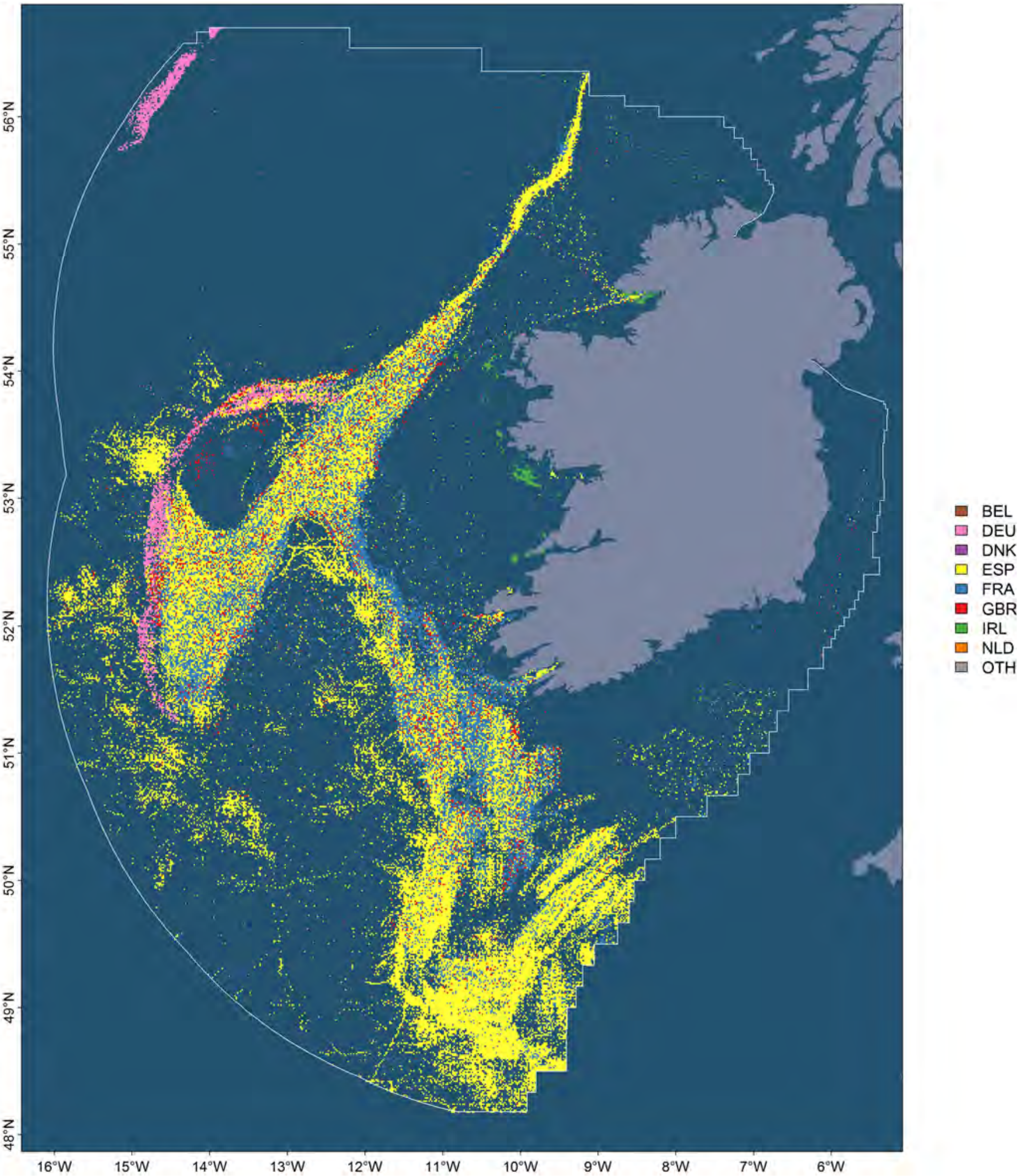


Figure 44. (Figure 24: Distribution of international longline effort in the Irish EEZ by country in 2014-18, page 28 from Atlas of Commercial Fisheries Around Ireland, Third Edition. Marine Institute, 2019.) Ireland acounted for 1% of the total effort inside the EEZ. Spain is responsible for the vast majority of longline effort in Irish waters.

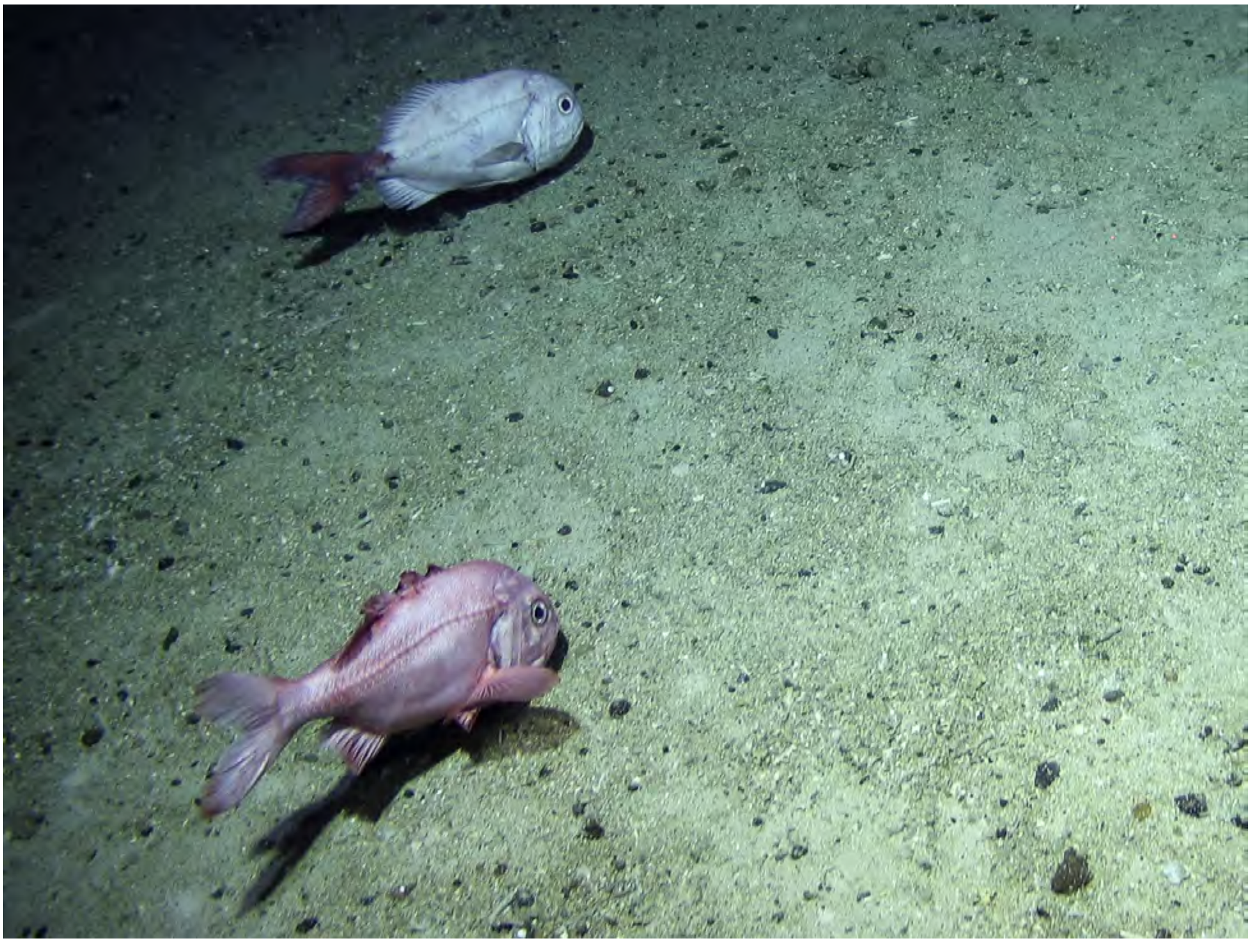


Figure 45. Orange roughy Hoplostethus atlantica*, previously the target of a fishery but now listed as endangered.*

Figure 46. Gill nets tangled on the seabed.

3.4 Testing predictive models for coral and sponge distribution

The SeaRover survey collected data to ground truth published models of habitat suitability for *Lophelia* reef and the bird's nest glass sponge *Pheronema carpenteri* (Ross & Howell, 2013).

Distribution of *Pheronema carpenteri*

Figure 48 maps the probability of encountering the bird's nest glass sponge *Pheronema carpenteri* according to the habitat suitability model devised by Ross & Howell (2013). The dives where SeaRover observed *P. carpenteri* together with its relative abundance is also shown. For Dive 683 the model predicted a 0.91 probability (91% likelihood) of *Pheronema* being present and SeaRover recorded it as abundant at this site. Dive 497 recorded *Pheronema* as occasional and the model predicted 0.61 probability (61% likelihood) of it being present. Dive 475 was selected as a suitable site for ground truthing the model which gave a probability of 0.74, however no *Pheronema* was observed on this dive. Similarly, Dive 544 was also within the area where *Pheronema* was predicted with P=0.746 (75% likelihood), however it wasn't observed by SeaRover.

On Dive 690 the SeaRover survey recorded *Pheronema* as abundant however the model did not predict it to occur here. For the following dives *Pheronema* was recorded as rare (R) or occasional (O) however they were not within the predicted distribution: D532 (R)); D541 (O); D542 (R)); D549 (R)); D551 (R)); D570 (R)); D558 (R)); D663 (R)).

Distribution of *Lophelia (Desmophyllum pertusum)*

Figure 49 maps the probablility of encountering the cold water coral *Lophelia* according to the model of Ross & Howell (2013). The SeaRover dives are shown in blue and the areas where *Lophelia* was encountered are colour coded according to its relative abundance. Most of the SeaRover dives were deeper than the predicted distribution and did not encounter *Lophelia*. The following are the dives where the abundance of *Lophelia* was recorded as Common (C) – Super abundant (S) that fell within the predicted area: D452 (C); D451 (A); D450 (A); D669 (S); D649 (A); D652 (A). The area where *Lophelia* was most abundant was D669 within the Belgica Mound SAC where it was topping a raised mound but actually outside the model's predicted area (Figure 49).

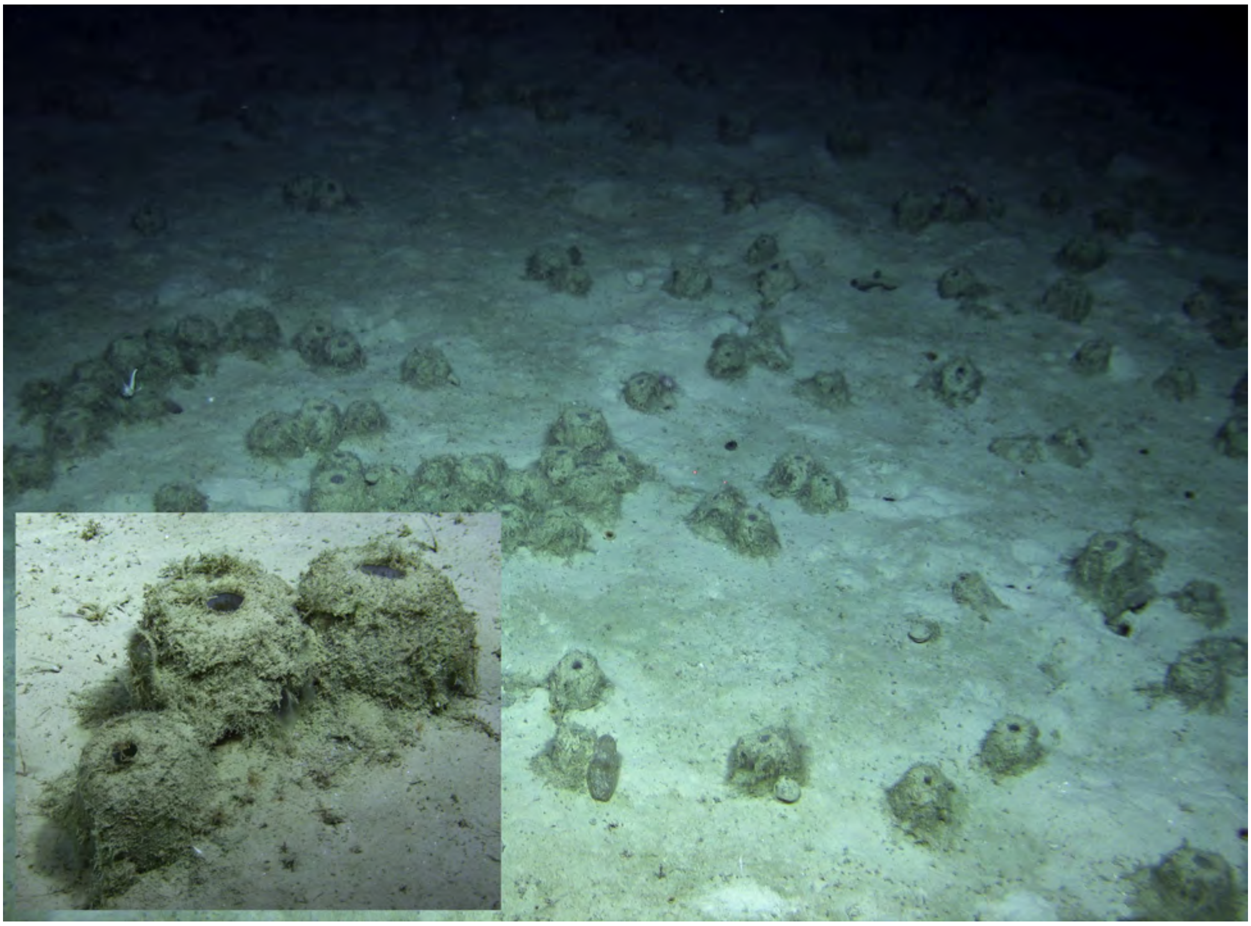


Figure 47. Aggregations of the glass sponge, Pheronema carpenteri.

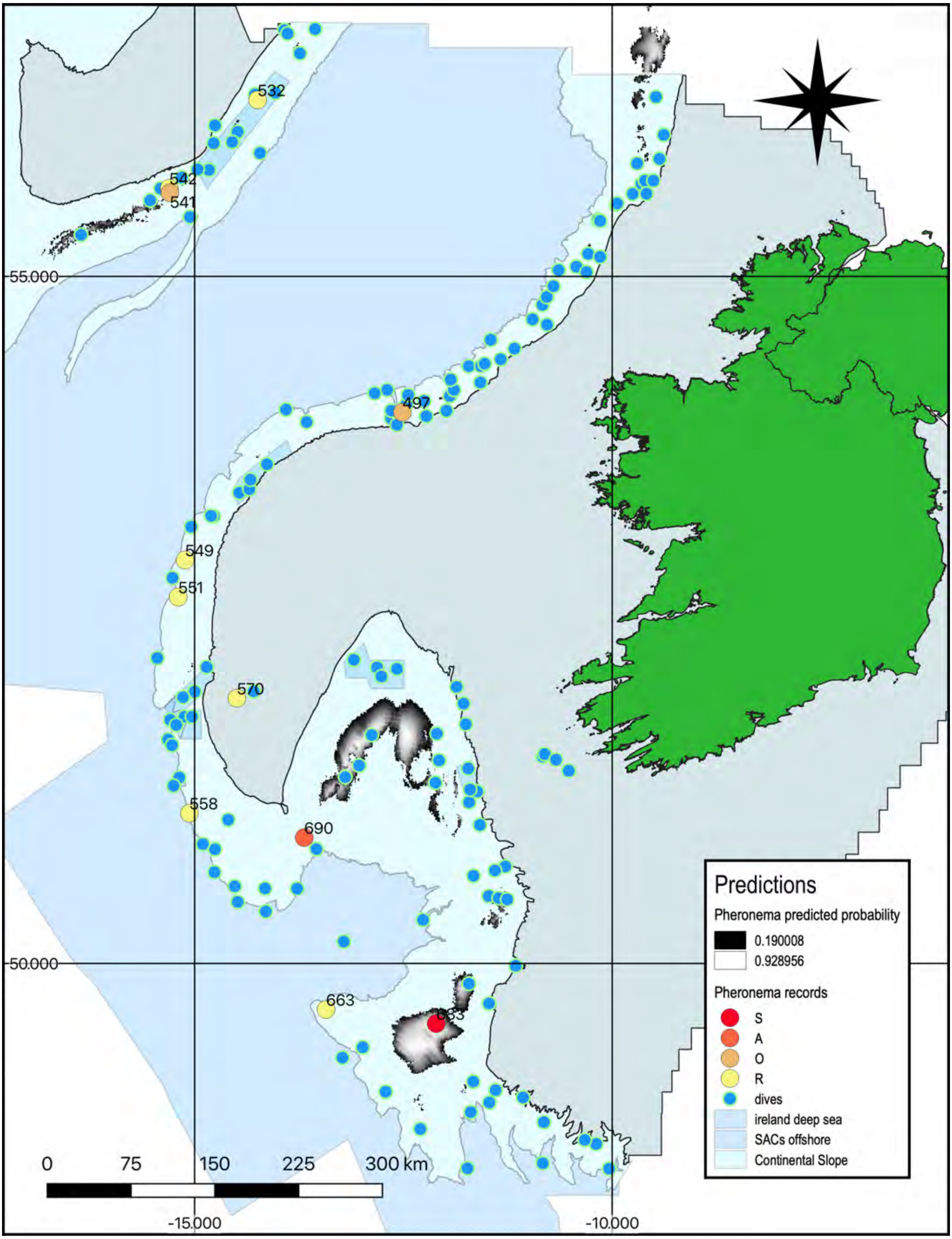


Figure 48. One of the objectives of SeaRover was to assess the predictive models (Ross & Howell, 2013) for three VME habitats. This map shows results for the bird's nest sponge, Pheronema carpenteri.

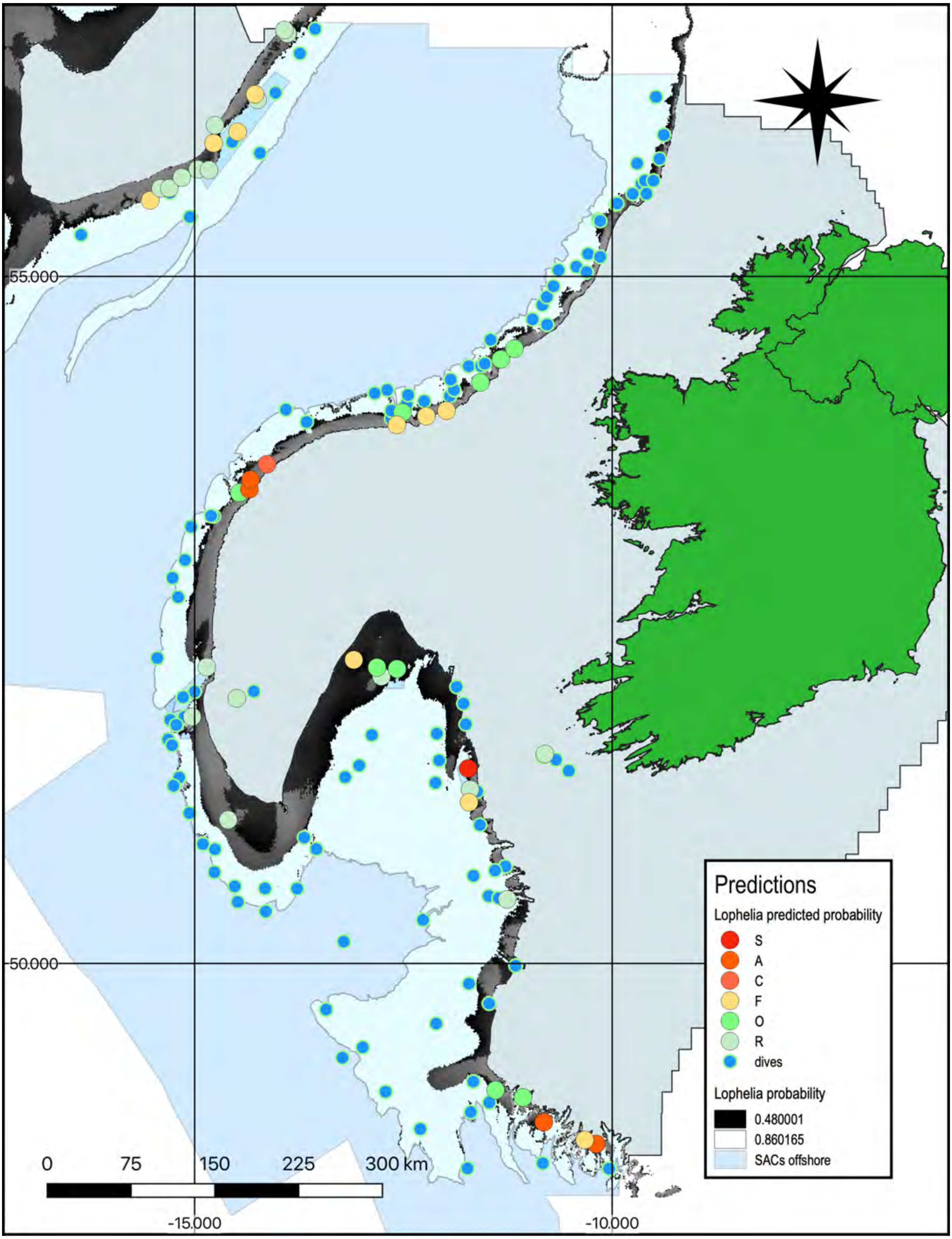


Figure 49. Observed distribution of Lophelia *compared with predictive model (Ross & Howell, 2013). SeaRover dives below the maximum depth predicted for* Lophelia *rarely encountered this coral but the two most abundant sites were slightly to the deeper side of the predicted distribution pattern.*

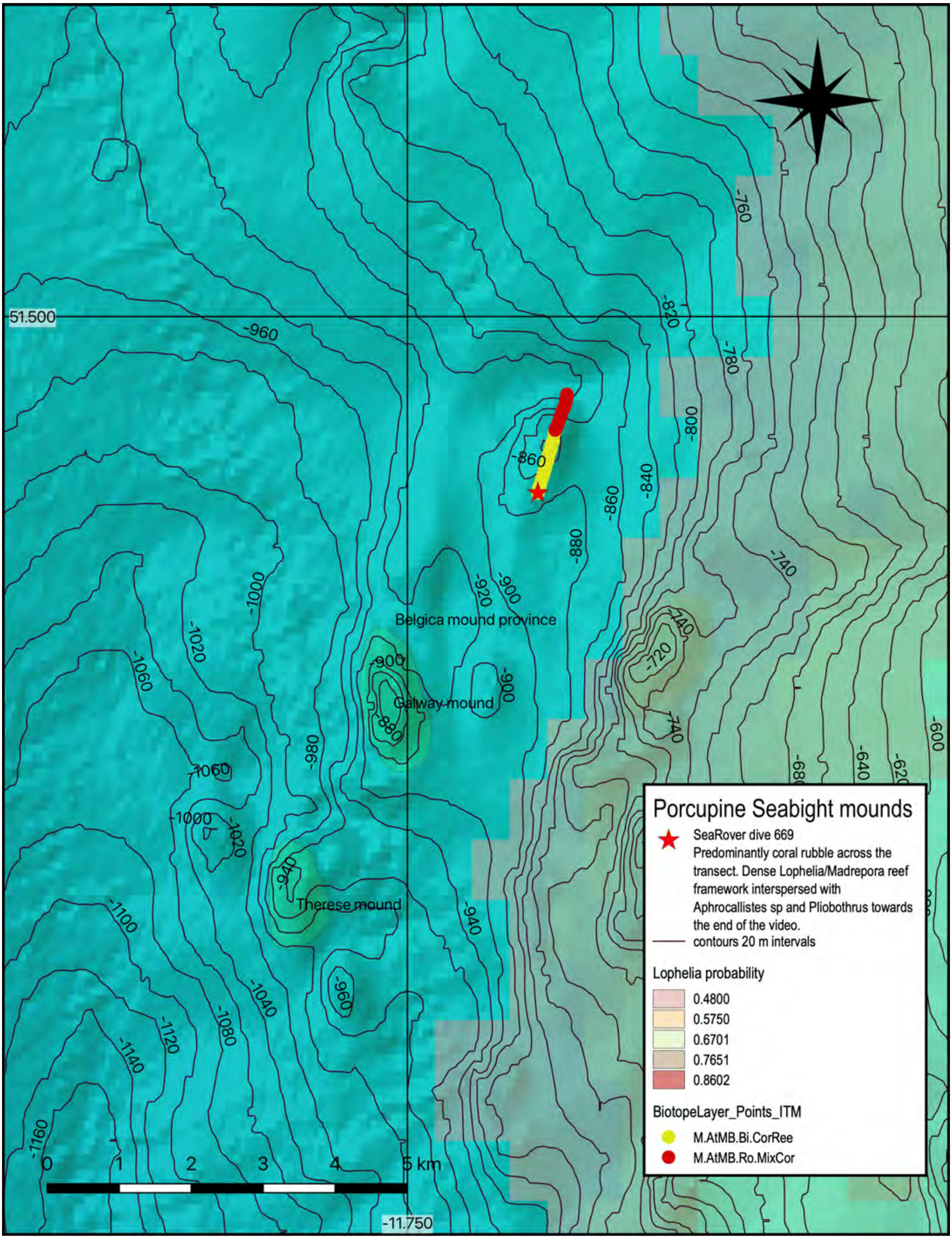


Figure 50. Dive 669 biotope observations overlain on EMODnet bathymetry with Lophelia *probability occurrence (Ross & Howell, 2013) layer in light brown to the East. Coral mounds here in the Belgica Mound Province SAC were not predicted to have reef by the model, but were clearly visible on the 2018 EmodNet bathymetry.*

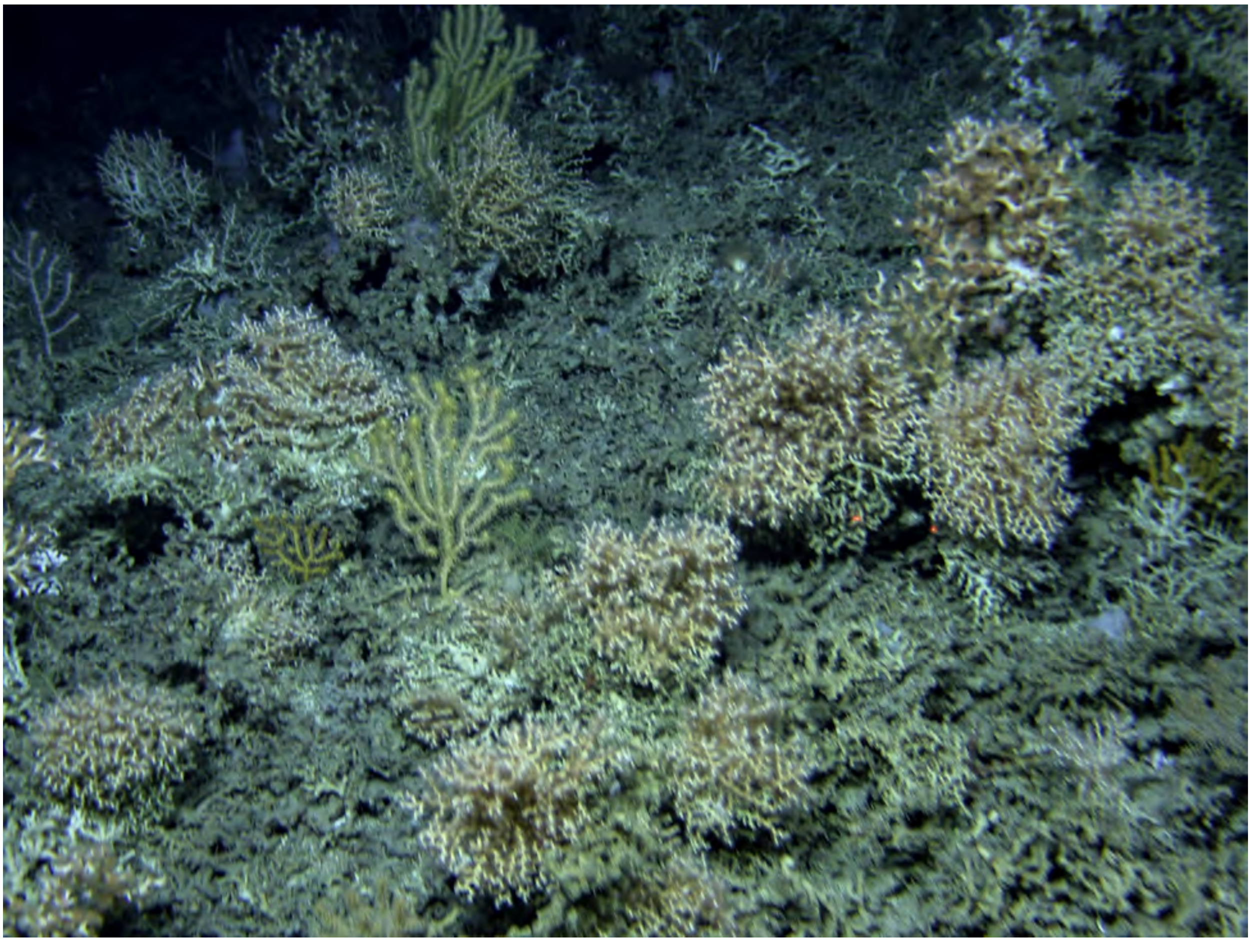


Figure 51. Cold water coral reef of Lophelia, Madrepora oculata *and sea fans.*

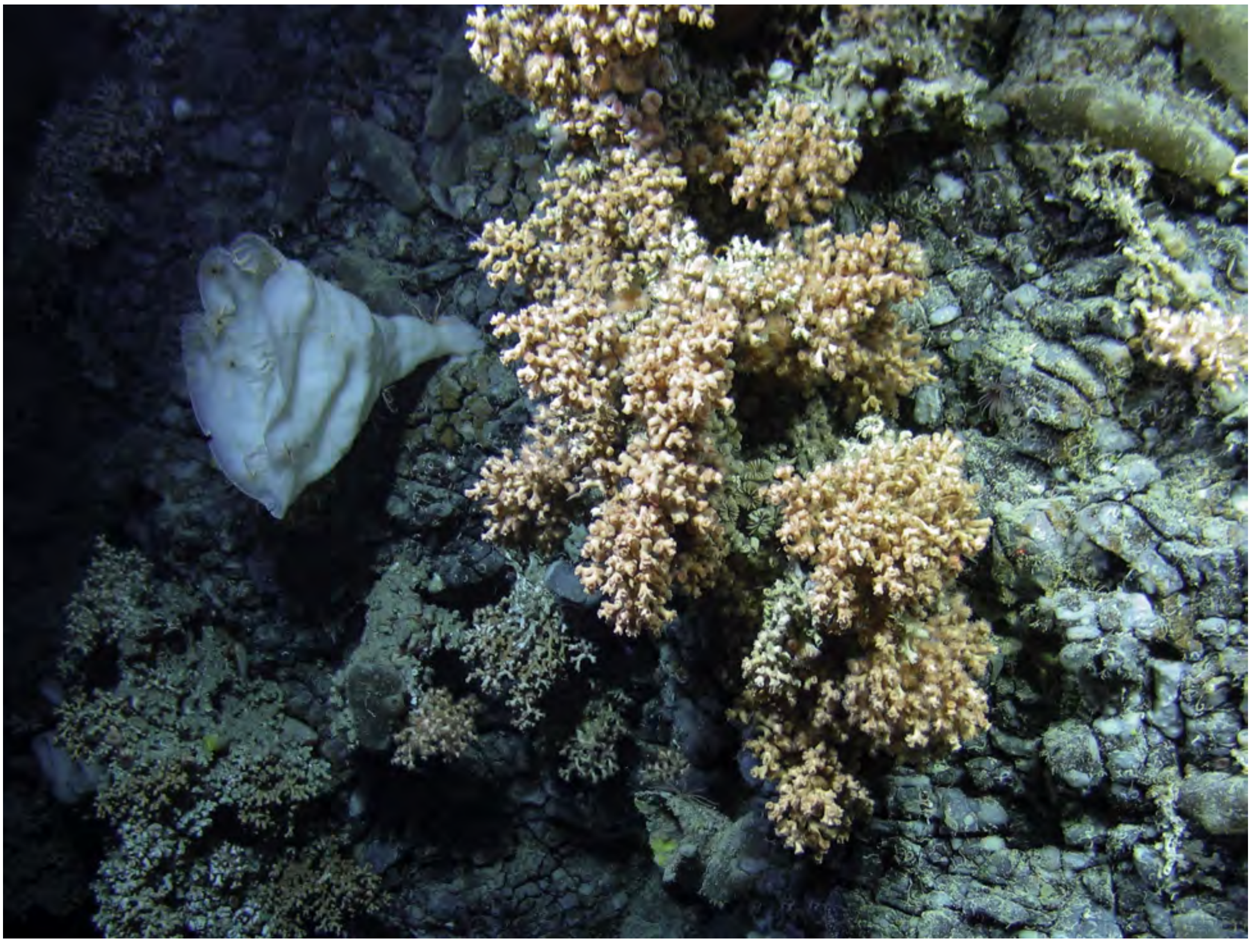


Figure 52. Cold water Solenosmilia variabilis *reef on rock with large glass sponge in background.*

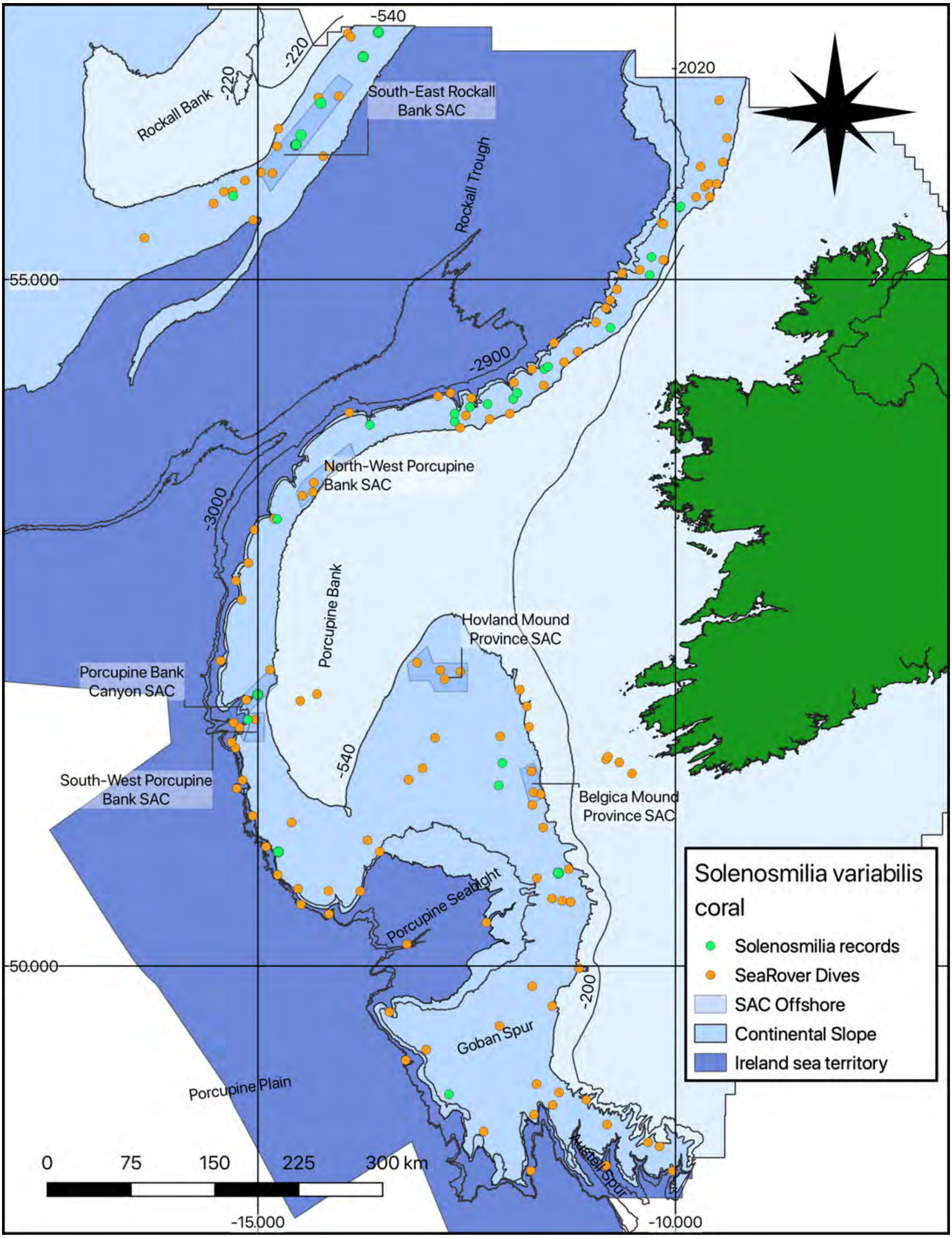


Figure 53. Solenosmilia variabilis *is believed to be a widely distributed coral found worldwide in deeper habitats than* Lophelia *and* Madrepora. *It forms smaller reefs, normally on rock. It is very slow growing with rates measured at less than 1 mm per year. SeaRover found it to be frequent on steep rock surfaces at depths of -800 to -2000 metres on steep geogenic reef habitats in canyons, epecially in the NW sector of the continental slope.*

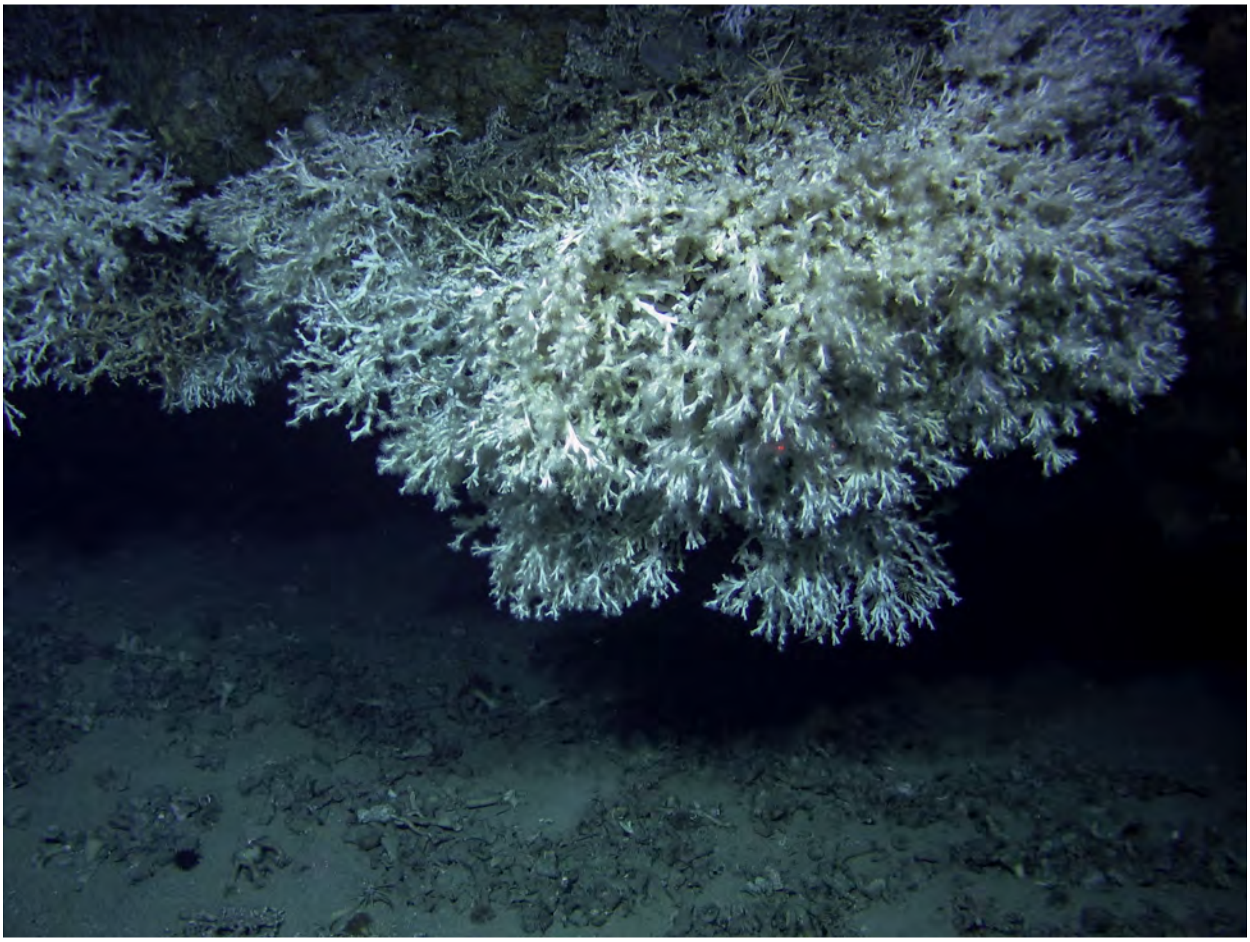


Figure 54. Lophelia coral reef on edge of an escarpment.

Figure 55. Solenosmilia *coral with the gaping file shell,* Acesta *and a large sea anemone.*

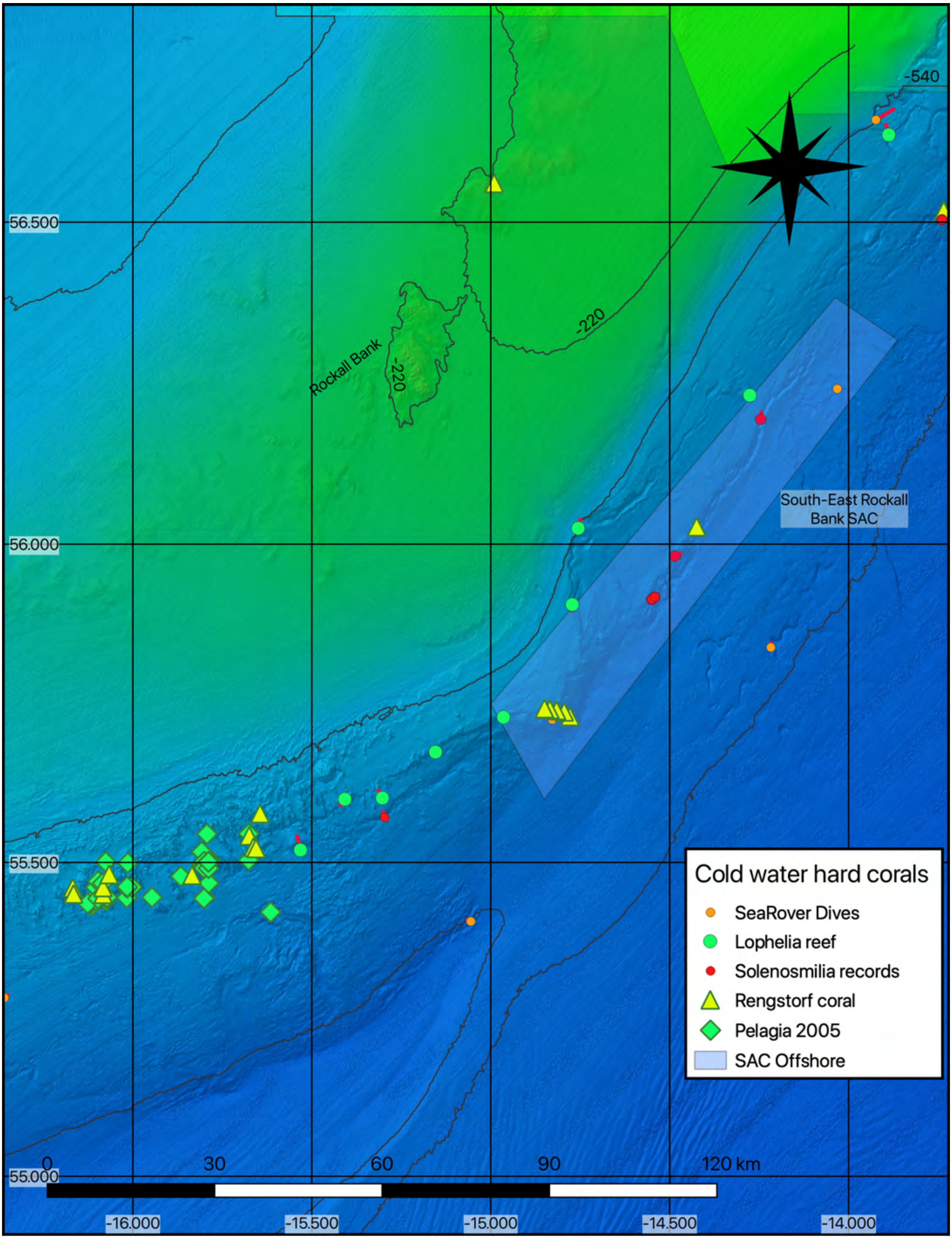
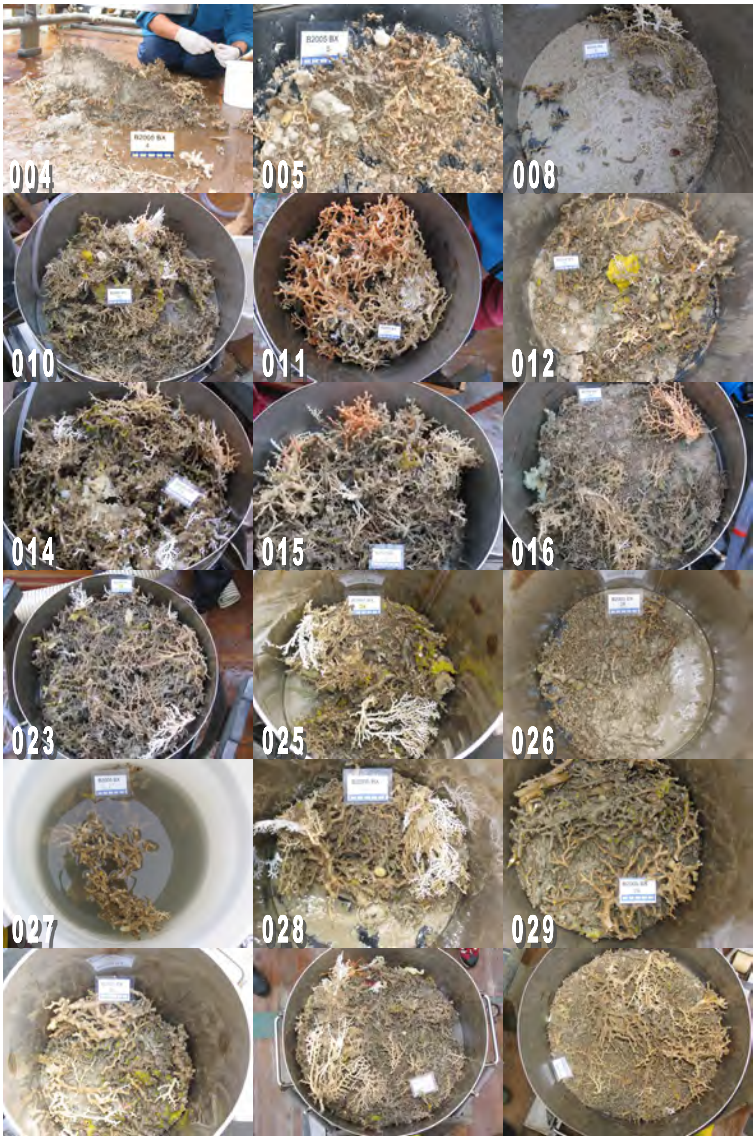
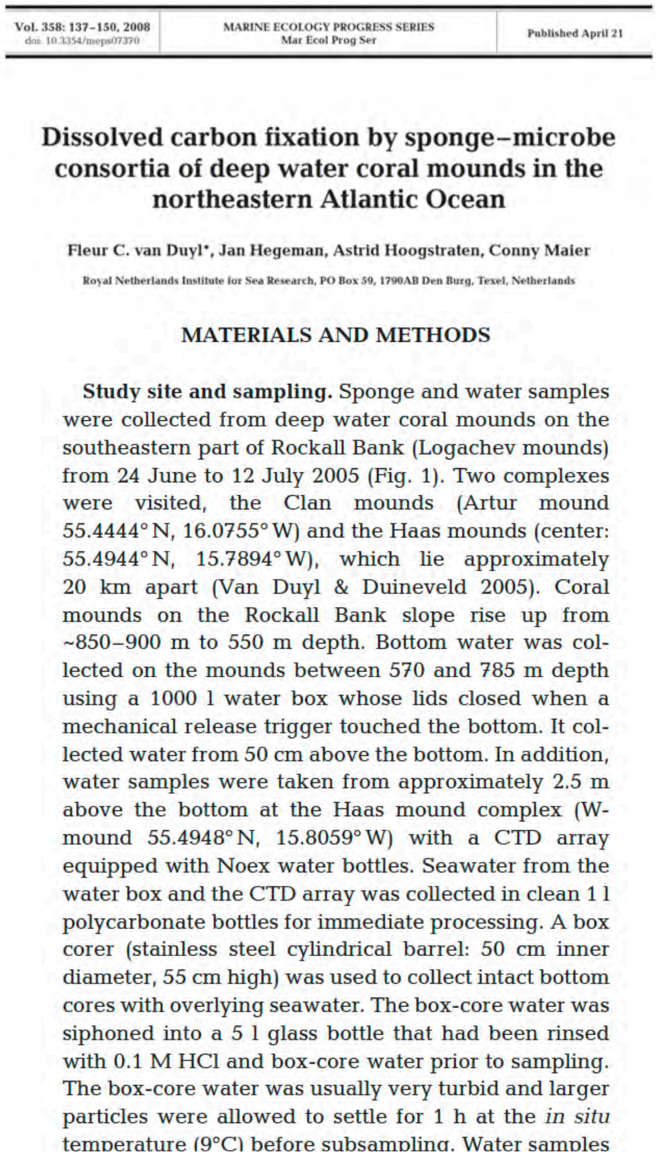


Figure 56. At all sites surveyed Lophelia *coral was confined to shallower water, usually above -700 metres, whilst* Solenosmilia *coral was found in deeper water in areas with steep topography. Earlier work on cold water coral reefs in Irish waters did not always distinguish between the hard coral species recorded, with an assumption that* Lophelia *was the main species present.*

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Dissolved carbon fixation by sponge–microbe consortia of deep water coral mounds in the northeastern Atlantic Ocean

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MATERIALS AND METHODS

Study site and sampling. Sponge and water samples were collected from deep water coral mounds on the southeastern part of Rockall Bank (Logachev mounds) from 24 June to 12 July 2005 (Fig. 1). Two complexes were visited, the Clan mounds (Artur mound 55.4444° N, 16.0755° W) and the Haas mounds (center: 55.4944° N, 15.7894° W), which lie approximately 20 km apart (Van Duyl & Duineveld 2005). Coral mounds on the Rockall Bank slope rise up from ~850–900 m to 550 m depth. Bottom water was collected on the mounds between 570 and 785 m depth using a 1000 l water box whose lids closed when a mechanical release trigger touched the bottom. It collected water from 50 cm above the bottom. In addition, water samples were taken from approximately 2.5 m above the bottom at the Haas mound complex (W-mound 55.4948° N, 15.8059° W) with a CTD array equipped with Noex water bottles. Seawater from the water box and the CTD array was collected in clean 1 l polycarbonate bottles for immediate processing. A box corer (stainless steel cylindrical barrel: 50 cm inner diameter, 55 cm high) was used to collect intact bottom cores with overlying seawater. The box-core water was siphoned into a 5 l glass bottle that had been rinsed with 0.1 M HCl and box-core water prior to sampling. The box-core water was usually very turbid and larger particles were allowed to settle for 1 h at the *in situ* temperature (9°C) before subsampling. Water samples

Figure 57. Boxcores and a resulting paper from the Rockall Bank collected by Pelagia *in 2005.*

Species diversity from detailed specimen sampling

Although this investigation is not mentioned by Forde et al., 2017, sponge diversity and community composition in bathyal cold water coral reefs (CWRs) were examined at -500 to -900 m depth on the southeastern slopes of Rockall Bank and the northwestern slope of Porcupine Bank, to the west of Ireland, in 2004 and 2005 using sampling with boxcores. Figure 56 shows some of a total of 104 boxcore samples, supplemented with 10 trawl/dredge attempts, which were analyzed for the presence and abundance of sponges, using microscopical examination of (sub)samples of collected coral branches, and semi-quantitative macroscopic examination (van Duyl et al, 2008). These boxcores collected by the *Pelagia* cruise in 2005 were studied by a number of workers. Van Soest examined mostly dead *Lophelia* for sponges and lists 191 species of sponge (van Soest et al., 2007a). Van Soest et al., 2007b, described a mass occurrence of a species from these reefs which was later found to be a new species of glass sponge (Dohrmann et al., 2012). Whilst most diversity consists of small animals not visible to ROV observers there is also a huge taxonomic deficit in relation to most invertebrate groups, especially sponges and cnidarians which are two of the most species rich groups in the deep sea.

Van Soest concluded: “Bathyal reefs of the regions to the west of Ireland were found to have a combined sponge species richness of 191 species, exceeding the richness of individual reef mound areas by c. 38-45%. Sponge presence in CWRs is clearly structured and controlled by biotic and abiotic factors. In particular, live coral presence appears a significant predictor of cold water reef (CWR) sponge composition and diversity.”

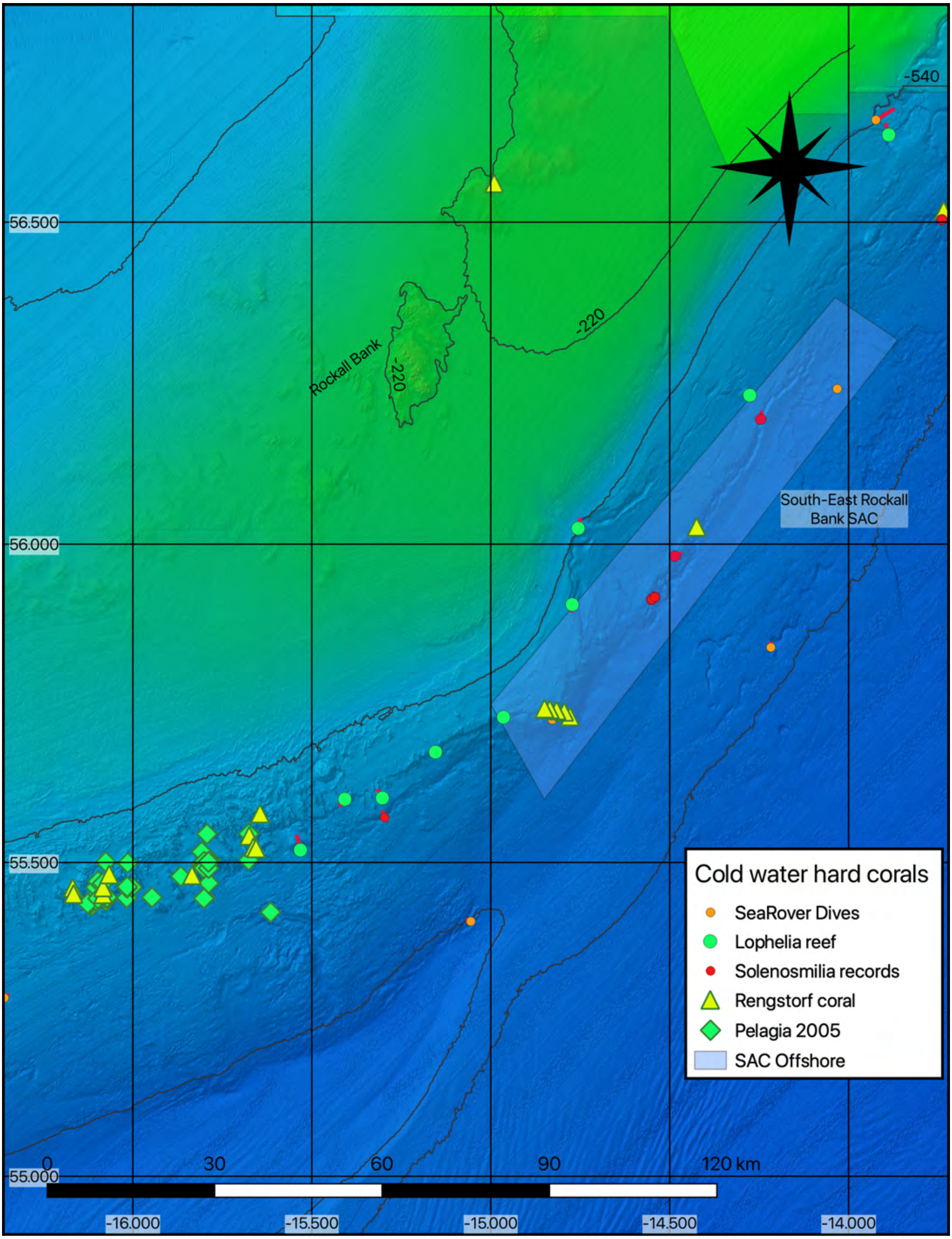

Figure 58. Distribution of cold water hard corals on the Rockall Bank showing records from SeaRover and previous expeditions including box core collections by Pelagia, *2005.*

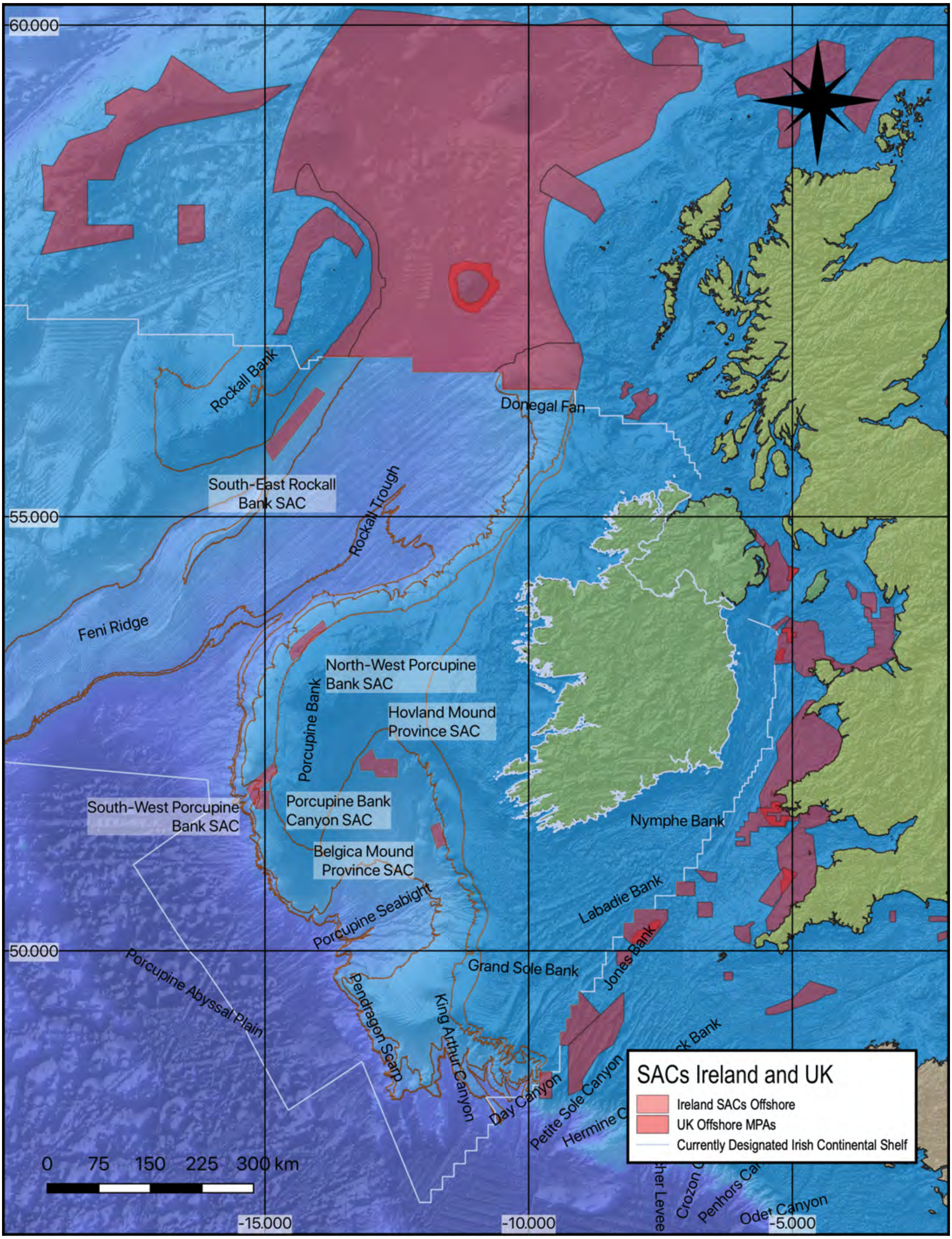

Figure 59. SACs currently designated in the Irish offshore region. These SACs were designated in 2015 to protect cold water coral reef where it was known to occur. In September 2020 a large Marine Proected Area (MPA) was designated by the Scottish government (West of Scotland Marine Protected Area Order 2020) in an area including the Northern part of the Rockall Trough and adjacent continental slope.

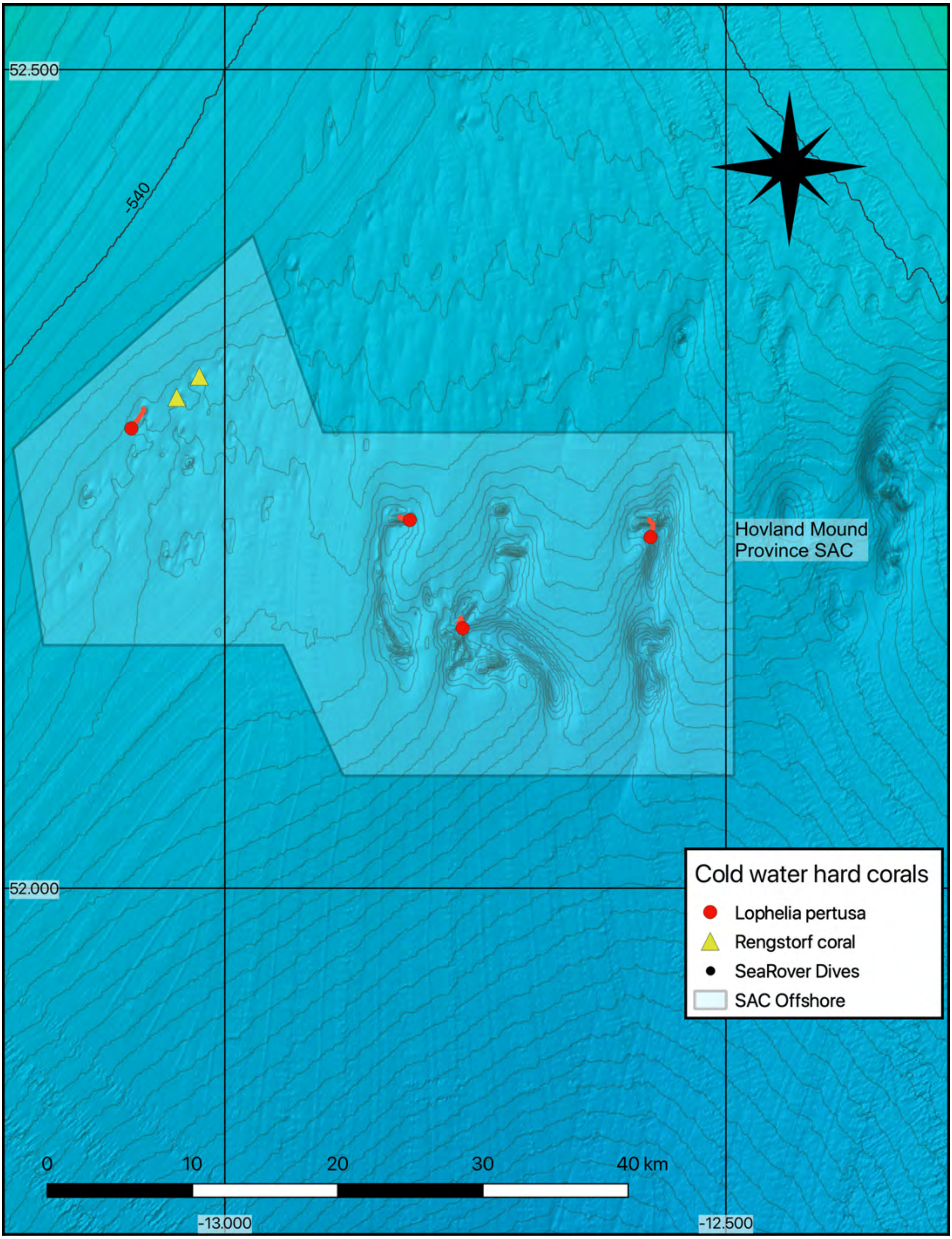

Figure 60. The Hovland mound SAC was designated to protect coral reef which has formed biogenic reefs in this area since the ice retreat 10,000 years ago. SeaRover visited four sites within this SAC and found living reef. EMODnet 2018 bathymetry reveals large mounds to the east of the present SAC. The coral reefs are frequently surrounded by a moat of deeper water and this may be the result of current scour due to acceleration of the tidal streams by the reef structure, and disturbance of the seabed by associated animals including fish and crustaceans, on a timescale of thousands of years.

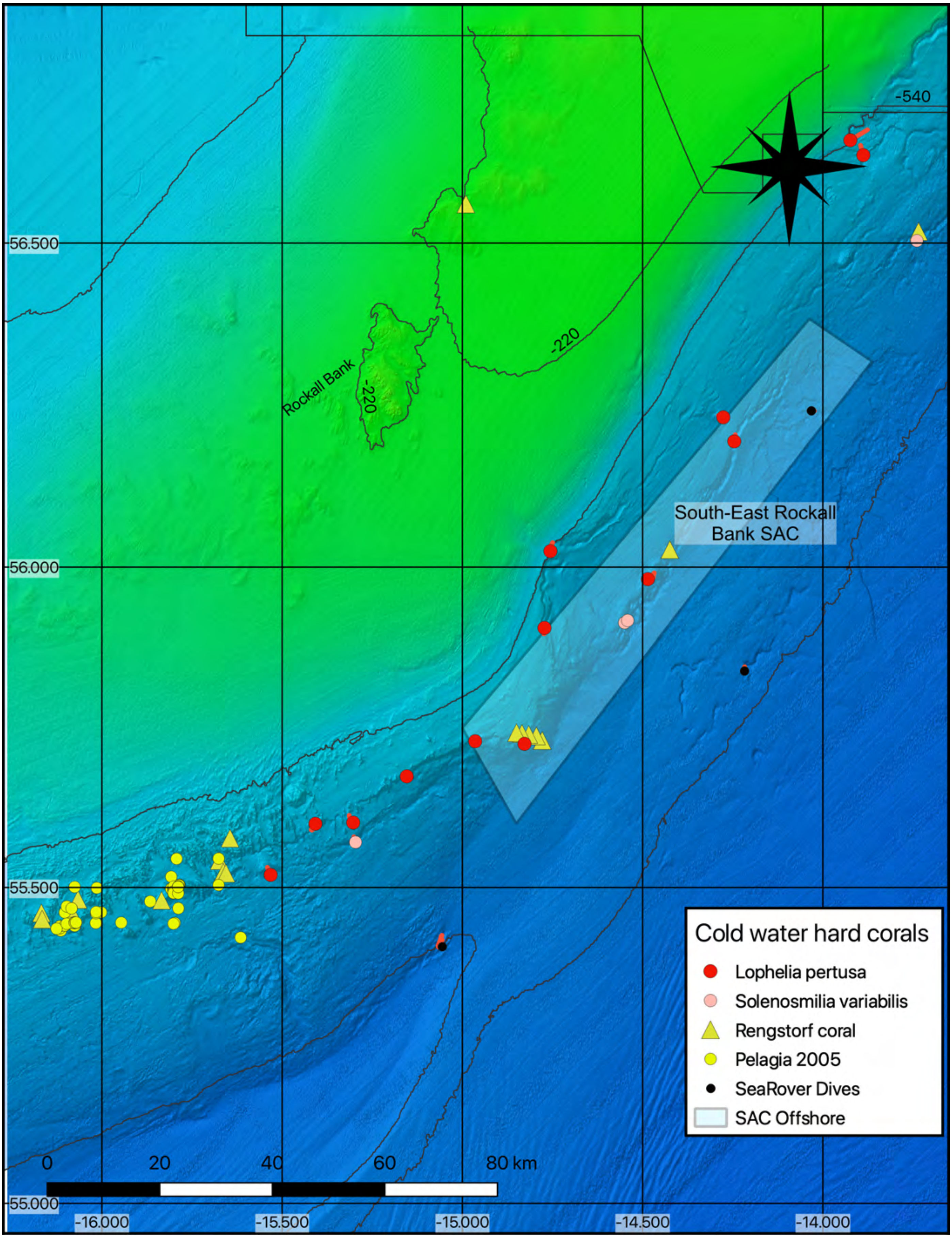

Figure 61. The South-East Rockall Bank SAC was designated in 2015 to protect coral reef on the Rockall Bank.

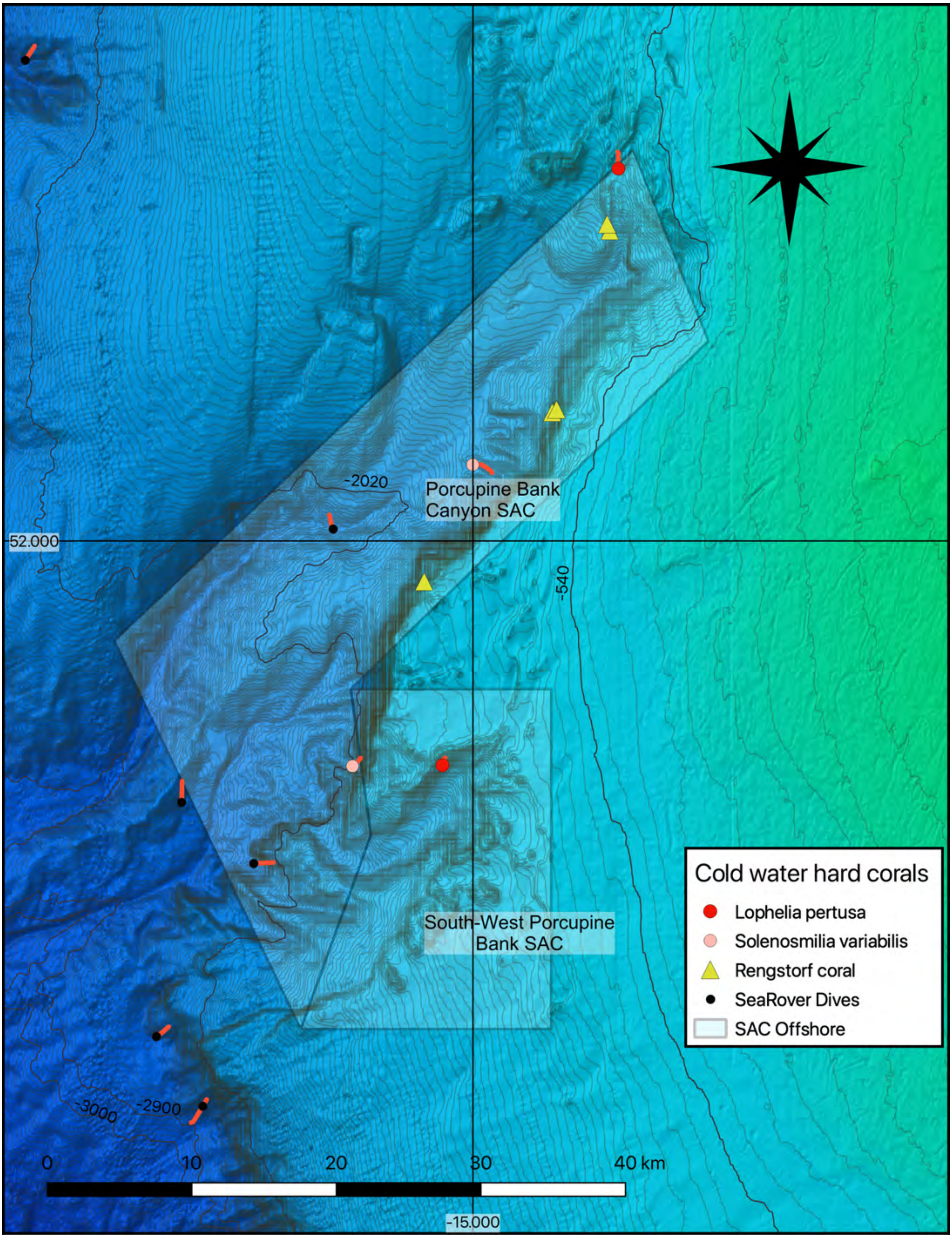

Figure 62. The Porcupine Bank Canyon SAC was designated to protect coral reef which is associated with a large canyon system on the western edge of the Porcupine bank. SeaRover dives in this area revealed Lophelia *reefs at the top of spurs at the heads of the canyon and* Solenosmilia *reefs in deeper water.*

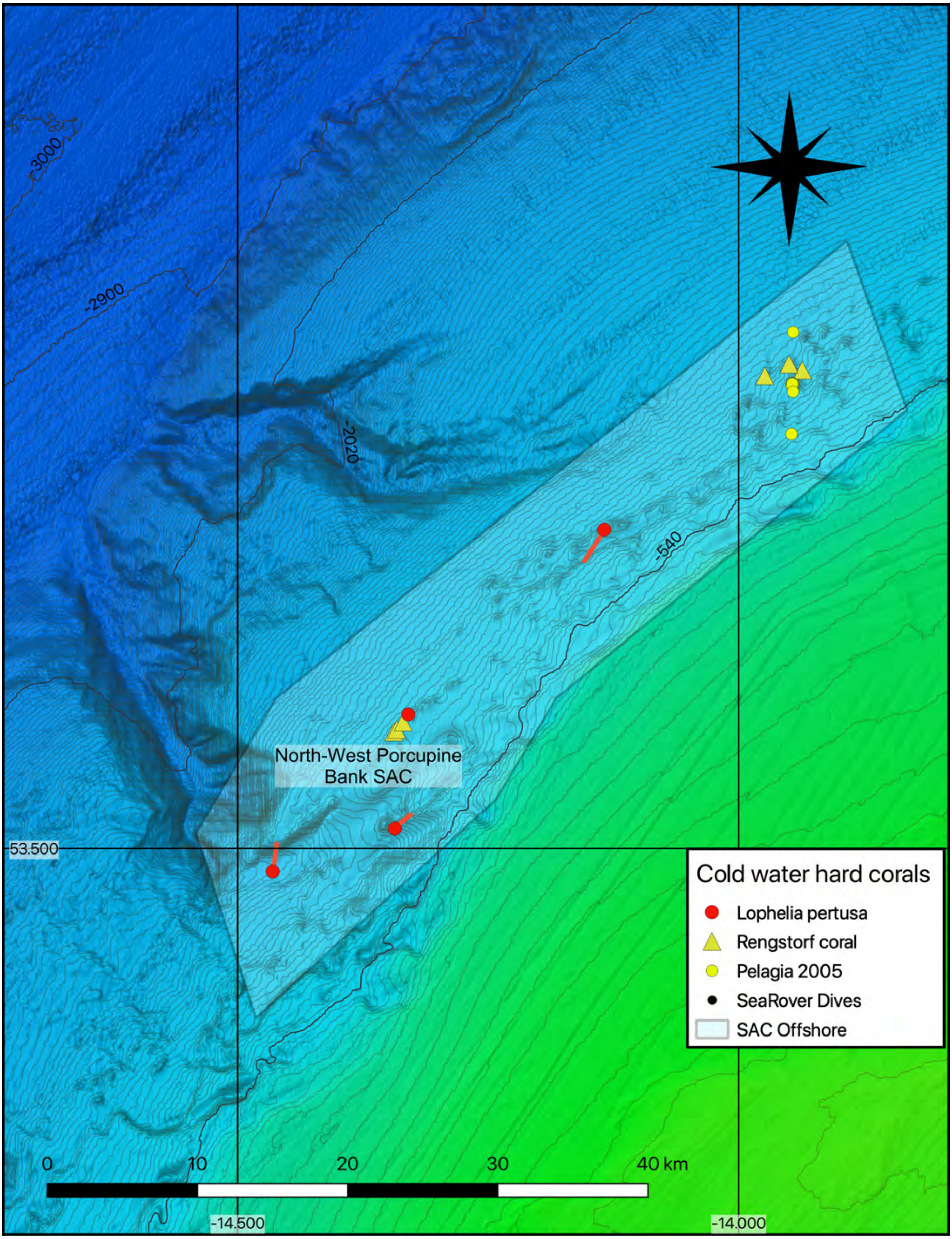

Figure 63. The North-West Porcupine Bank SAC was designated in 2015 to protect cold water coral reefs on the Porcupine Bank continental slope. High resolution bathymetry reveals reef areas all along this part of the continental slope. The SeaRover survey has shown that areas of reef topography on the continental slope always contain vulnerable marine ecosystems.

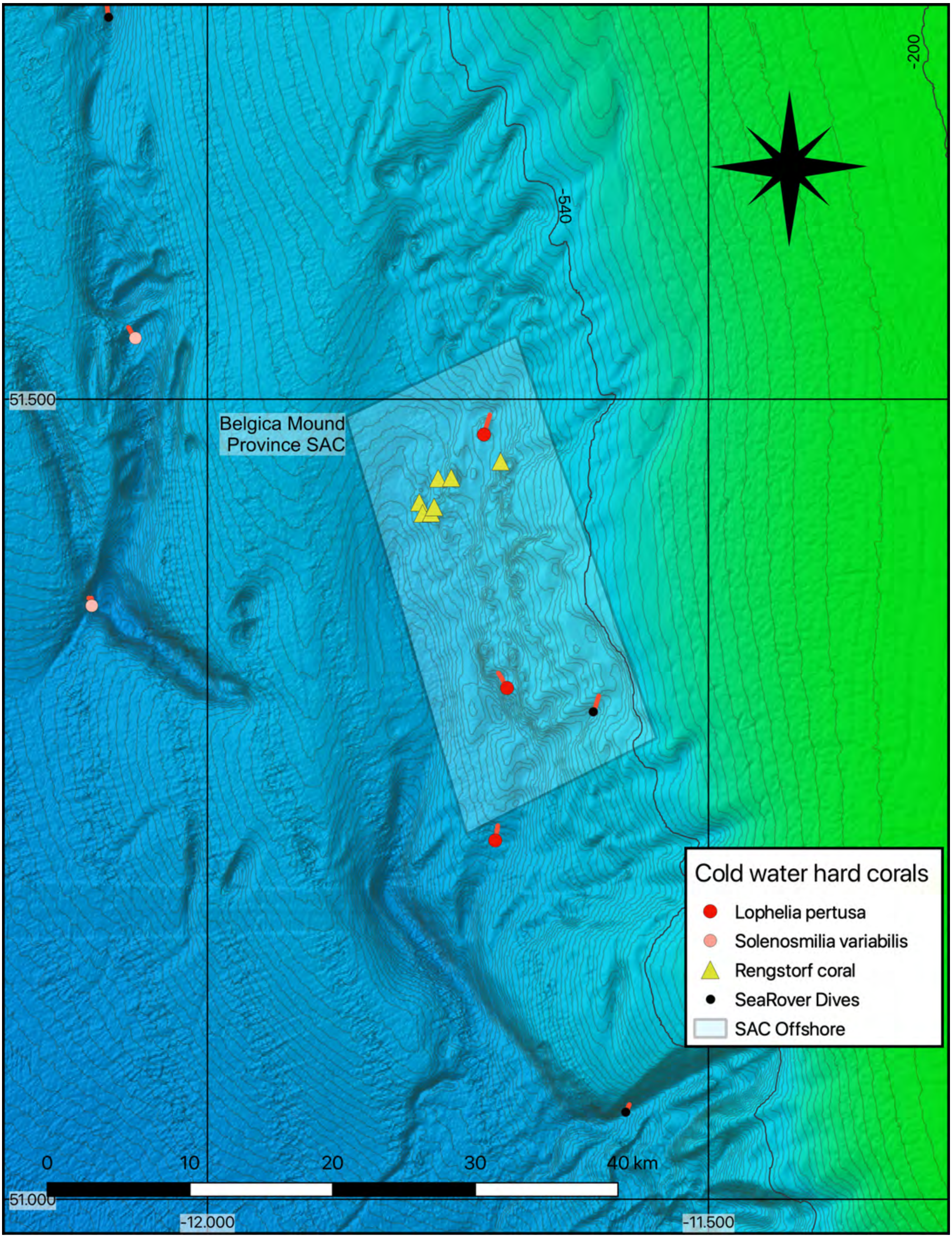

Figure 64. The Belgica mound SAC was designated to protect coral reef which has formed biogenic reefs in this area similar to those in the Hovland mound area. Three dives were carried out within the SAC and four others in the vicinity. Lophelia *reef was confirmed to be present in shallower water and just outside the SAC boundary to the South. A deep water canyon system to the west of Belgica contained* Solenosmilia *corals.*

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Ecological Role of Submarine Canyons and Need for Canyon Conservation: A Review

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Submarine canyons are major geomorphic features of continental margins around the world. Several recent multidisciplinary projects focused on the study of canyons have considerably increased our understanding of their ecological role, the goods, and services they provide to human populations, and the impacts that human activities have on their overall ecological condition. Pressures from human activities include fishing, dumping of land-based mine tailings, and oil and gas extraction. Moreover, hydrodynamic processes of canyons enhance the down-canyon transport of litter. The effects of climate change may modify the intensity of currents. This potential hydrographic change is predicted to impact the structure and functioning of canyon communities as well as affect nutrient supply to the deep-ocean ecosystem. This review not only identifies the ecological status of canyons, and current and future issues for canyon conservation, but also highlights the need for a better understanding of anthropogenic impacts on canyon ecosystems and proposes other research required to inform management measures to protect canyon ecosystems.

Keywords: submarine canyons, ecosystem service, anthropogenic impacts, conservation, management

INTRODUCTION

As resources on land are increasingly depleted, humanity is turning to the oceans, as never before, for new sources of food and materials (Ramirez-Llodra et al., 2011). A complex and mixed interplay of impacts resulting from fisheries, oil and gas operations, mining practices, and many other anthropogenic activities, have caused unintended damage to ecosystems (Davies et al., 2007). This, in turn, may affect the supply of targeted resources, as well as impact other ecosystem services. This scenario hinders the achievement of UN Millennium Assessment goals relating to human wellbeing, including having sufficient food at all times and having a healthy physical

Figure 65. SeaRover data will result in scientific papers such as this one on the role of Submarine Canyons in providing ecosystem services.

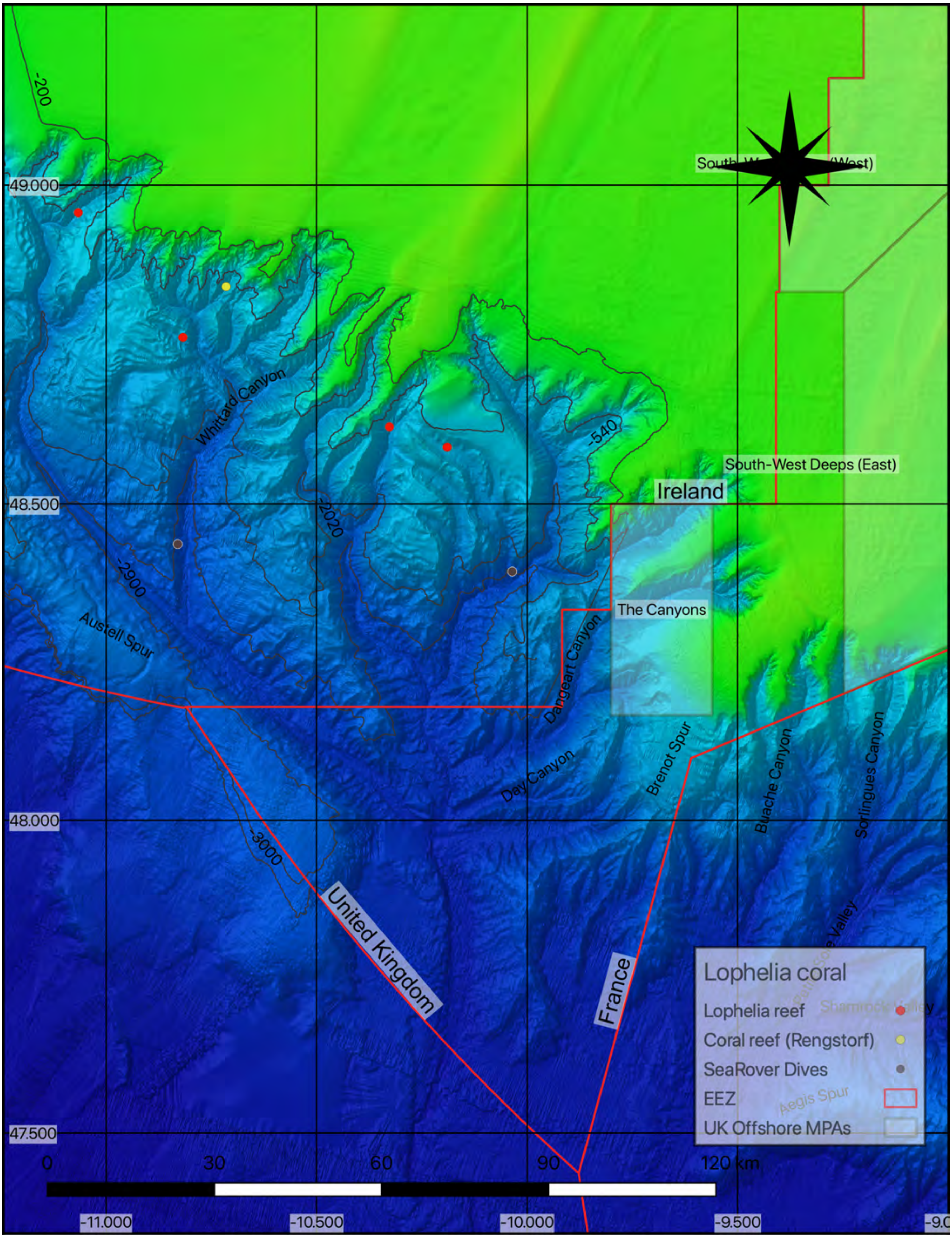

Figure 66. The Whittard canyon is at the southern edge of the Irish continental slope. It contains Lophelia *reef on the spurs between the canyons and* Acesta *and* Solenosmilia *on the canyon walls. It is partly in UK territorial waters where an SAC has been designated, The Canyons SAC, with two SACs designated on the nearby shelf. These are the only SACs in the region advised by Natural England which are on the continental margin.*

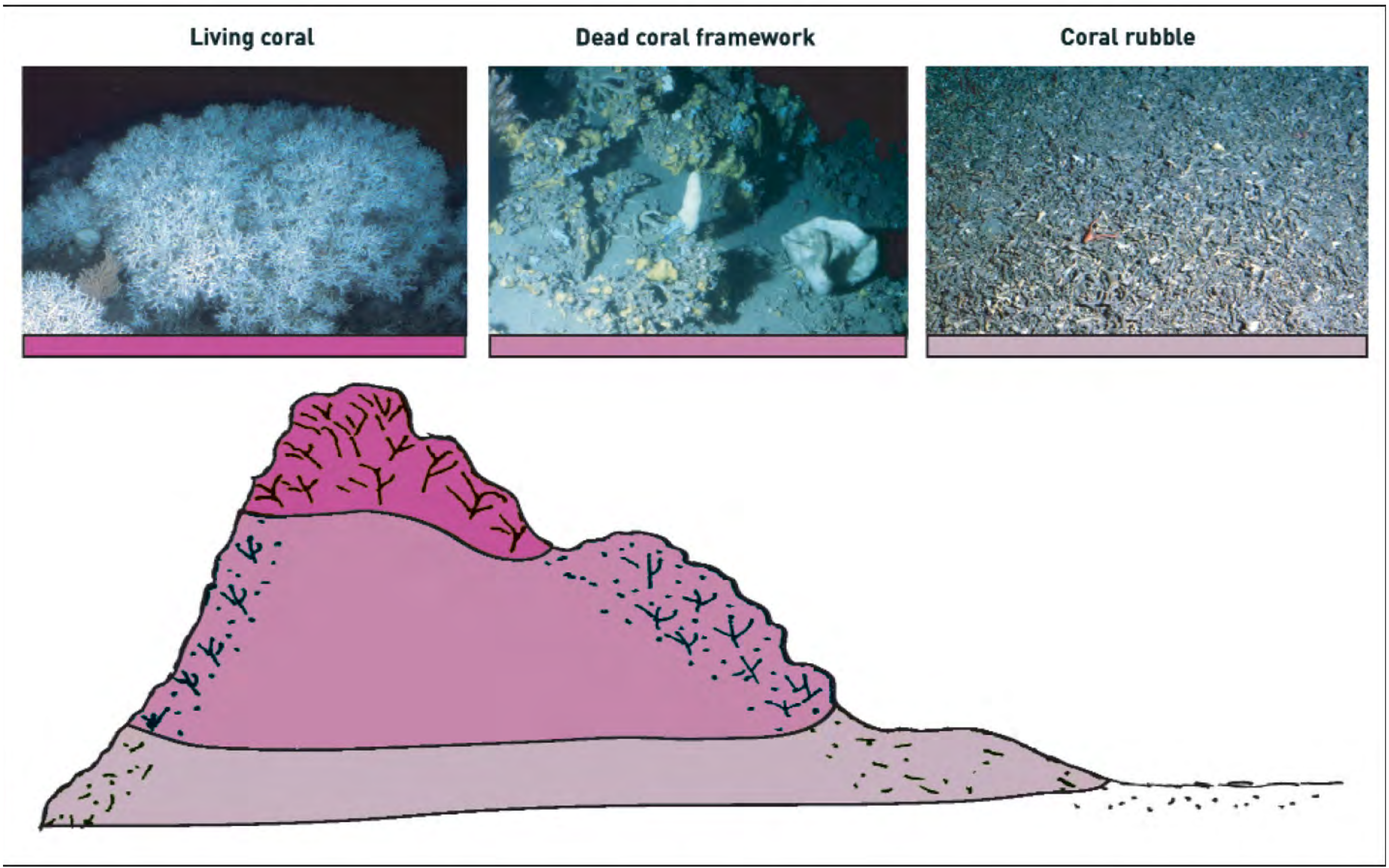

Figure 8: Schematic sketch of the major habitats of a *Lophelia* reef (not to scale) Photos: the JAGO-Team

Figure 67. Figure 8 from Freiwald et al., (2004). Lophelia *reefs frequently occur as small patches of living reef at the top of mounds with dead coral framework beneath and a base of coral rubble. The mounds have been shown to be up to 8,000 years old.*

3.5 Vulnerable marine ecosystems

Carbonate mounds and *Lophelia* reefs in the Porcupine Seabight

The Hovland Mound Province and Belgica Mound Province offshore SACs were designated to protect carbonate mounds in the Porcupine Seabight and on the continental slope (NPWS, 2013). One SeaRover objective was to survey additional sites inside or close to these SACs and to monitor their condition since the cessation of bottom fishing within them.

A number of dives were carried out to compare known carbonate mounds topped with cold water coral reefs in the Belgica Mound Province and Hovland Mound Province SACs and to test predictive modelling of these habitats. The predictive model of *Lophelia* distribution from Ross & Howell, (2013) was overlain in the GIS onto the SeaRover positions. Figure 50 shows how this predictive layer compares with SeaRover groundtruthing of *Lophelia* reef extent in the Belgica Mound Province SAC. The occurrence model is insufficiently granular to predict actual habitat transitions and does not predict *Lophelia* reef below -800 m or on mound tops. Later, Ross et al. 2015 provided another model for predicted distribution of *Lophelia pertusa*, *Pheronema carpenteri* and *Syringammina fragilissima* habitat using higher resolution bathymetry and with more emphasis on rugosity than bathymetry. SeaRover data will allow a comparison of these models which have important value for predicting these VMEs in areas where detailed bathymetry has not yet been obtained.

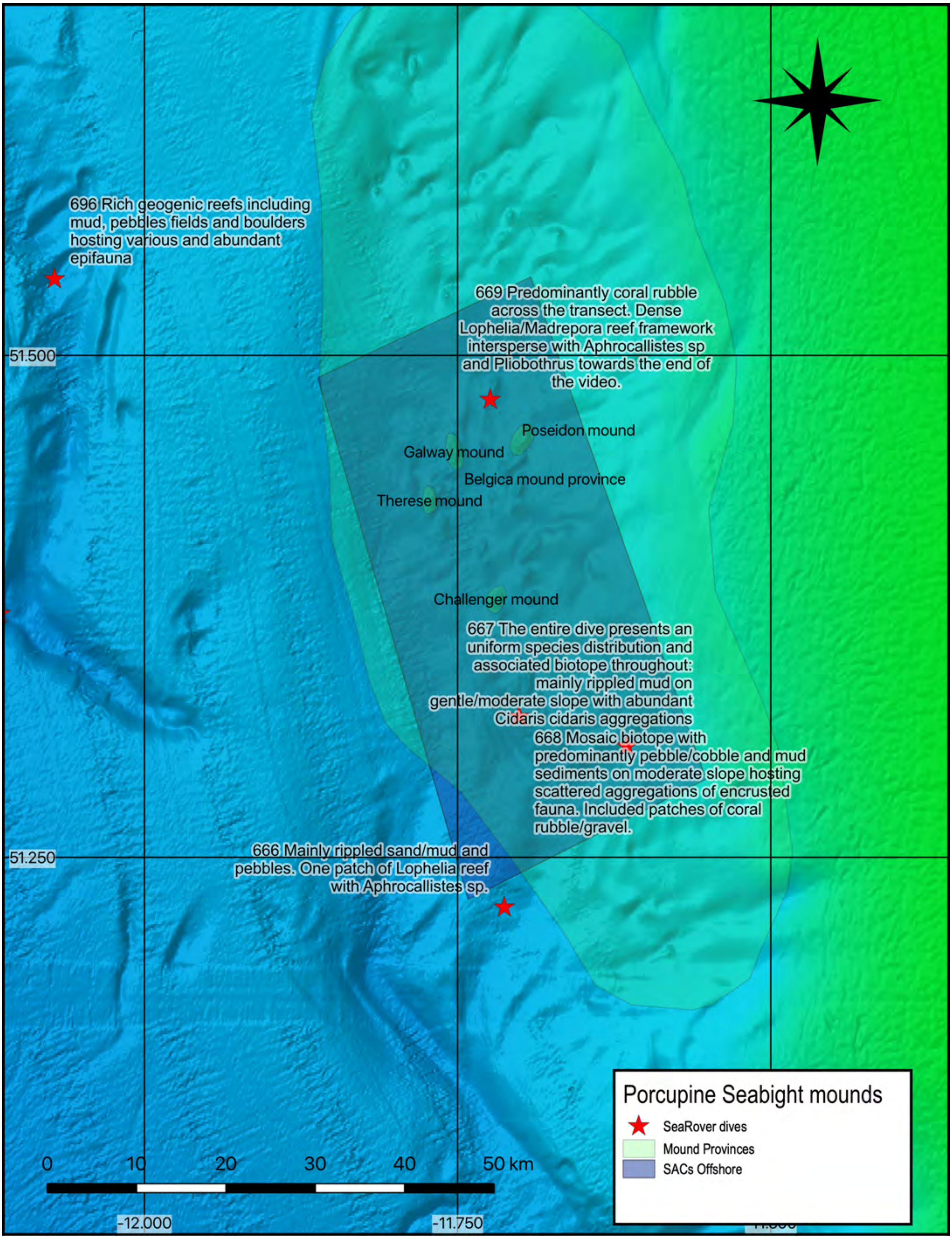

Figure 68. Biotope observations within Belgica Mound Province overlain on EMODnet bathymetry. Dive summaries displayed on this map are within the layer definition shapefile as one set of attributes and can be switched on or off within the GIS.

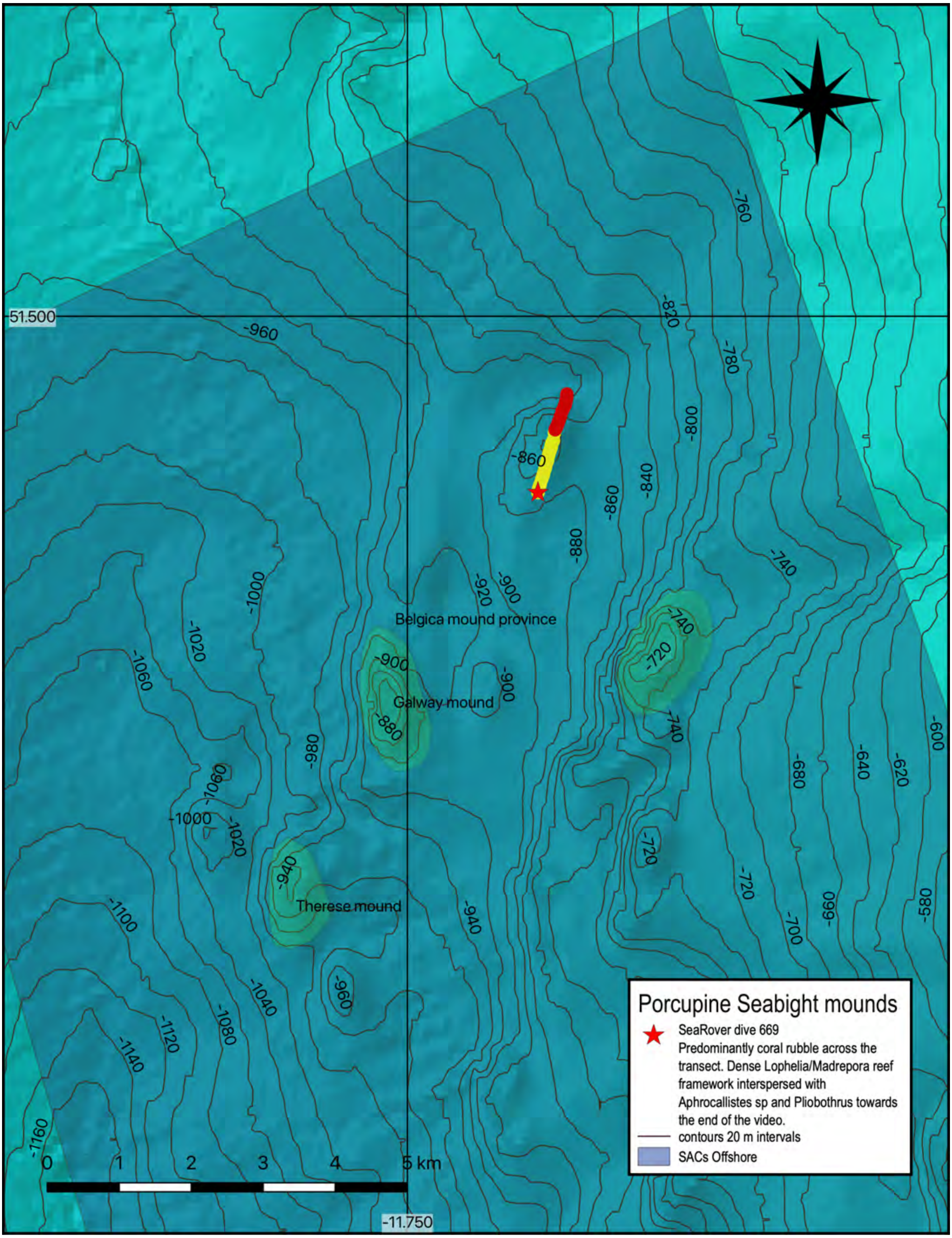

Figure 69. Larger scale view of dive 669 biotope observations overlain on EMODnet bathymetry with 20 m contour lines to show location of dive within the Belgica mound province SAC. At this resolution the carbonate mounds are easily distinguishable on the high resolution bathymetry. EMODnet bathymetry is sufficient to show the shape of the carbonate mounds and these are normally topped by live reef (Freiwald et al., 2004).

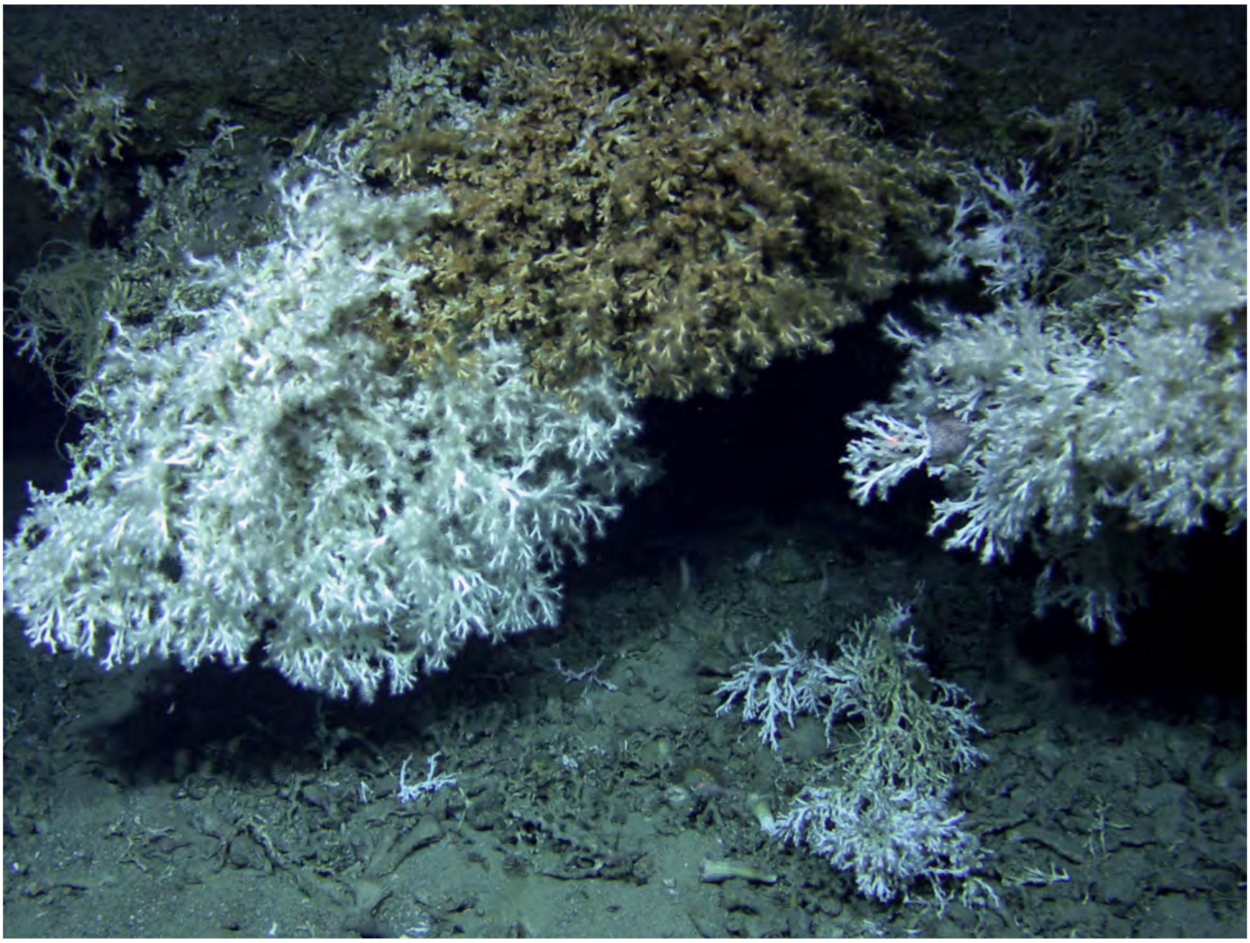

Figure 70. Lophelia *coral reef.*

Solenosmilia variabilis is believed to be a widely distributed coral found worldwide in deeper habitats than *Lophelia* and *Madrepora*. It forms smaller reefs, normally on rock. It is very slow growing with rates measured at less than 1 mm per year. SeaRover found it to be frequent on steep rock surfaces at depths of 800-2000 metres on steep geogenic reef habitats in canyons, epecially in the NW sector of the continental slope.

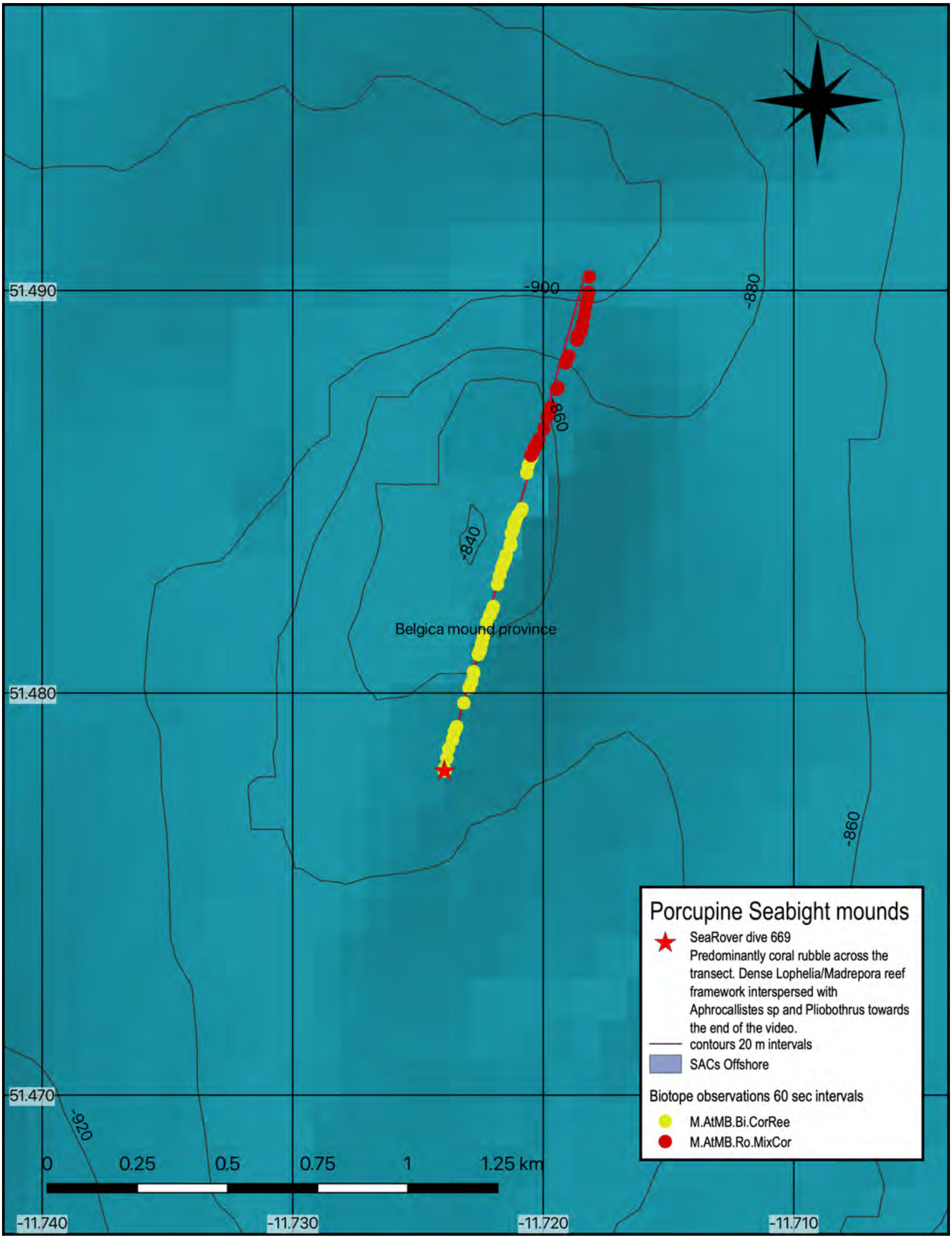

Figure 71. Larger scale view of dive 669 biotope observations overlain on EMODnet bathymetry with 20 m contour lines to show location of dive within the Belgica mound province SAC. At this resolution the high resolution bathymetry is visible as pixels but the transition from one coral biotope to the other recorded at this site is indicated by the change of symbol colour.

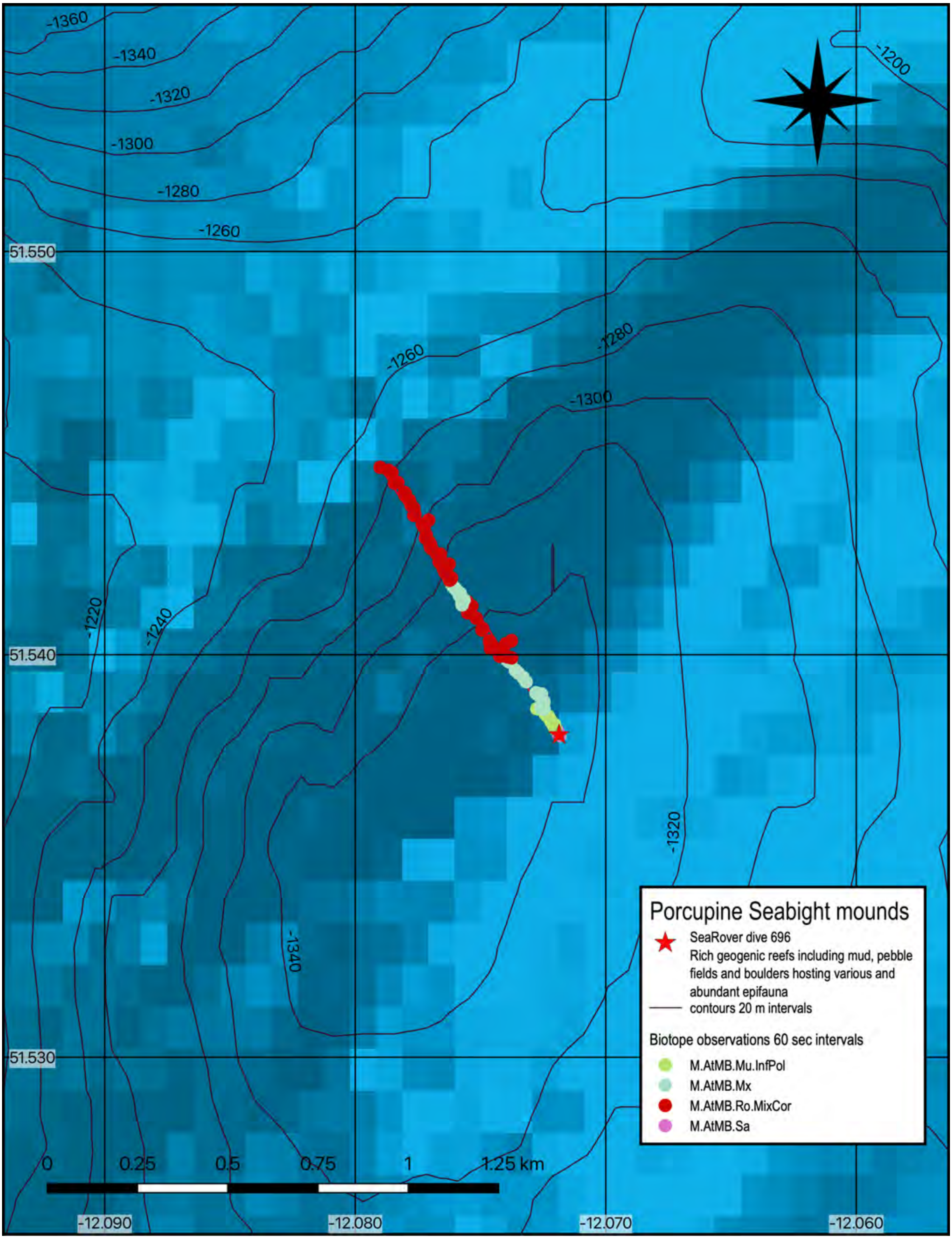

Figure 72. Larger scale view of dive 696 biotope observations overlain on EMODnet bathymetry with 20 m contour lines to show location of dive to the west of the Belgica mound province SAC. The biotope in red is the deep water Solenosmilia *coral instead of* Lophelia. *Habitat heterogenity is apparent on a scale of hundreds of metres.*

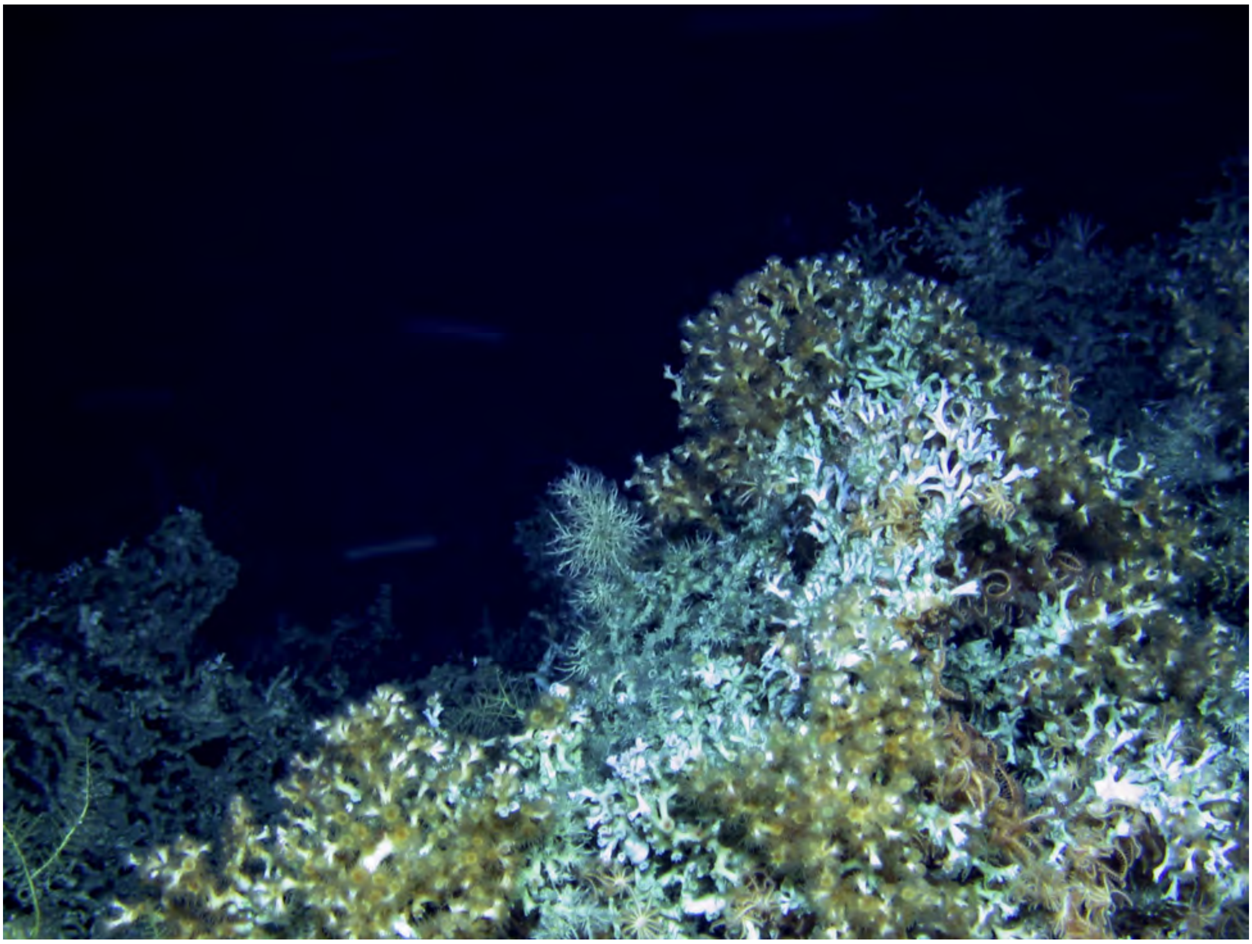

Figure 73. Vulnerable marine ecosystems (VMEs); cold water coral reef of Lophelia pertusa.

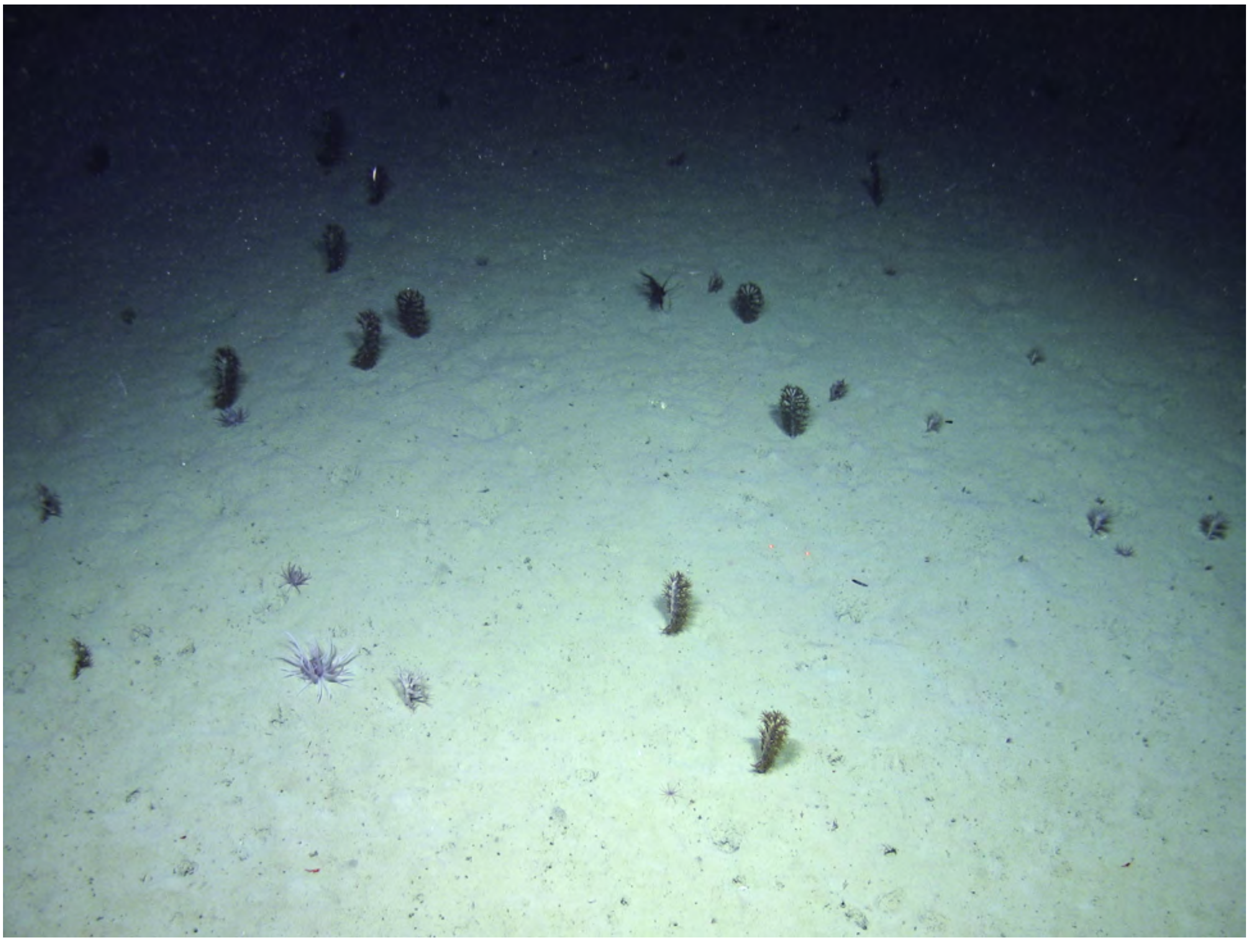

Figure 74. Vulnerable marine ecosystems (VMEs); sea-pen fields with burrowing anemones.

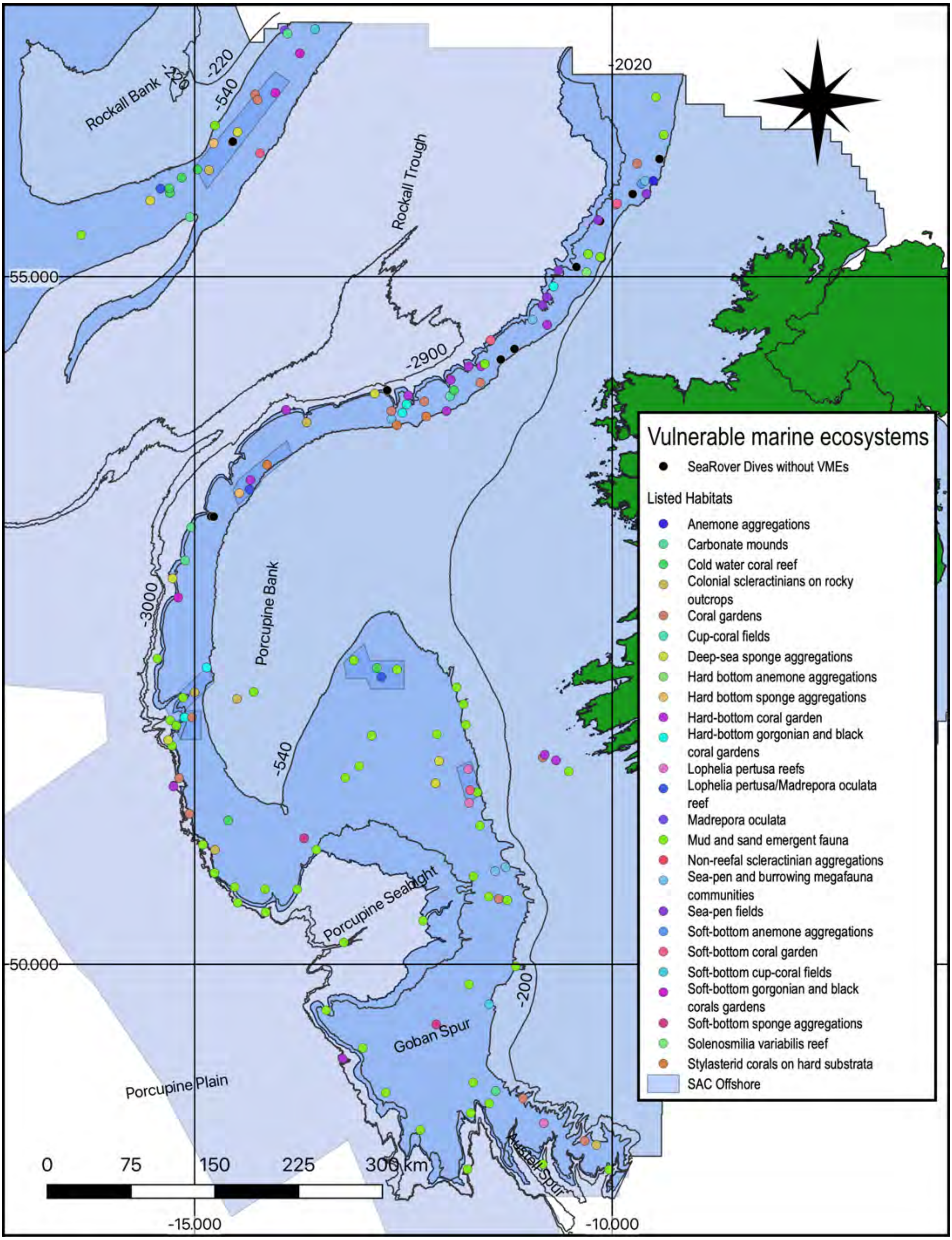

Figure 75. Vulnerable marine ecosystems (VMEs). Map to show distribution of VMEs and sites without recorded VME. VME categories are nested and some sites have multiple VMEs so map is only to show overall pattern of occurrence and a full list of VMEs and cannot be interpreted as presence or absence of specific VMEs. Figures 75 - 112 show distributions of individual VMEs.

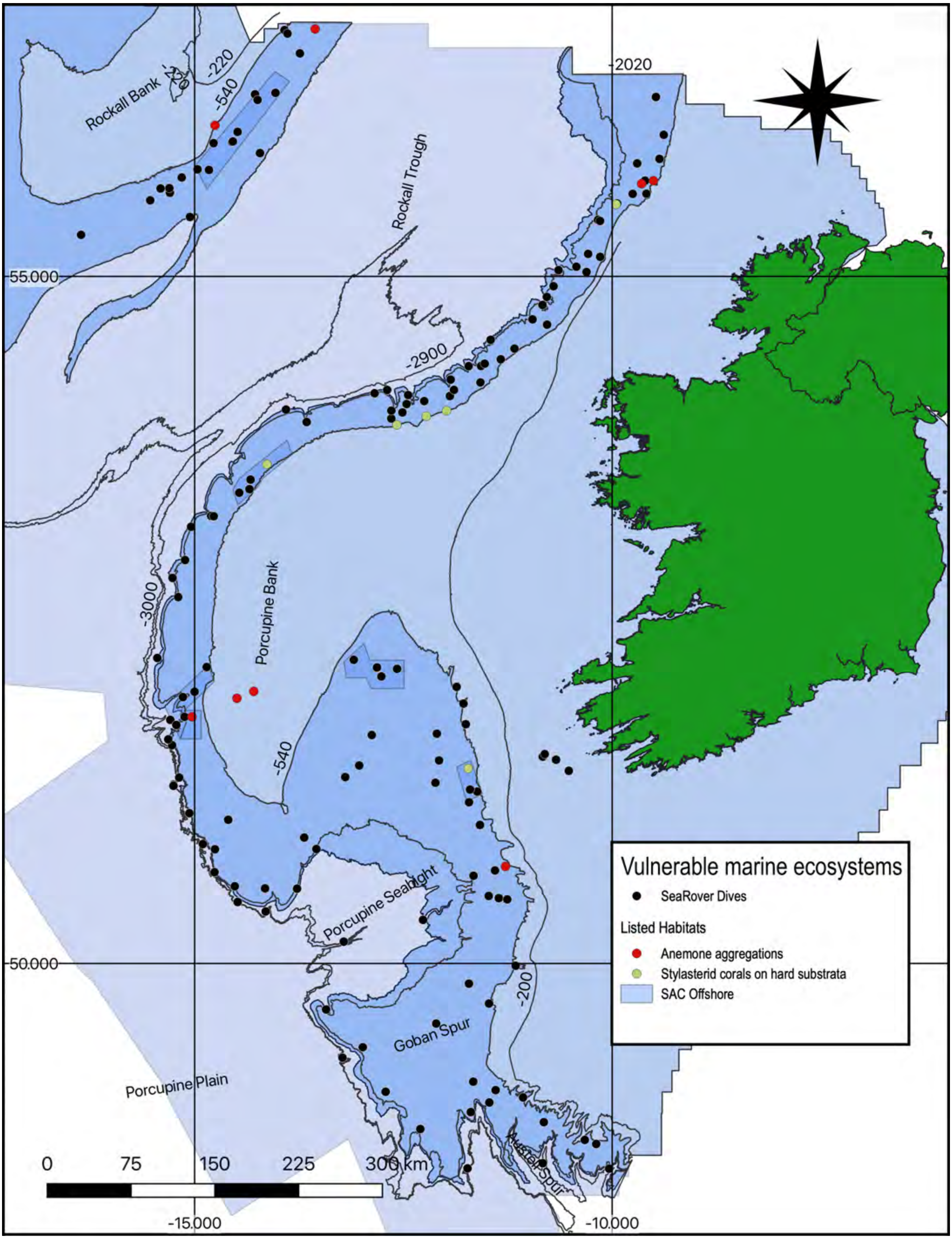

Figure 76. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as anemone aggregations and stylasterid corals on hard substrata. The two categories were mutually exclusive within the dataset.

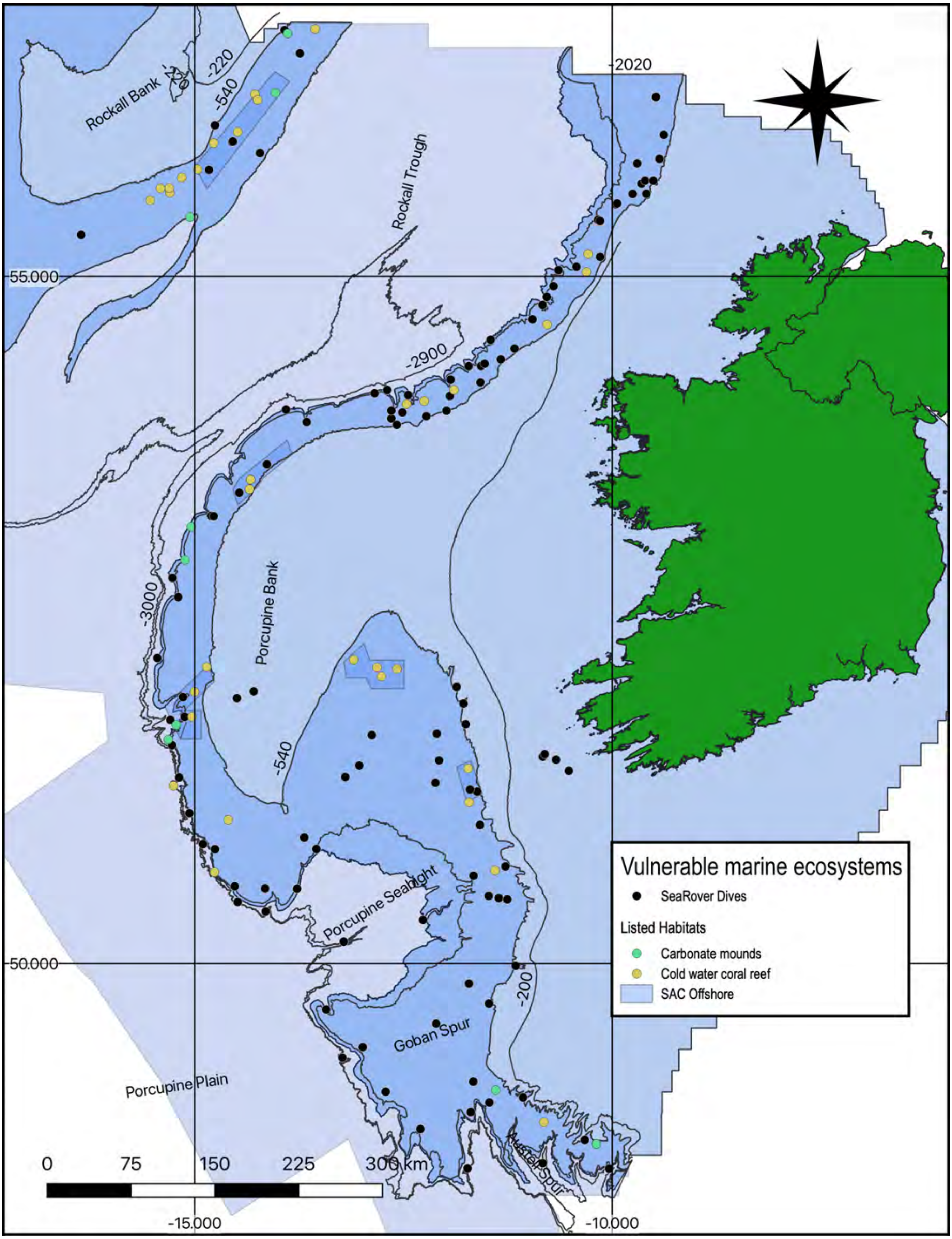

Figure 77. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as carbonate mounds and Cold water coral reef. The two categories were mutually exclusive within the dataset.

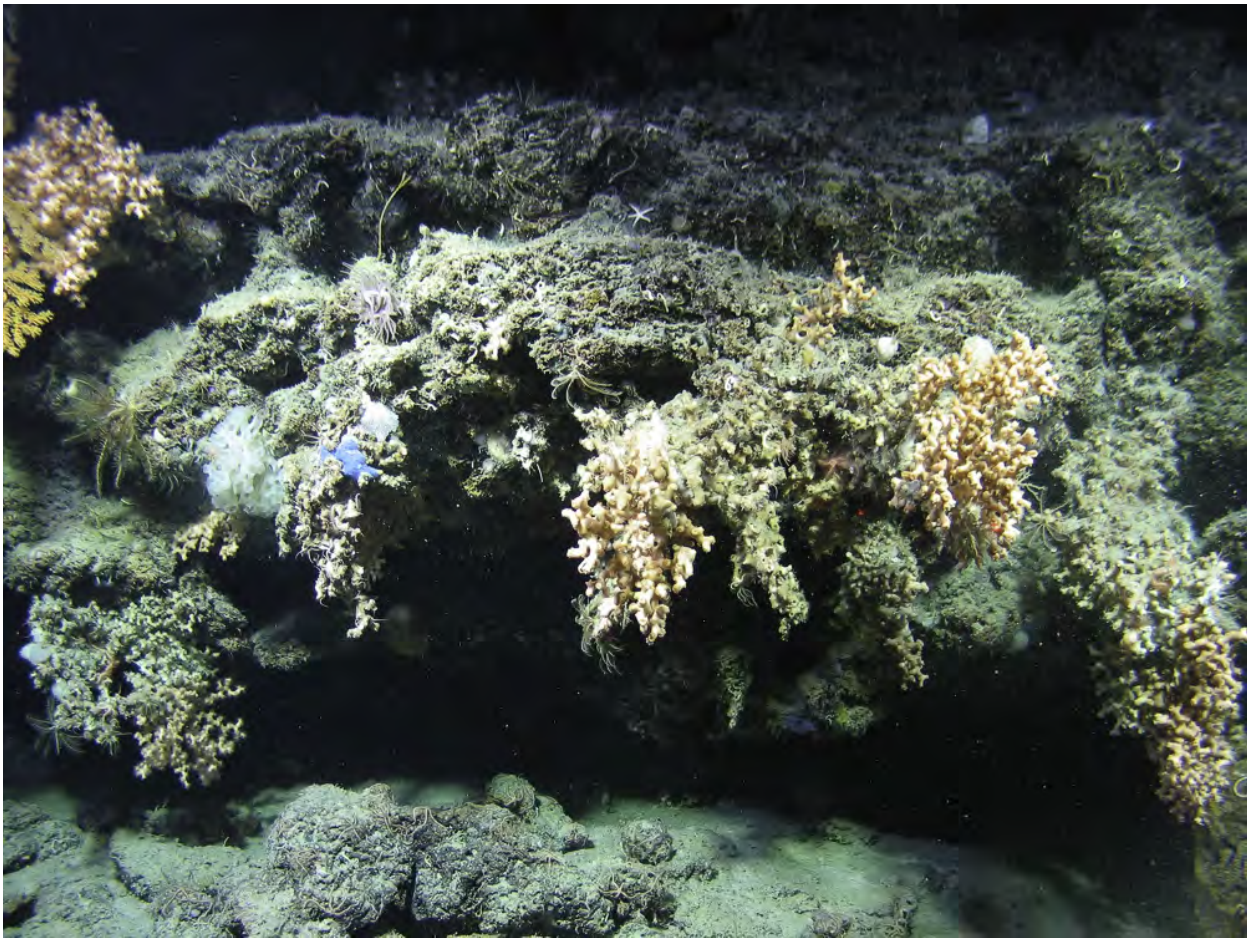

Figure 78. Vulnerable marine ecosystems (VMEs); colonial scleractinians on rocky outcrops. The slow growing hard coral Solenosmilia variabilis *was associated with geogenic reefs below -800 m.*

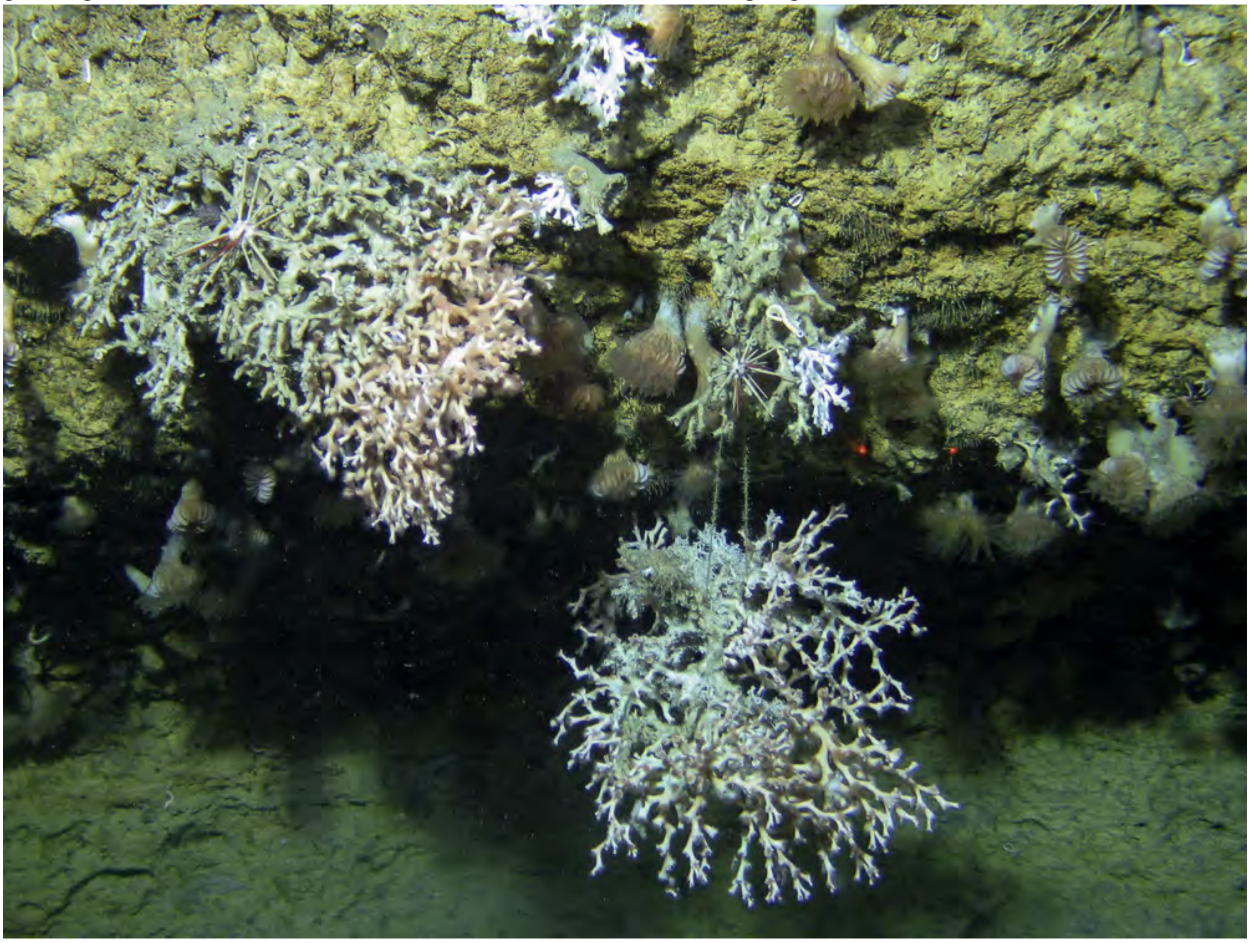

Figure 79. Vulnerable marine ecosystems (VMEs); colonial scleractinians on rocky outcrops.

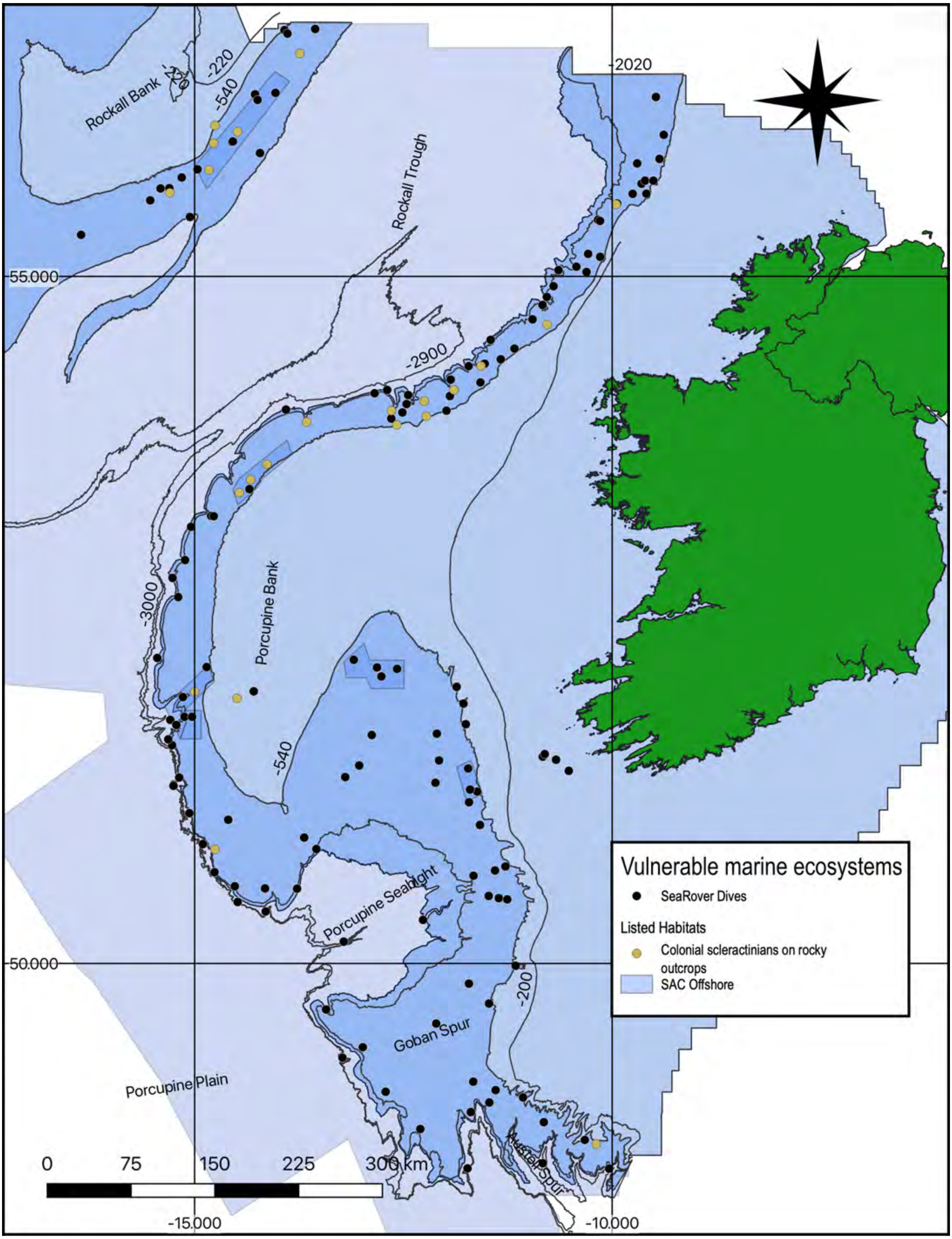

Figure 80. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as colonial scleractinians on rocky outcrops.

Figure 81. Vulnerable marine ecosystems (VMEs); Stylasterid hydrozoans on geogenic reef.

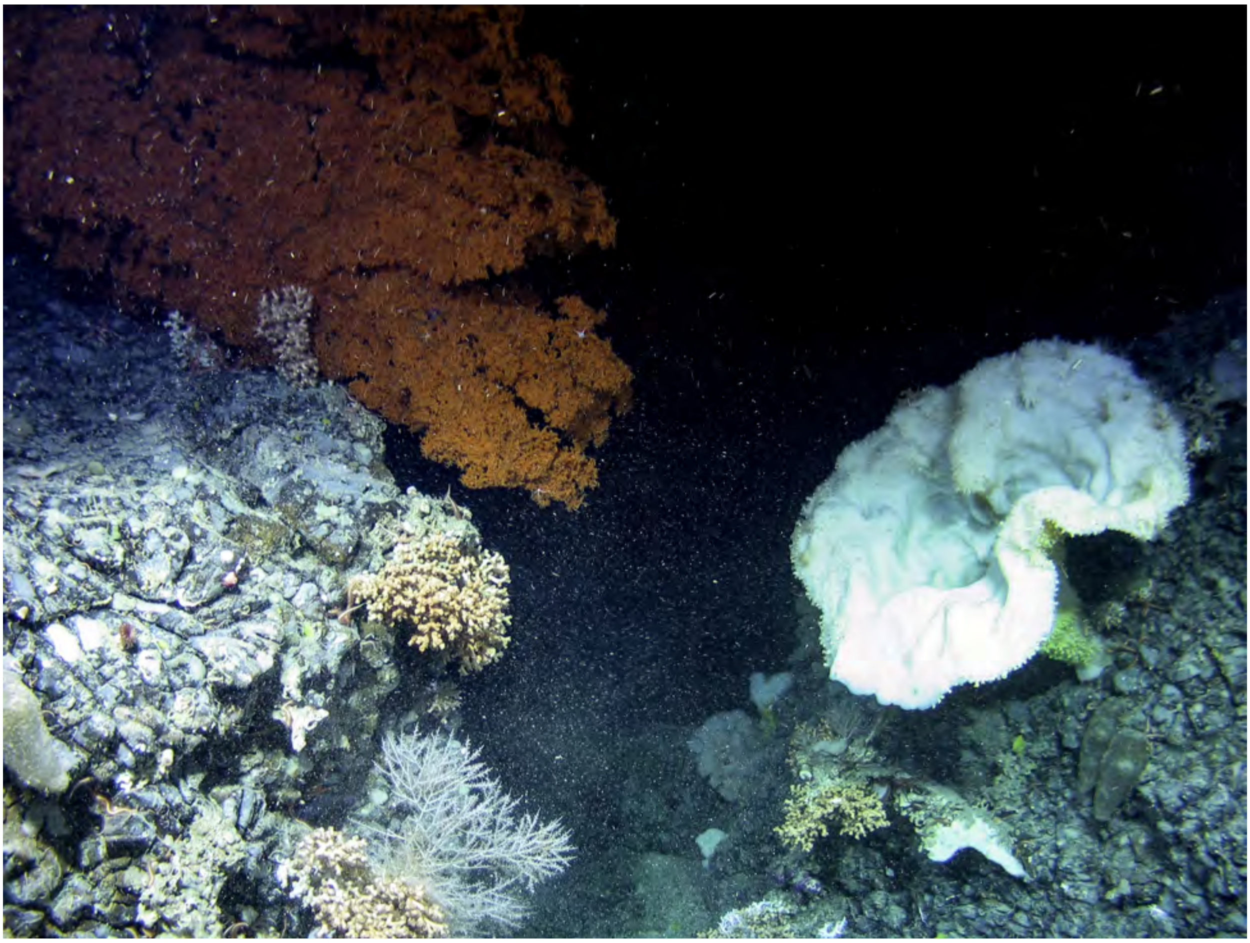

Figure 82. Vulnerable marine ecosystems (VMEs), coral gardens.

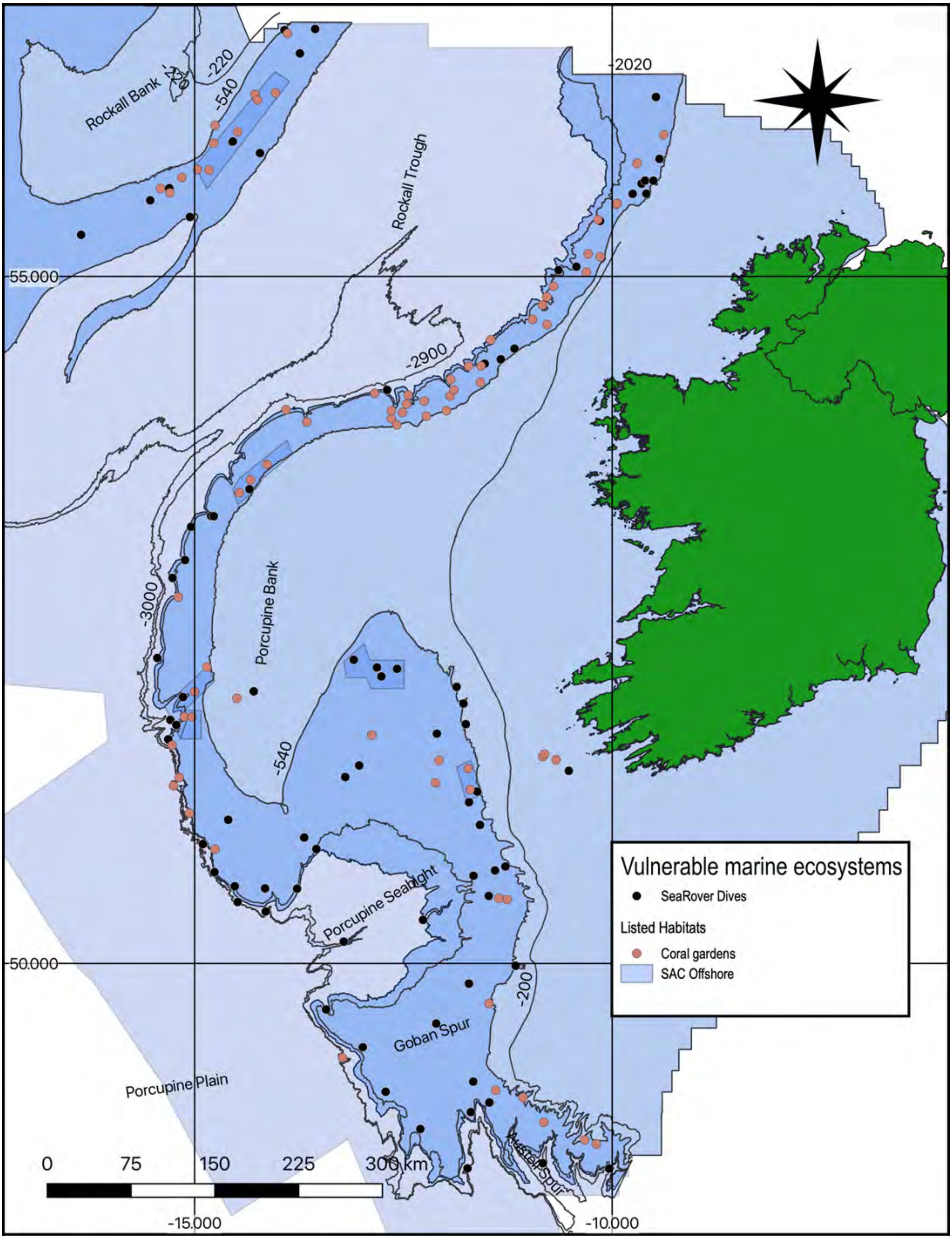

Figure 83. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as coral gardens

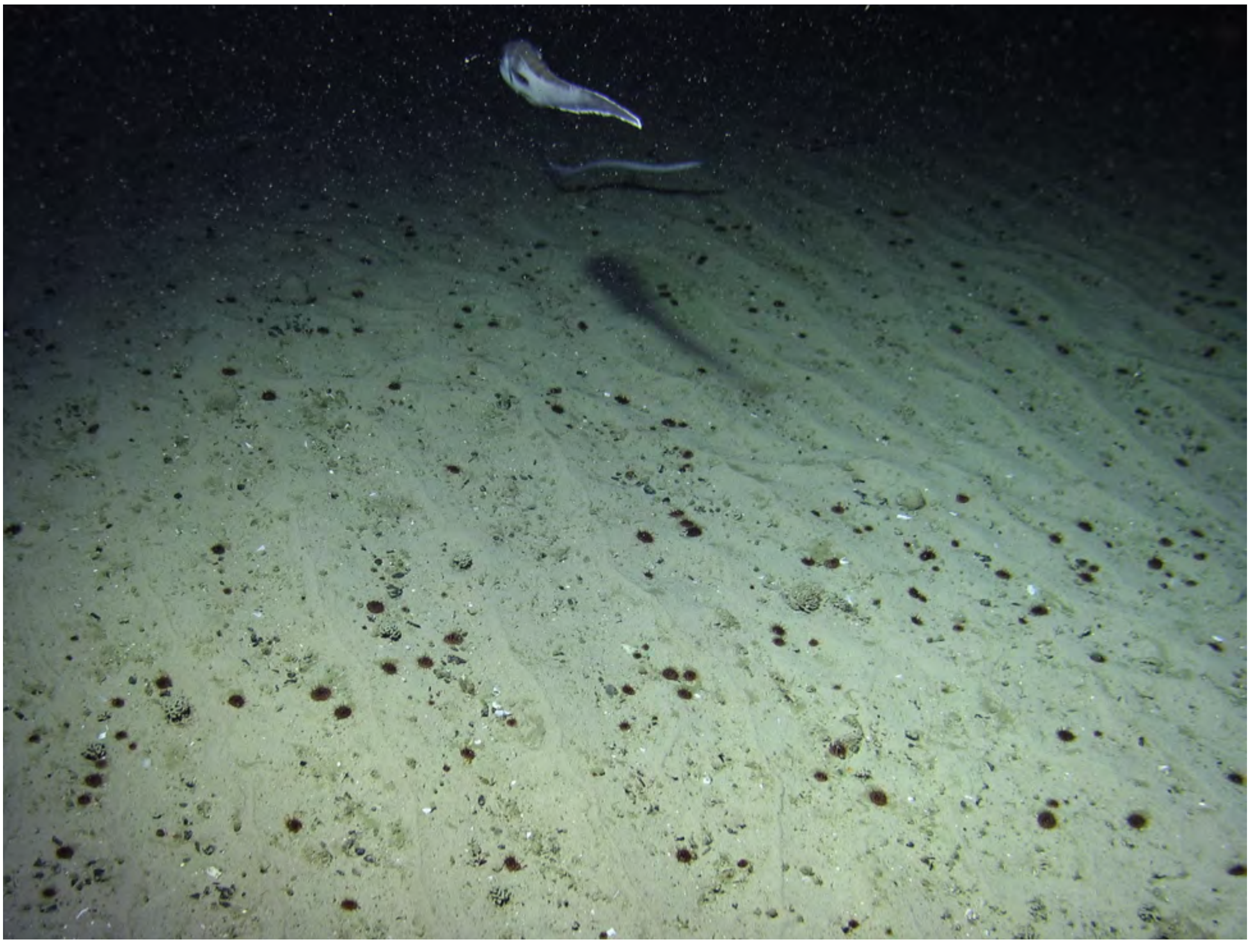

Figure 84. Vulnerable marine ecosystems (VMEs). Cup-coral fields on rippled sand.

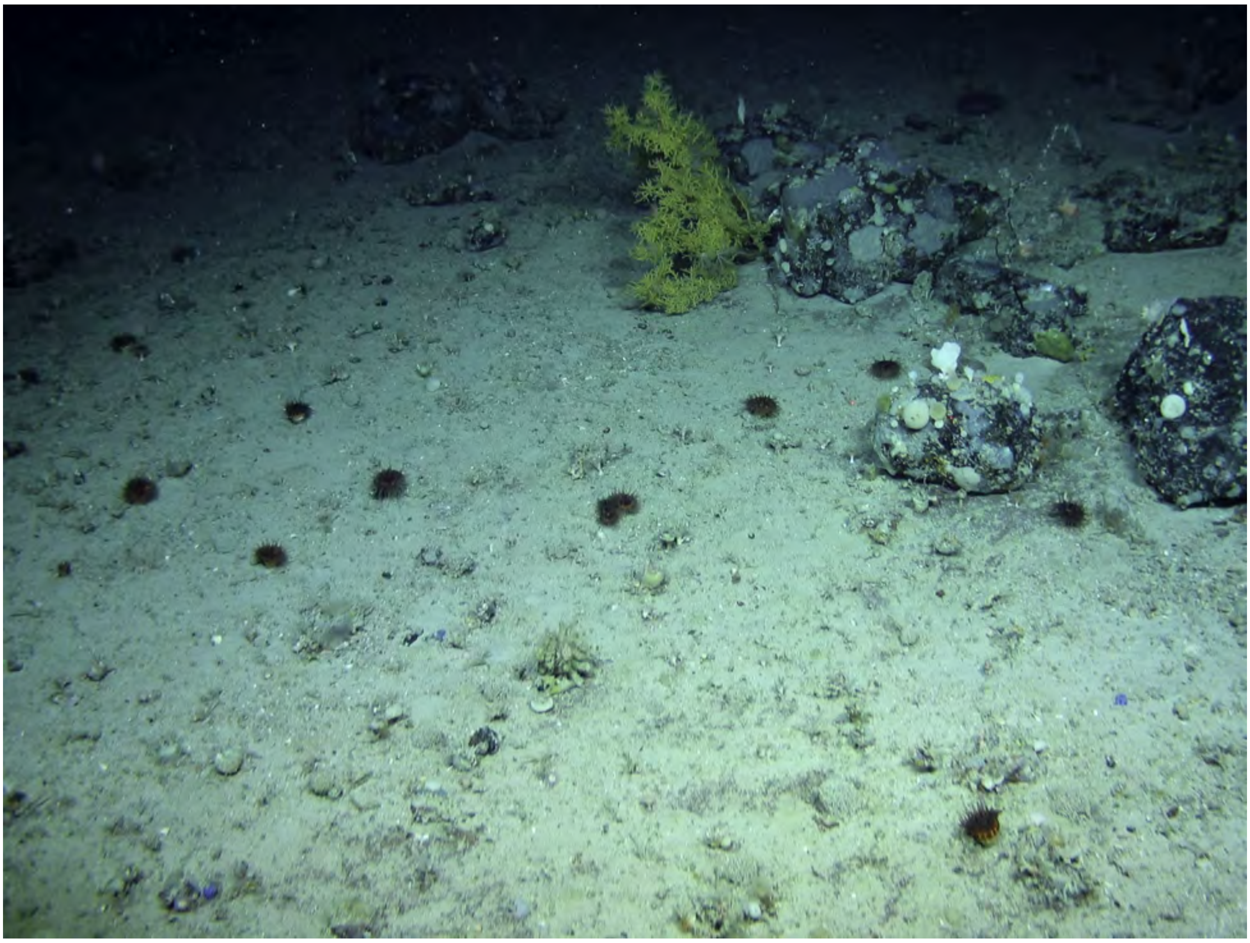

Figure 85. Vulnerable marine ecosystems (VMEs). Cup-coral fields adjacent to stony seabed with black corals.

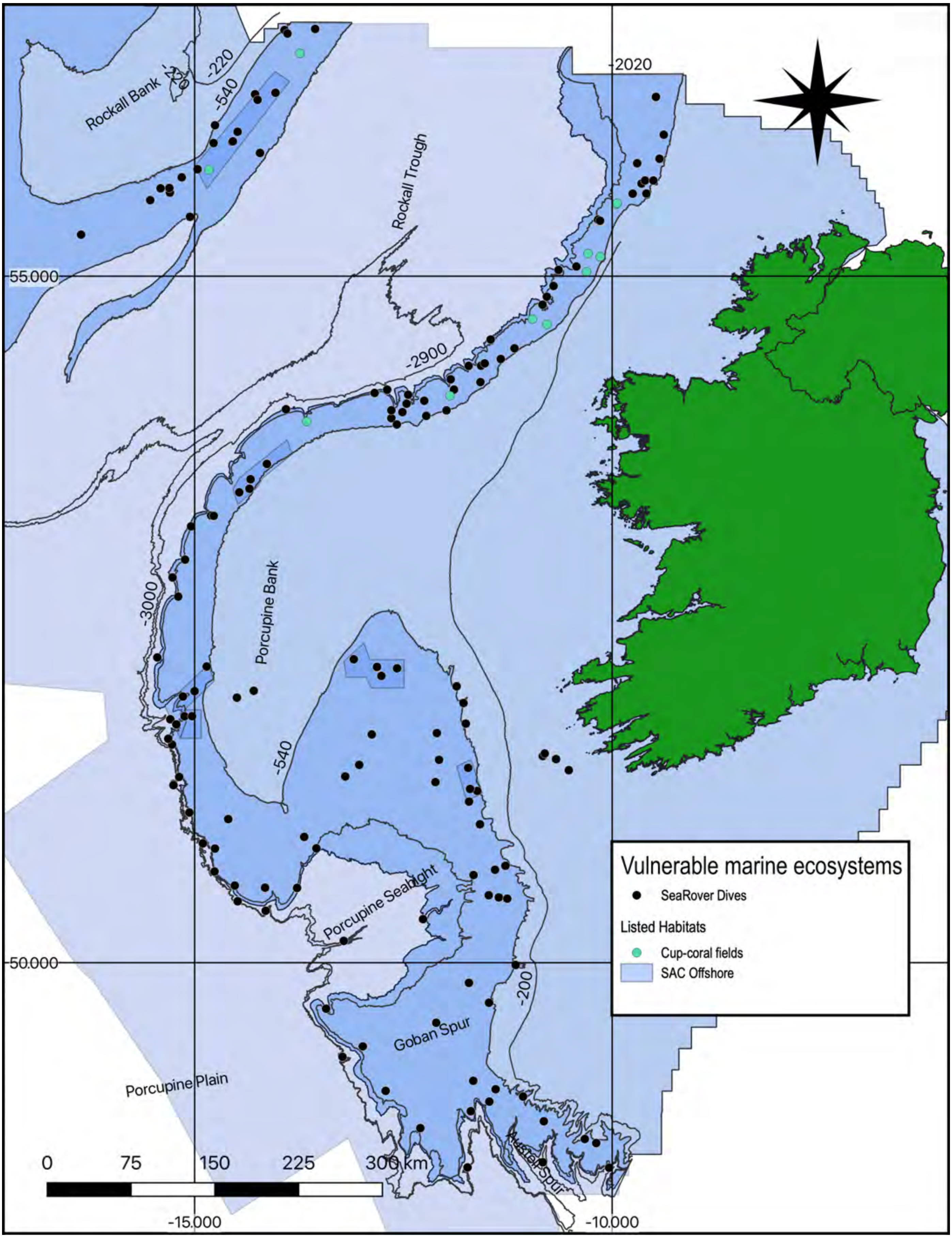

Figure 86. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as cup-coral fields

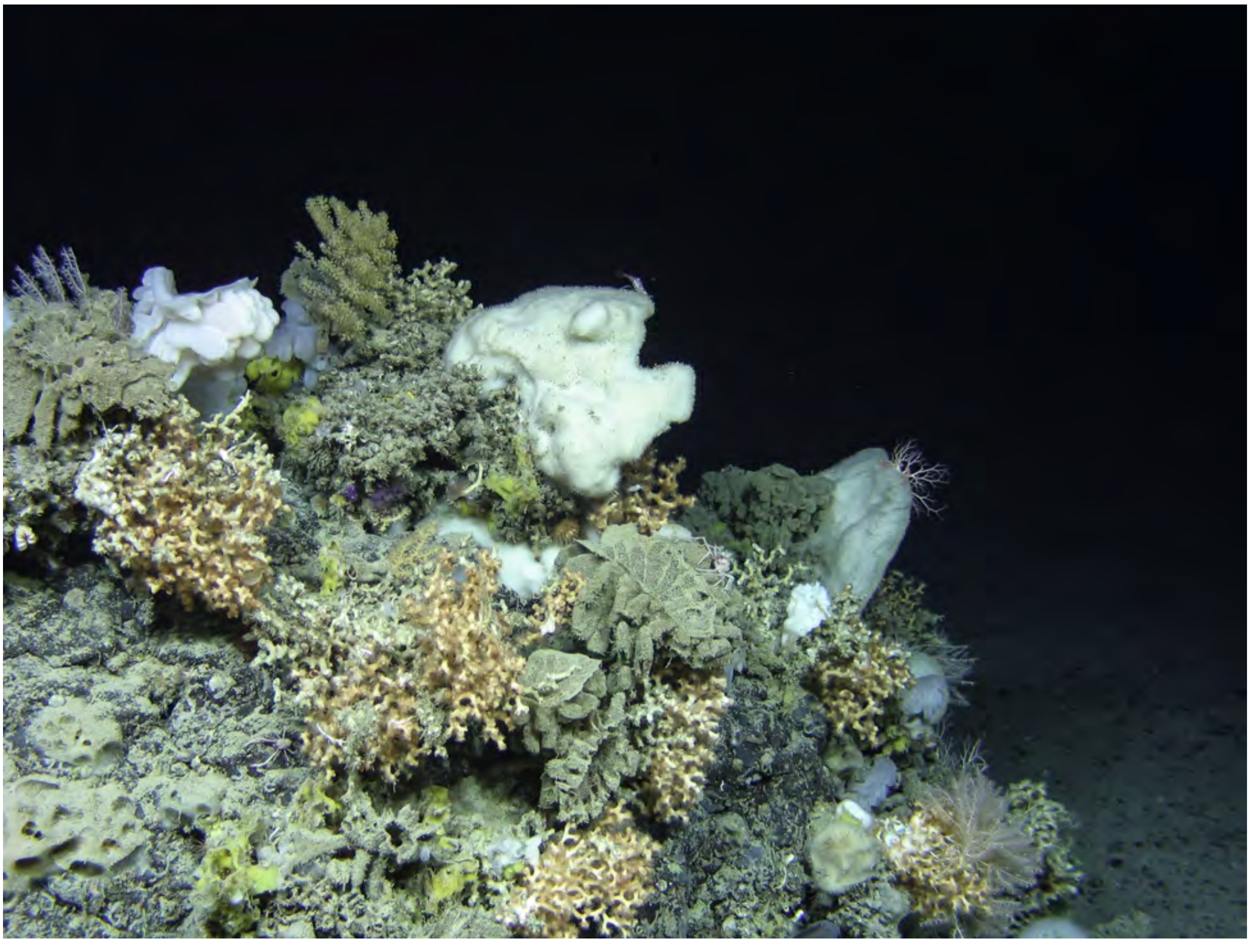

Figure 87. Deep sea sponge aggregations, glass sponges with Solenosmilia *coral.*

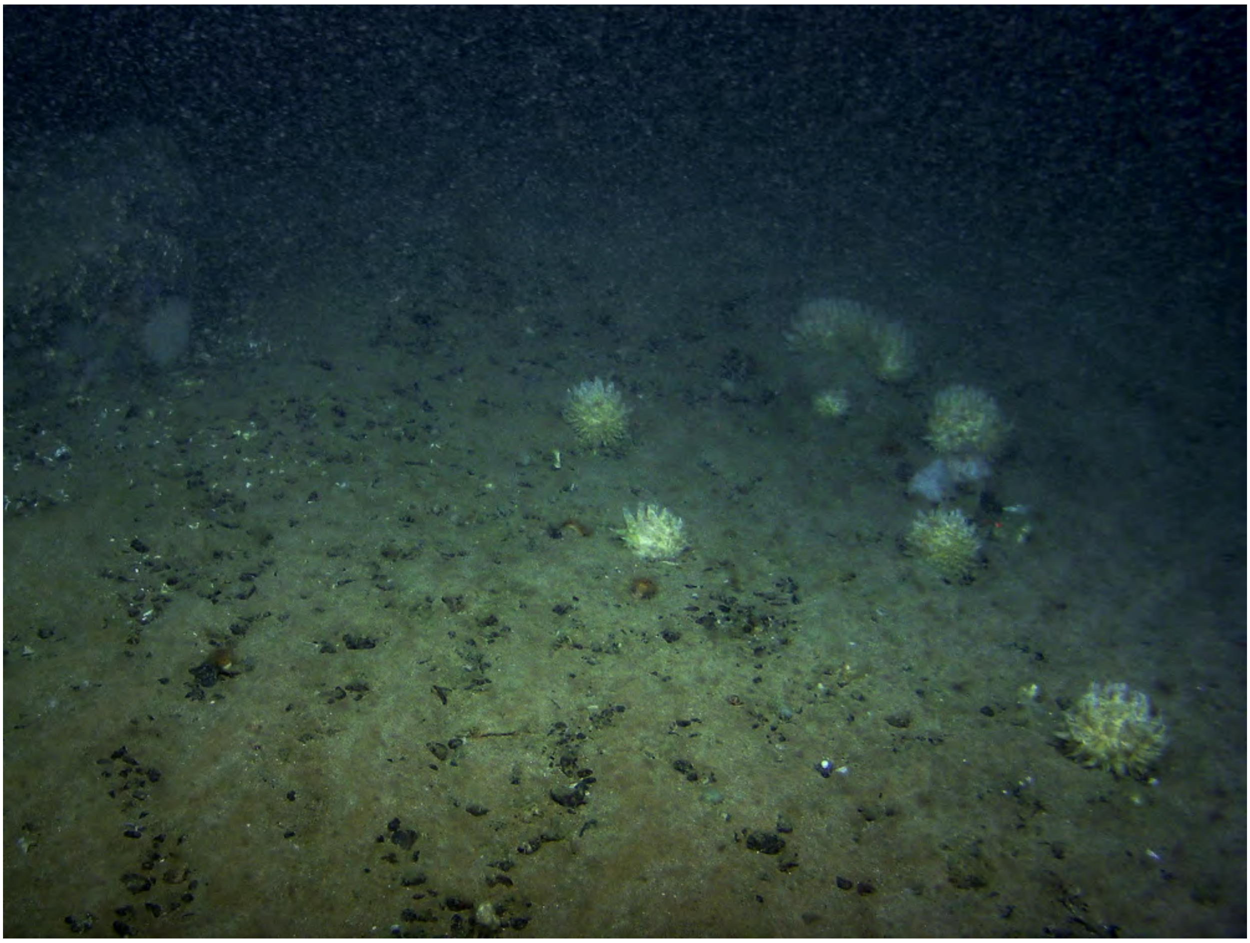

Figure 88. Deep sea sponge aggregations, Polymastiid sponges on mixed sediment adjacent to rocky reef.

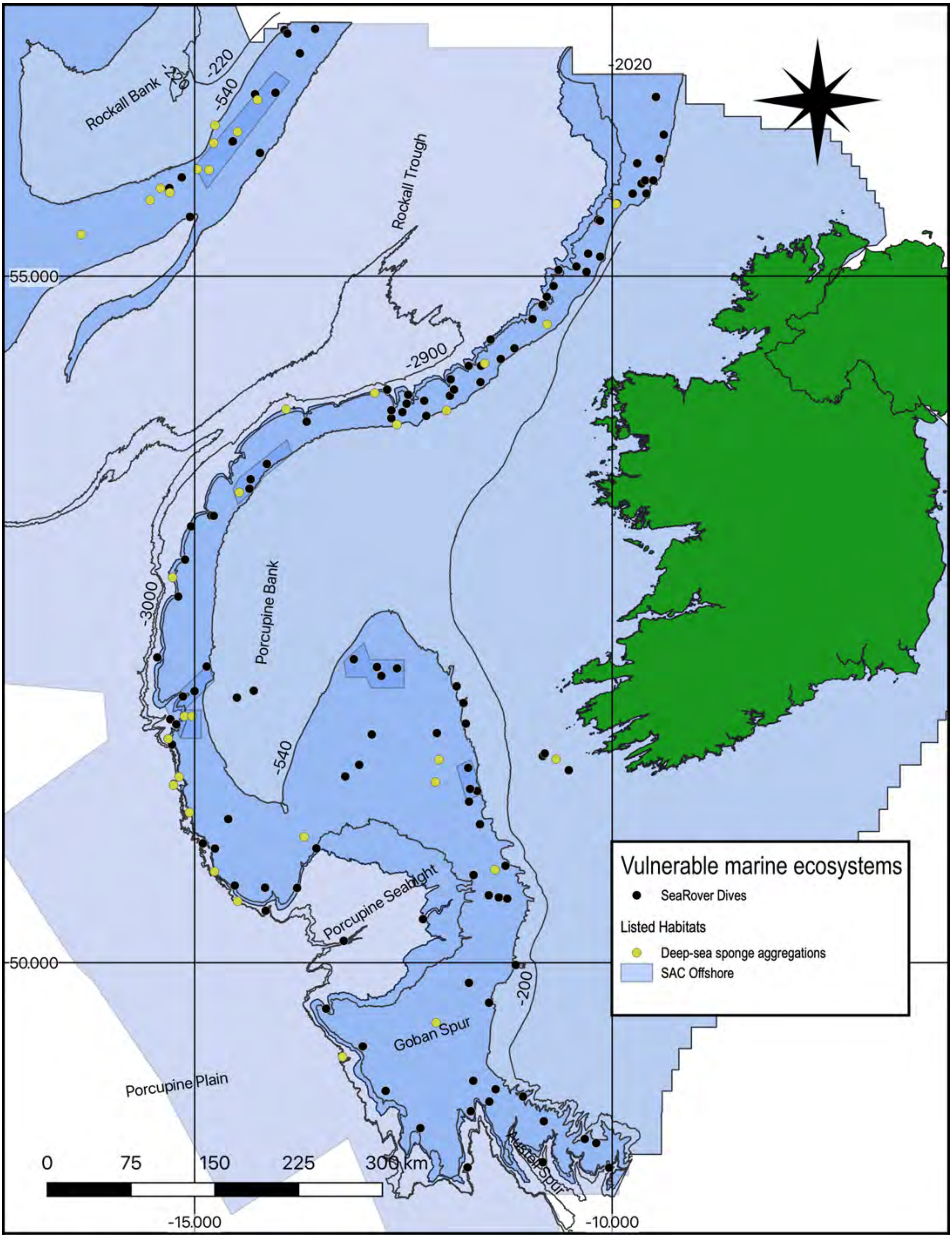

Figure 89. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as deep-sea sponge aggregations.

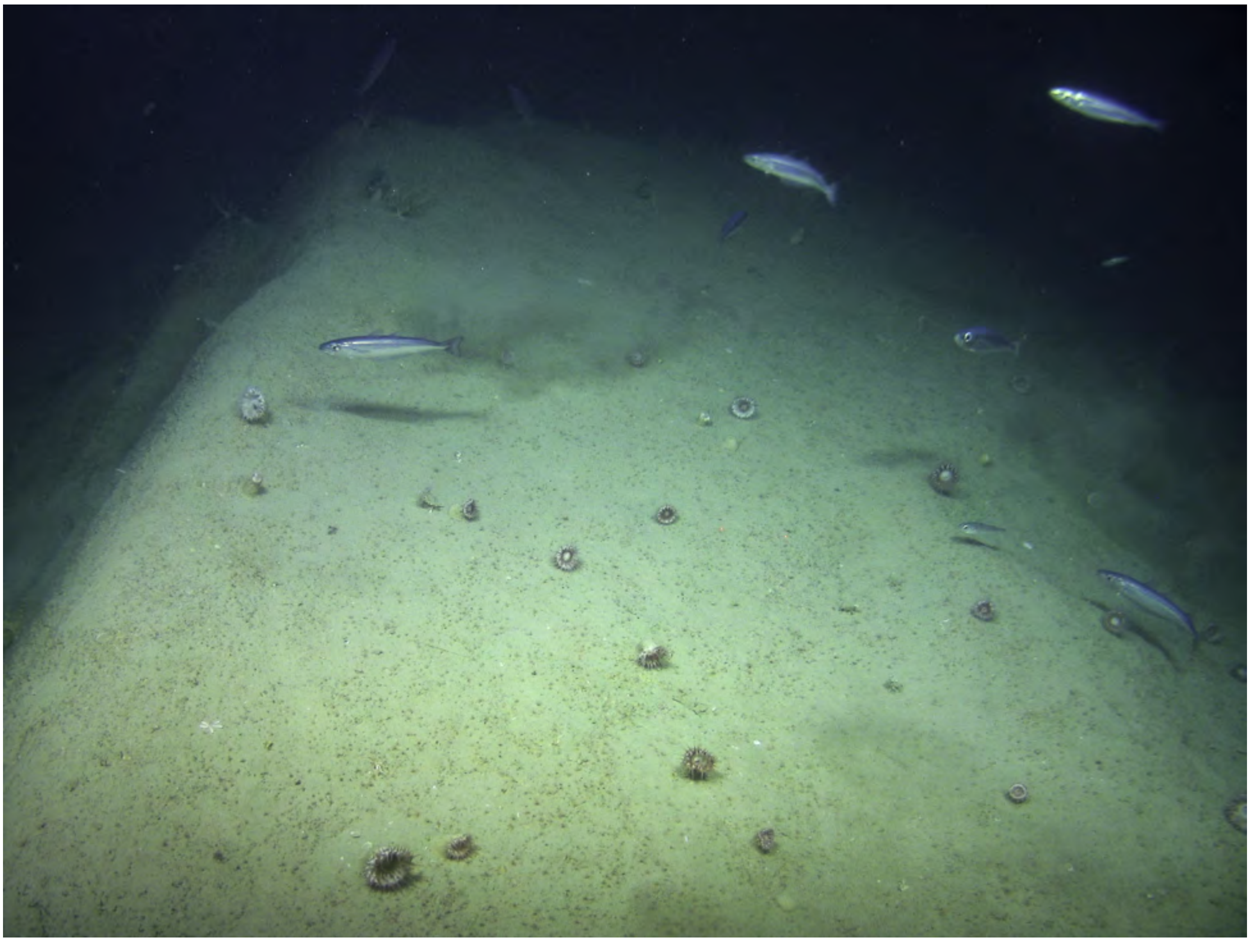

Figure 90. Hard bottom anemone aggregations.

Figure 91. Solenosmilia *reef with giant file shells,* Acesta*.*

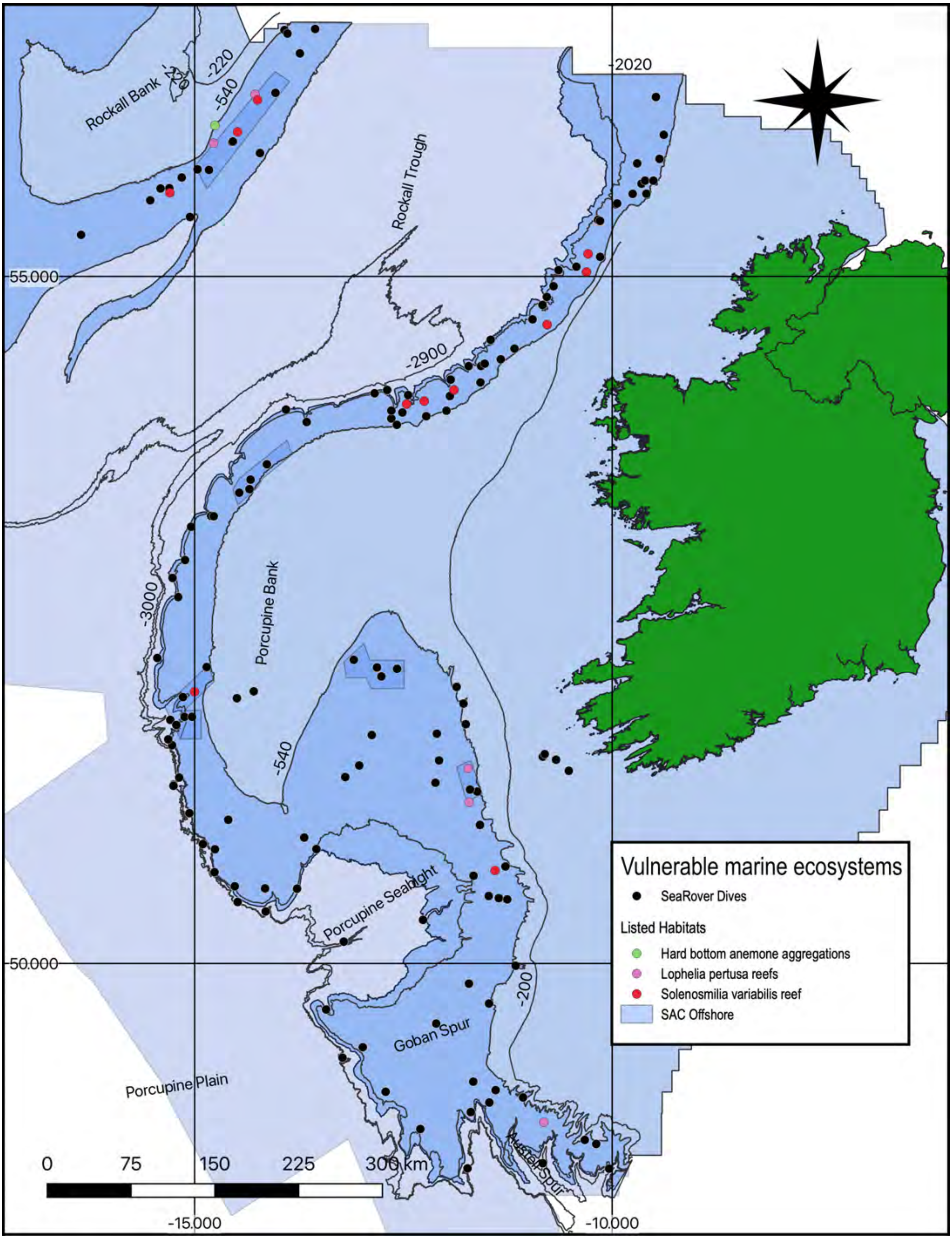

Figure 92. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as hard bottom anemone aggregations, Lophelia *reefs and* Solenosmilia *reefs. The categories were mutually exclusive within the dataset.*

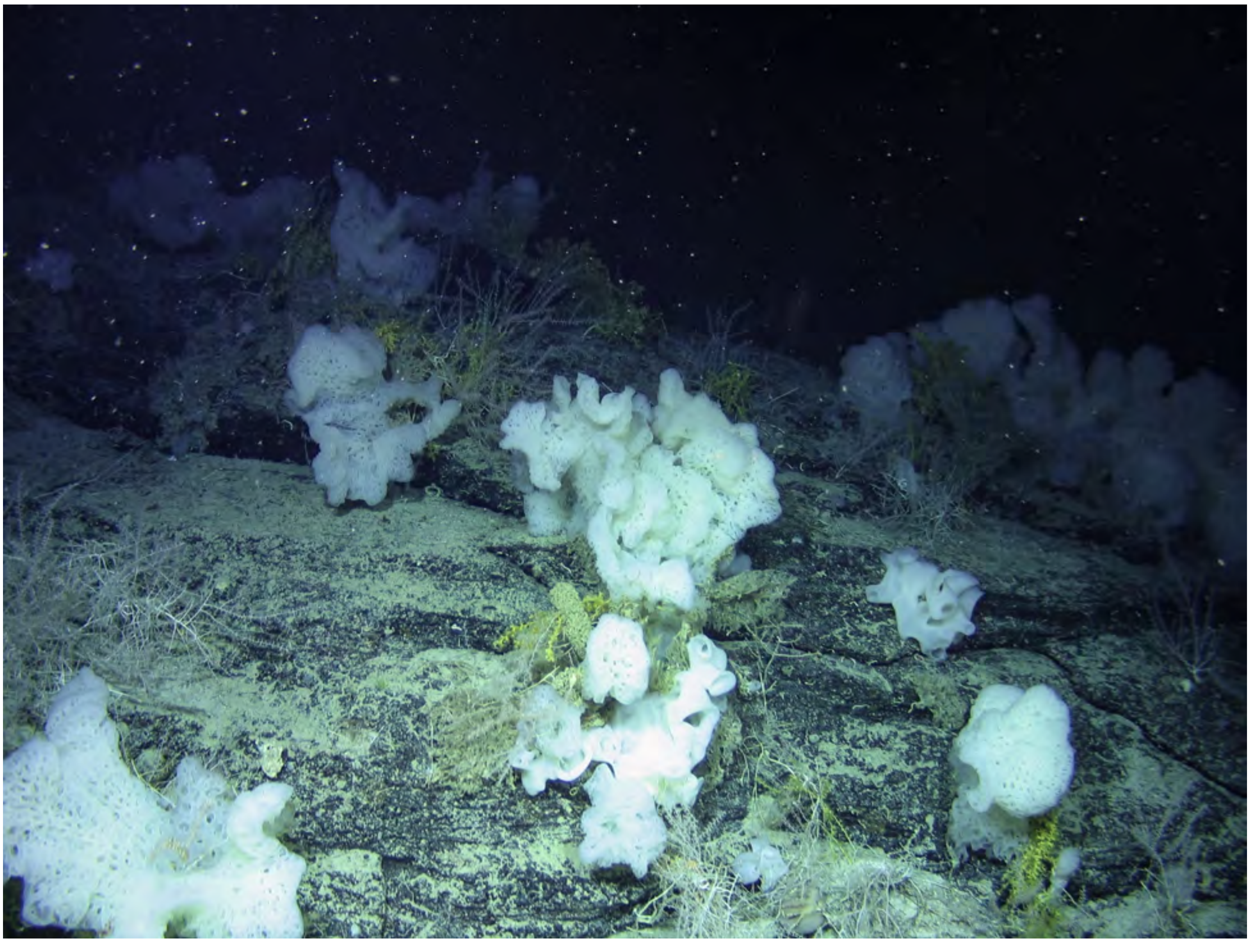

Figure 93. Vulnerable marine ecosystems (VMEs). Hard bottom sponge aggregations dominated by glass sponges.

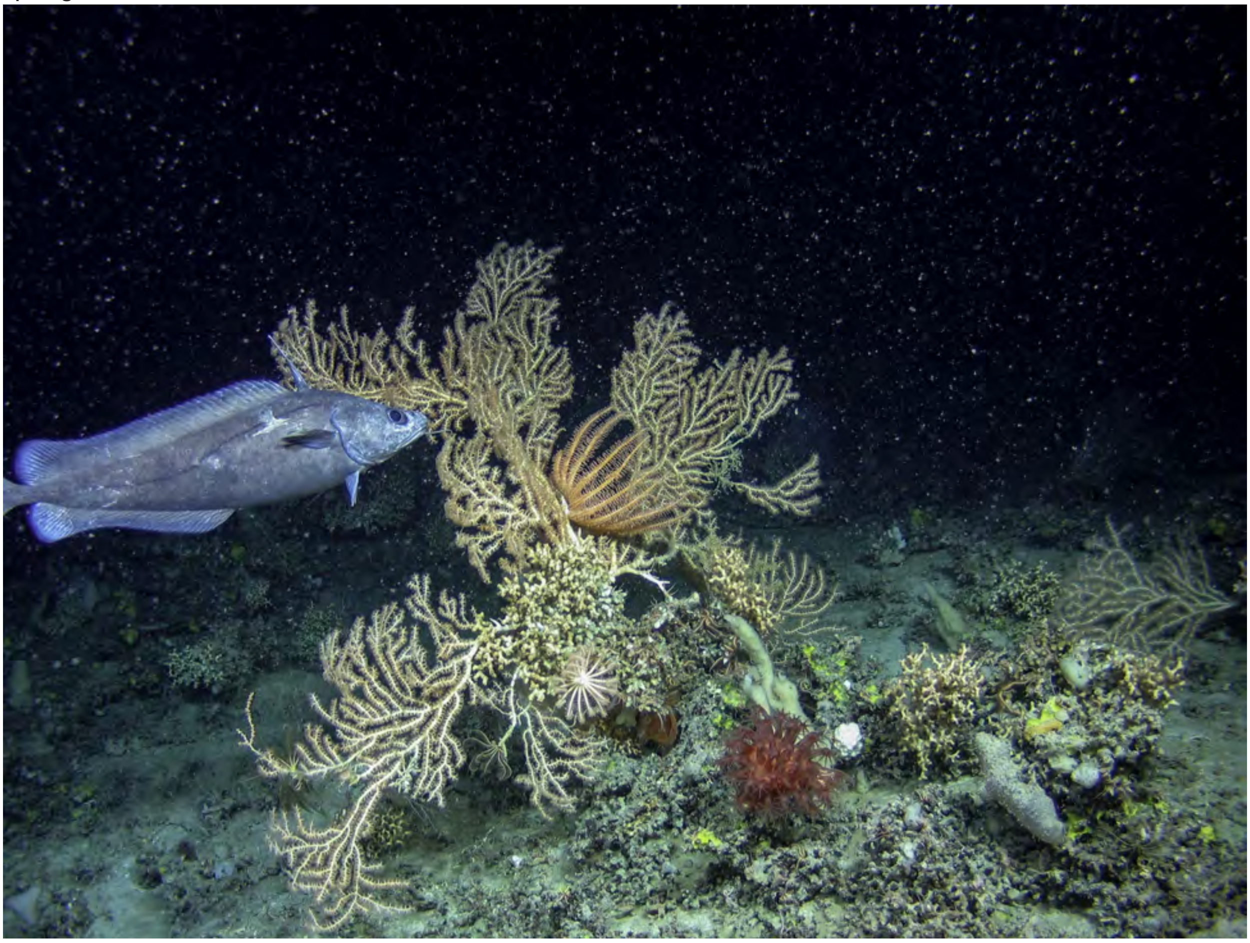

Figure 94. Coral gardens with soft corals, sea fans and sponges on scattered hard coral and coral rubble.

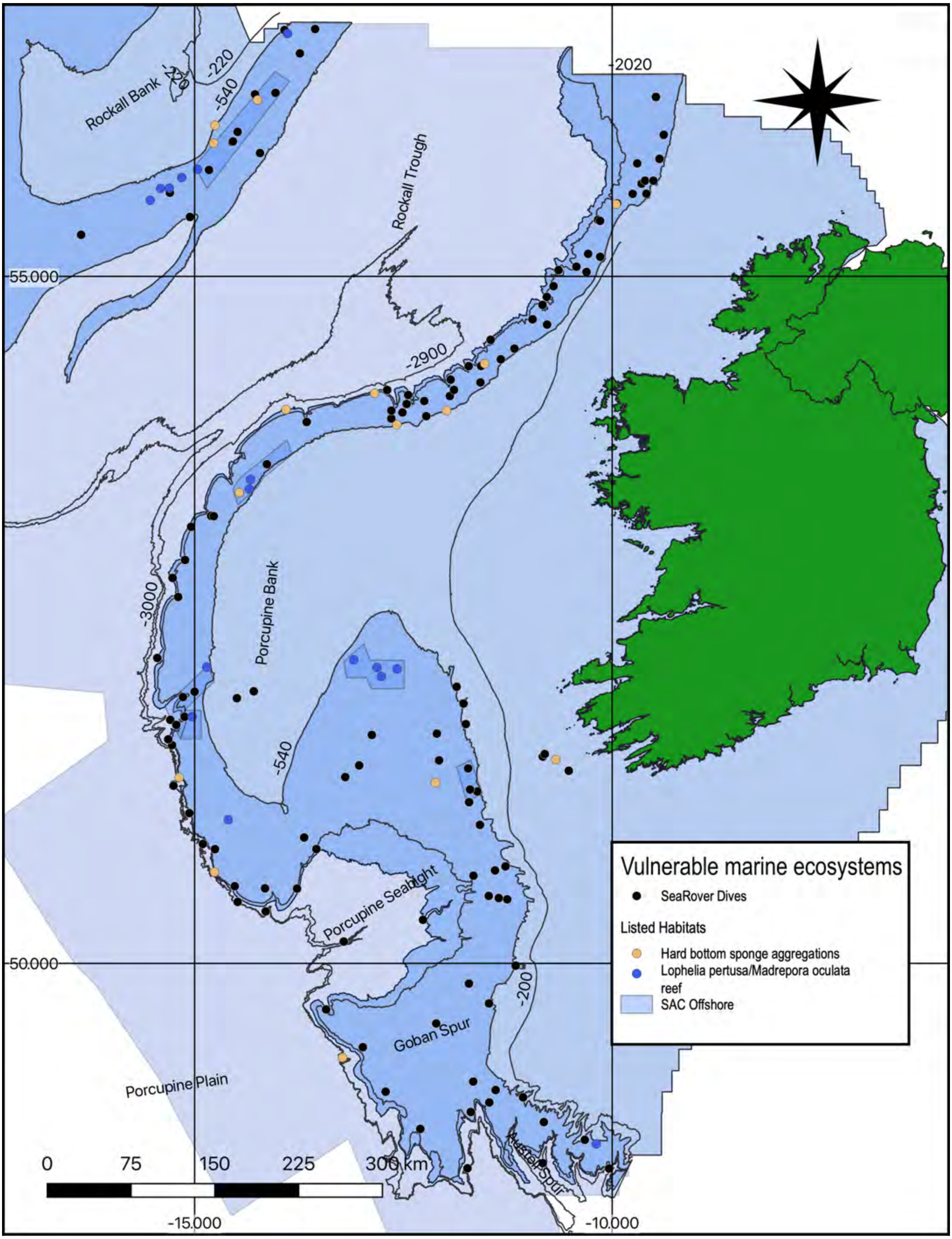

Figure 95. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as hard bottom sponge aggregations and Lophelia pertusa and Madrepora oculata corals. The two categories were mutually exclusive within the dataset.

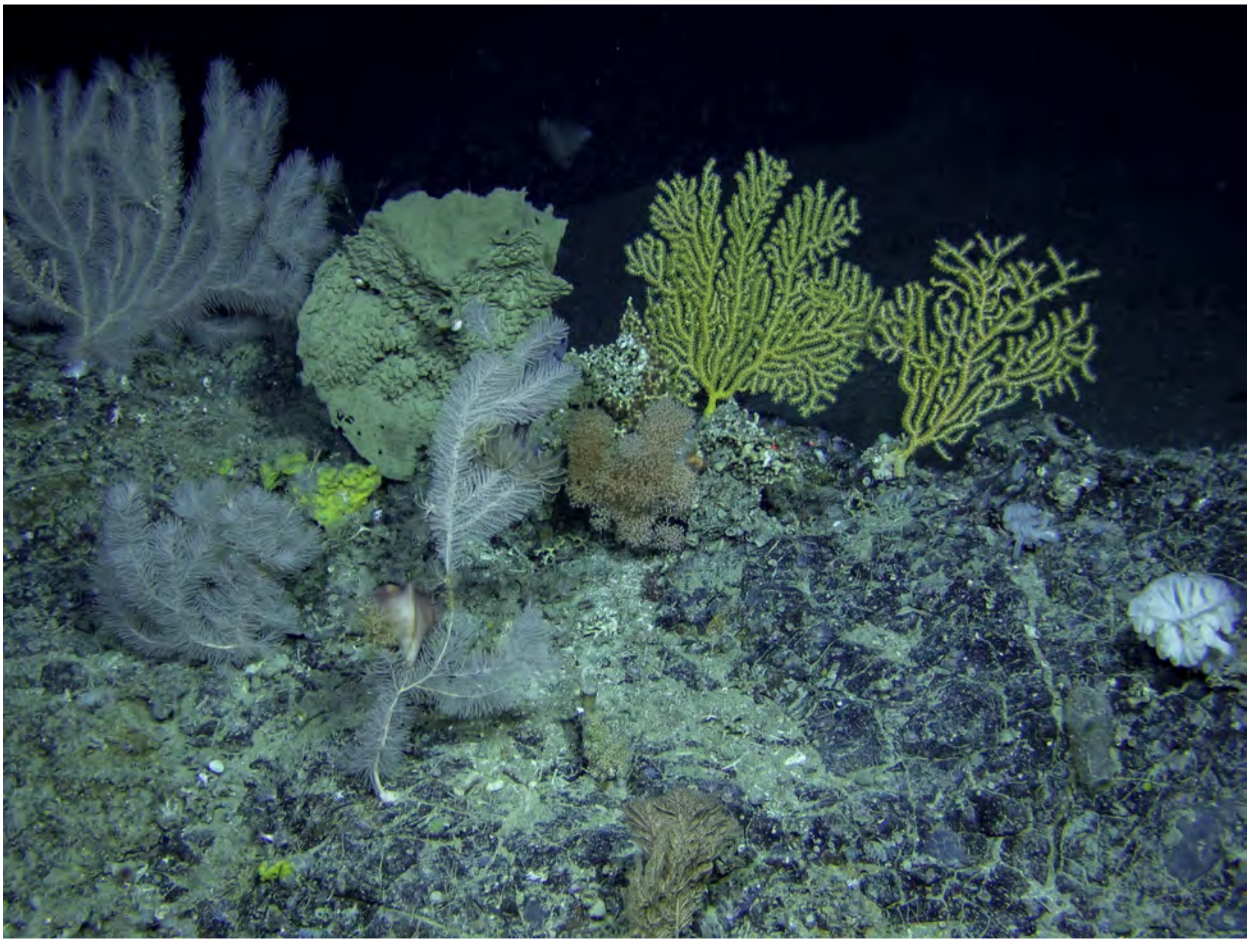

Figure 96. Hard bottom coral gardens with Thouarella *(left),* Paramuricea *(yellow) and sponges.*

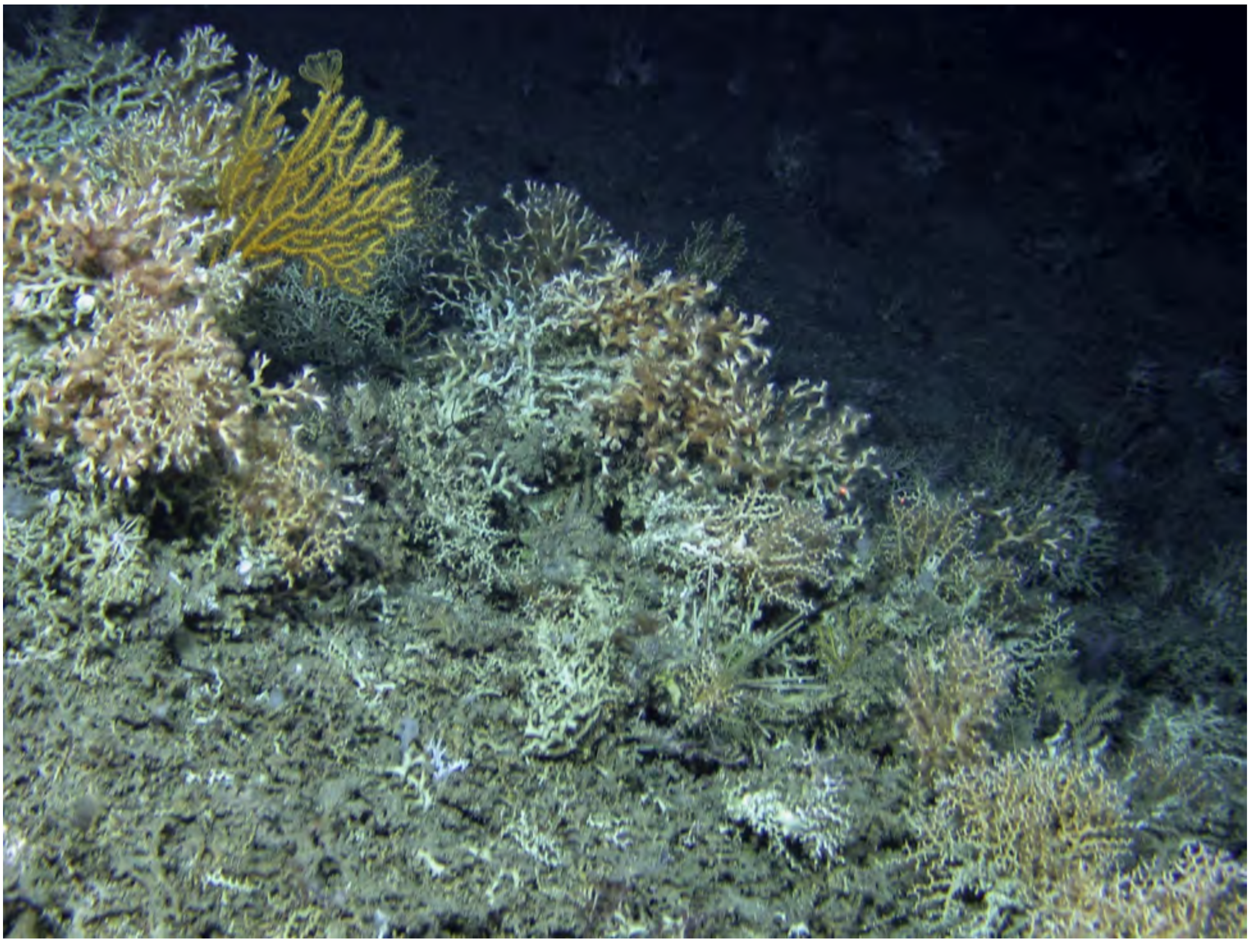

Figure 97. Madrepora oculata *reefs.*

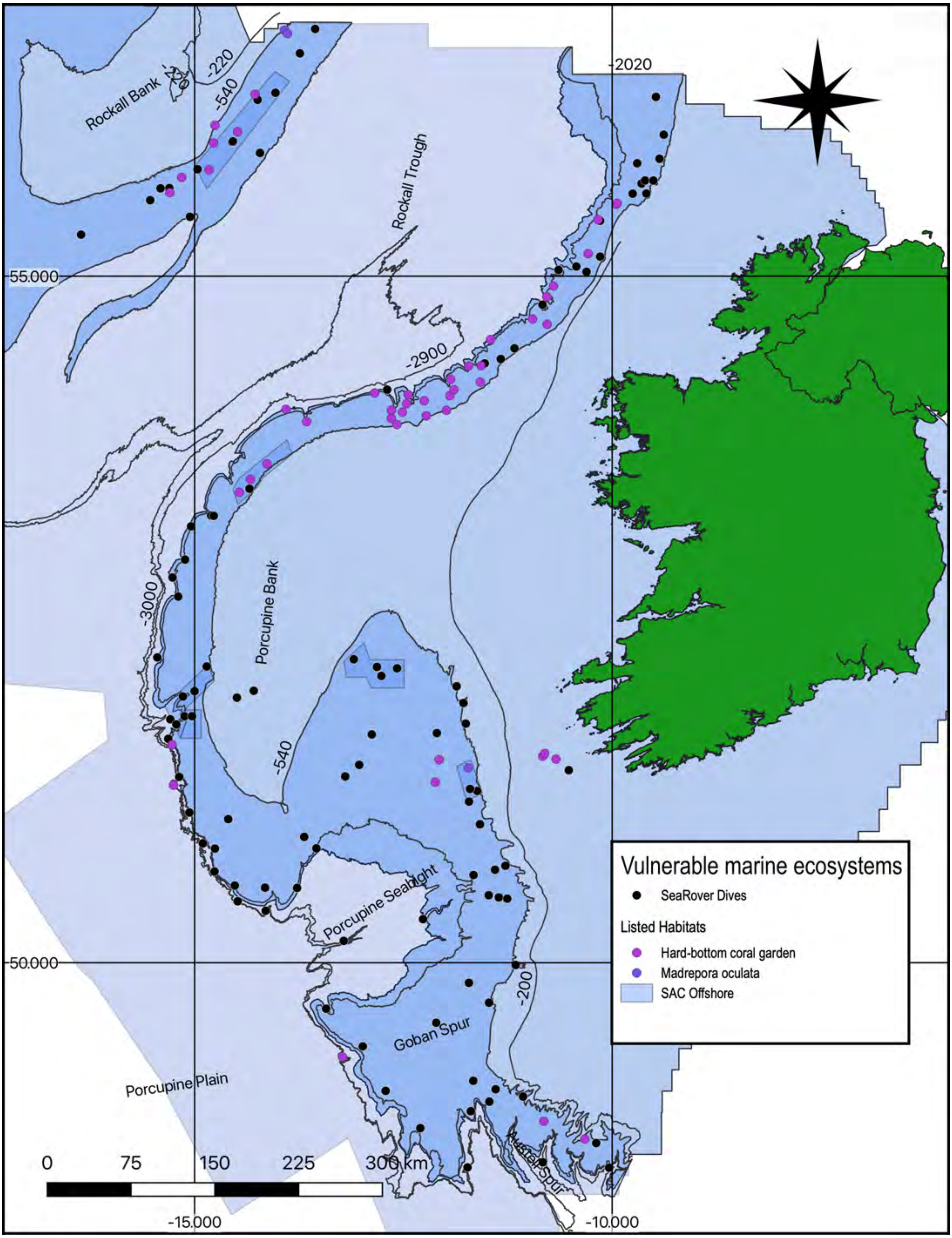

Figure 98. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as hard bottom coral gardens and Madrepora oculata reefs. The two categories were mutually exclusive within the dataset.

Figure 99. Coral gardens: hard bottom gorgonian and black coral gardens.

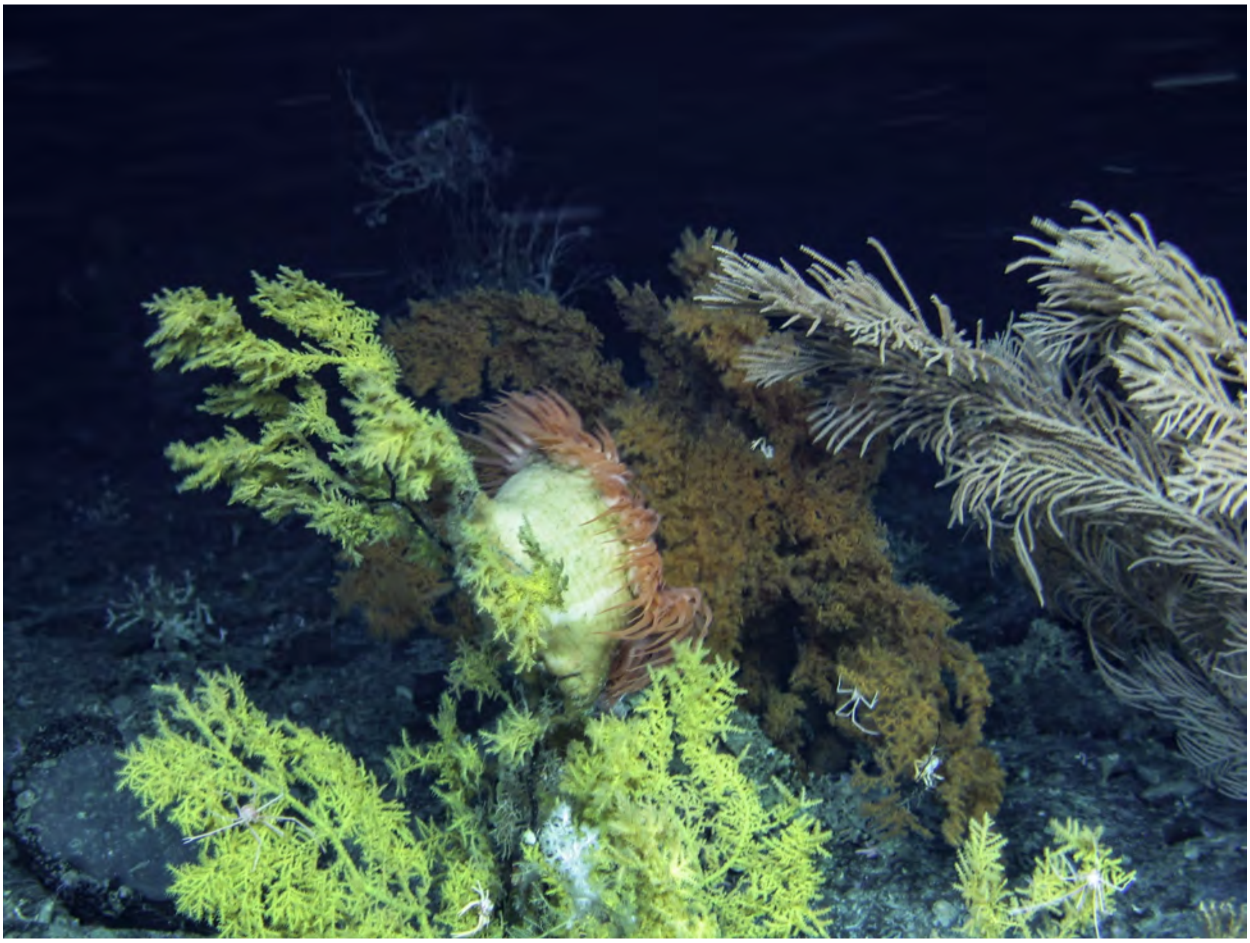

Figure 100. Coral gardens: hard bottom gorgonian and black coral gardens.

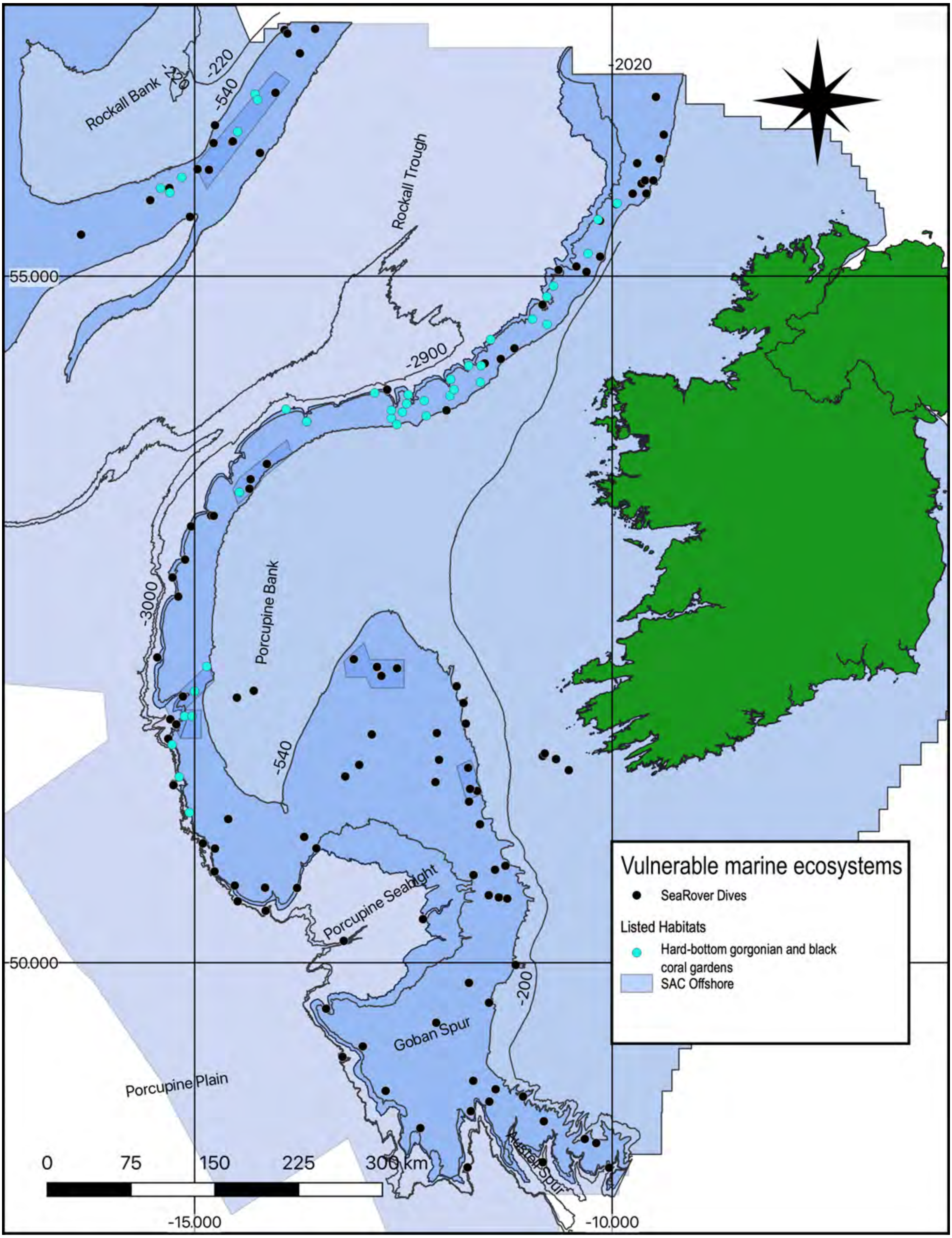

Figure 101. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as hard bottom gorgonian and black coral gardens.

Figure 102. Mud and sand with emergent fauna. The Xenophyophore Syringammina fragilissima *is characteristic of this biotope and usually present, here with the sea pen* Anthoptilum grandiflorum *(D462)*

Figure 103. Mud and sand with emergent fauna. The giant hydroid, Branchiocerianthus*, is a rare component of this biotope.*

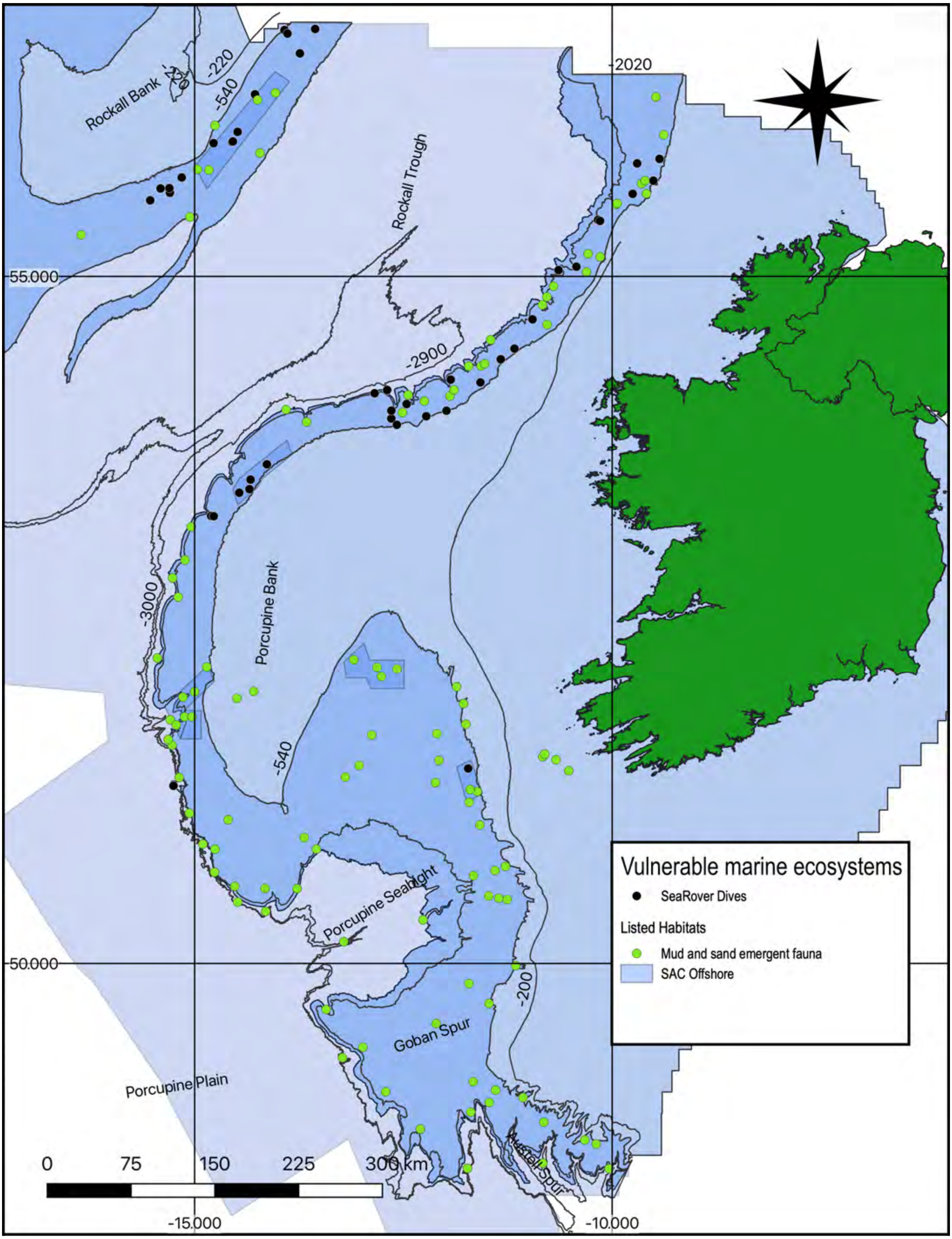

Figure 104. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as mud and sand with emergent fauna. Emergent fauna includes xenophyophores, burrowing anemones, crinoids, cerianthid anemones and other mud-dwelling filter and suspension feeders which are anchored in the seabed.

Figure 105. Non-reefal Scleractinian aggregations on an overhang.

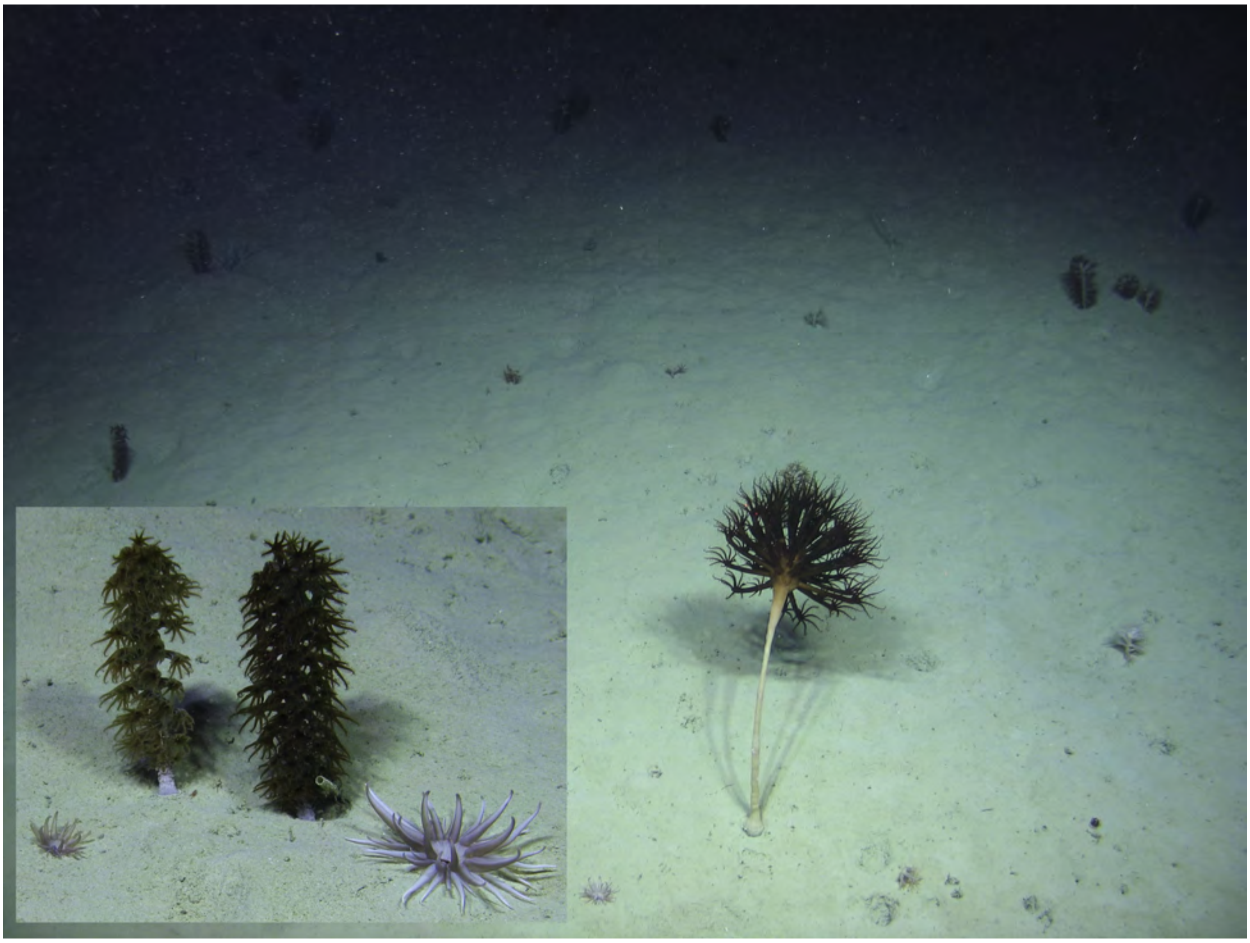

Figure 106. Sea pen and burrowing megafauna on mud and sand. The two most commonly seen sea pens in these habitats were Kophobelemnon *(inset, brown) and* Umbellula.

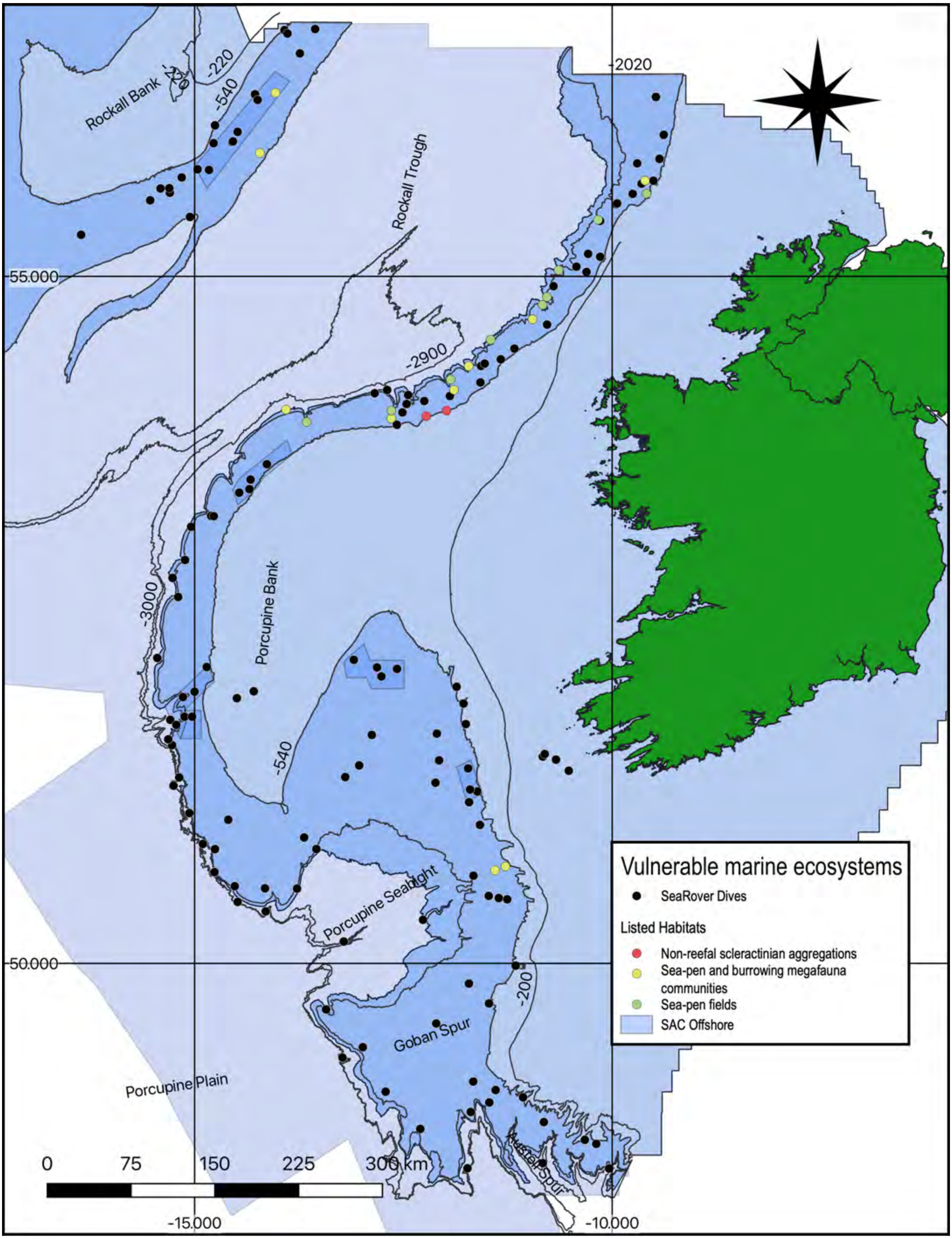

Figure 107. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as non-reefal scleractinian aggregations and sea-pen and burrowing megafauna communities and sea-pen fields on mud, sand and gravel. The sea-pen fields are where sea-pens are densely scattered and this category is included within sea-pen and burrowing megafauna in the dataset.

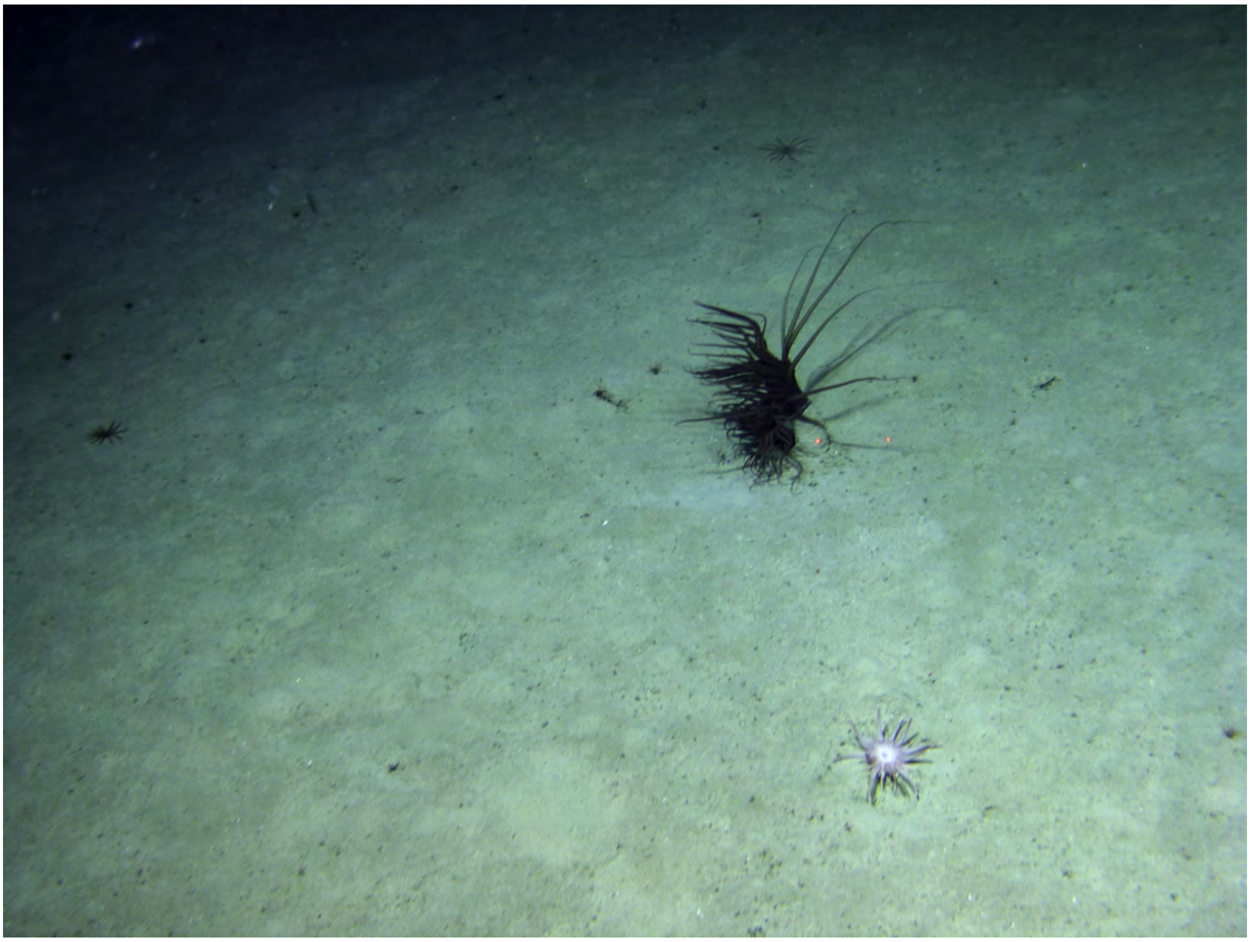

Figure 108. Soft bottom anemone aggregations. Spectacular black cerianthid tube anemone and burrowing actinian.

Figure 109. Soft bottom coral garden (ICES subcategory)

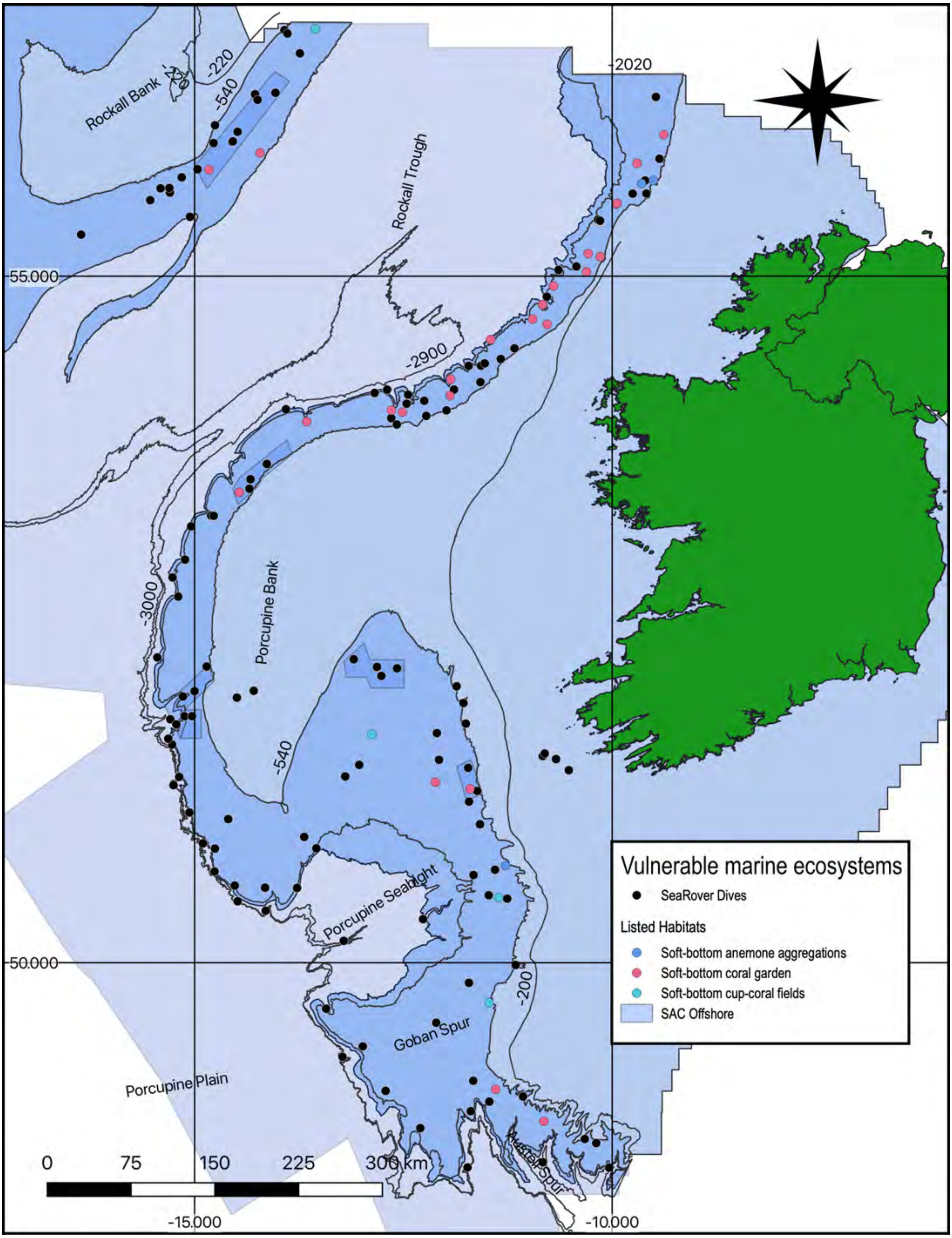

Figure 110. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as soft bottom anemone aggregations, coral gardens and cup-coral fields on mud and sand seabeds. The categories were mutually exclusive within the dataset.

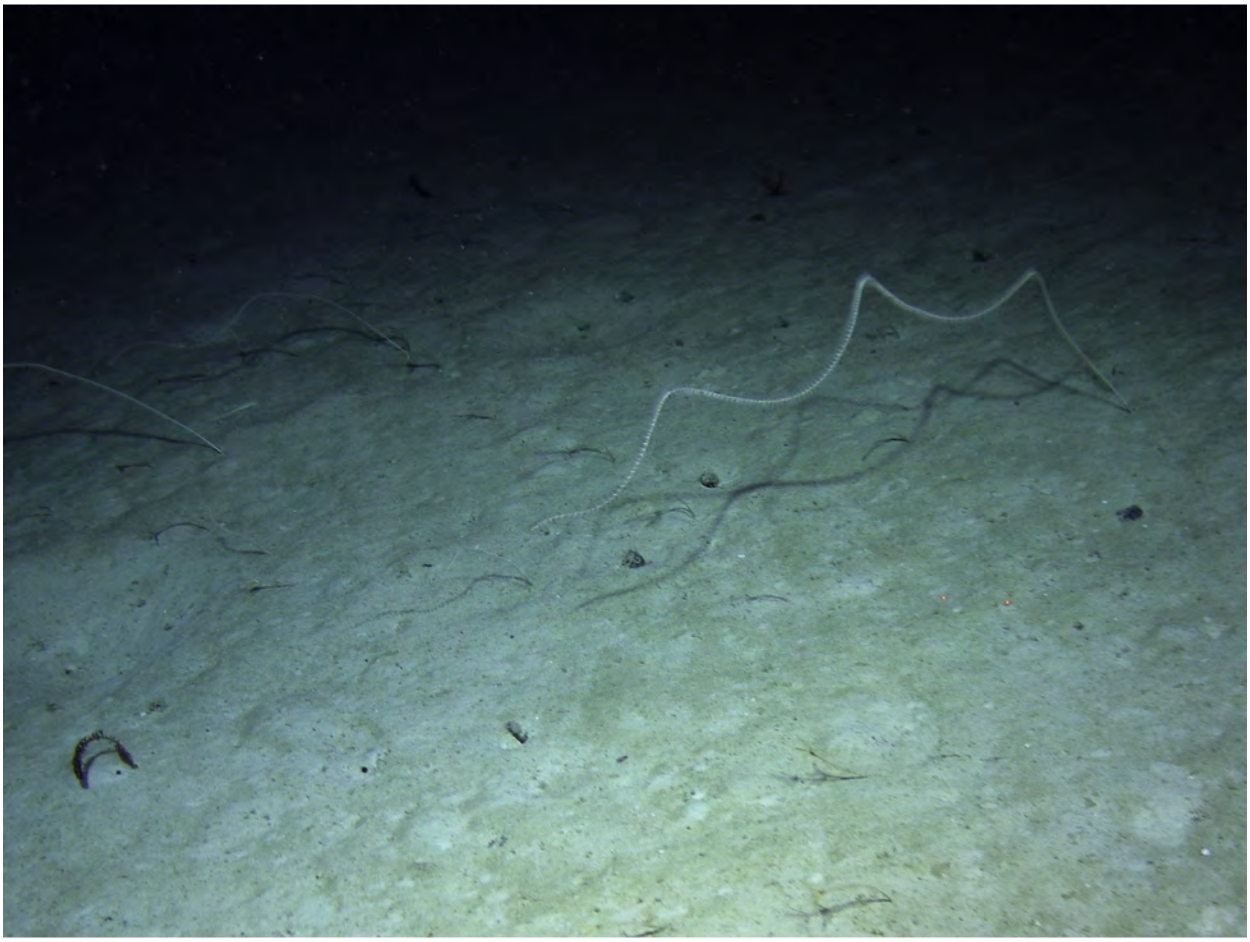

Figure 111. Soft bottom gorgonian and black coral gardens; the pig's tail coral Radicipes *cf.* gracilis*, the sea pen* Anthoptilum *sp. and the stalked crinoid* Democrinus *sp. (D467)*

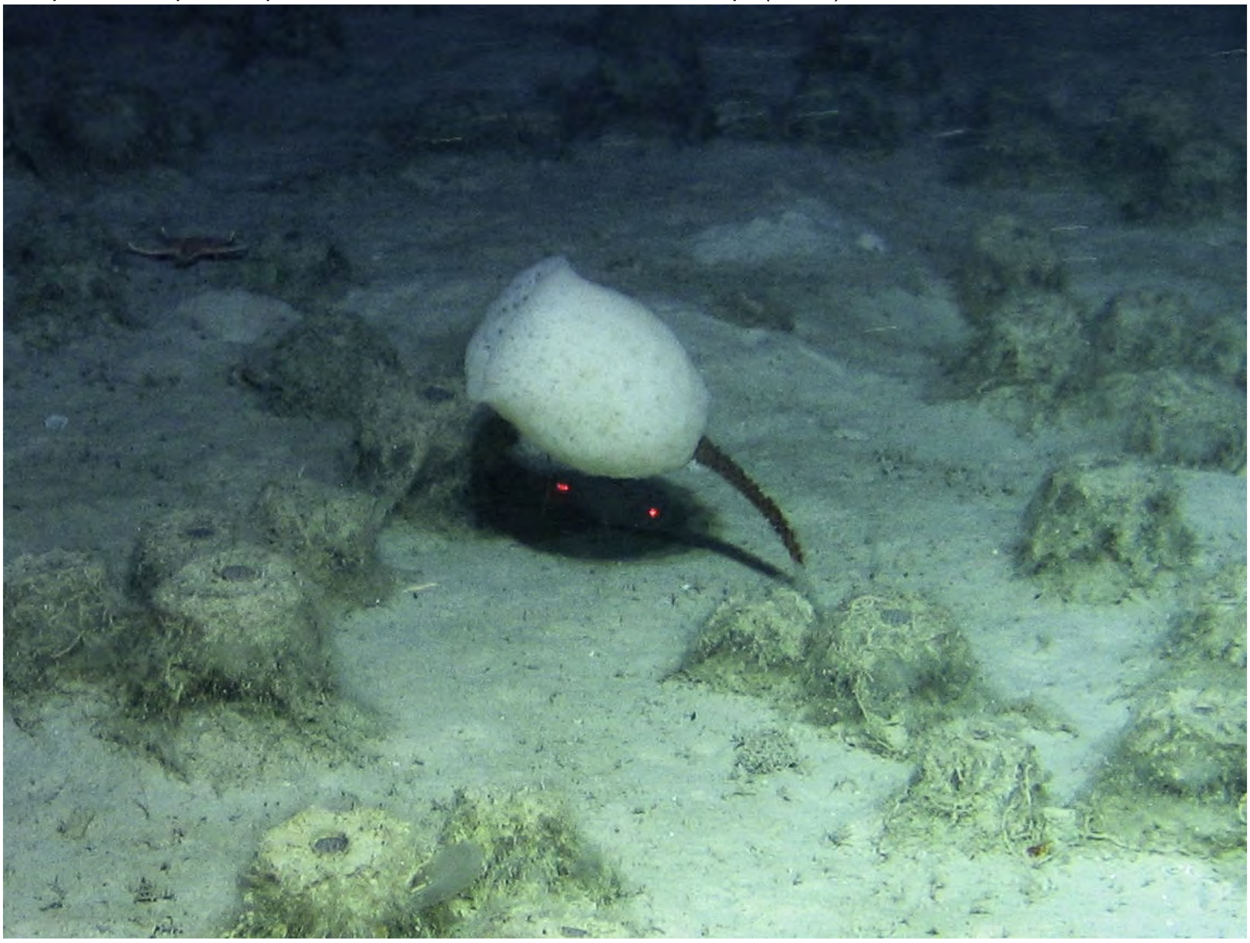

Figure 112. Sponge aggregations on mud and sand; the bird's nest sponge, Pheronema carpenteri *and a stalked glass sponge, probably* Hyalonema *sp.*

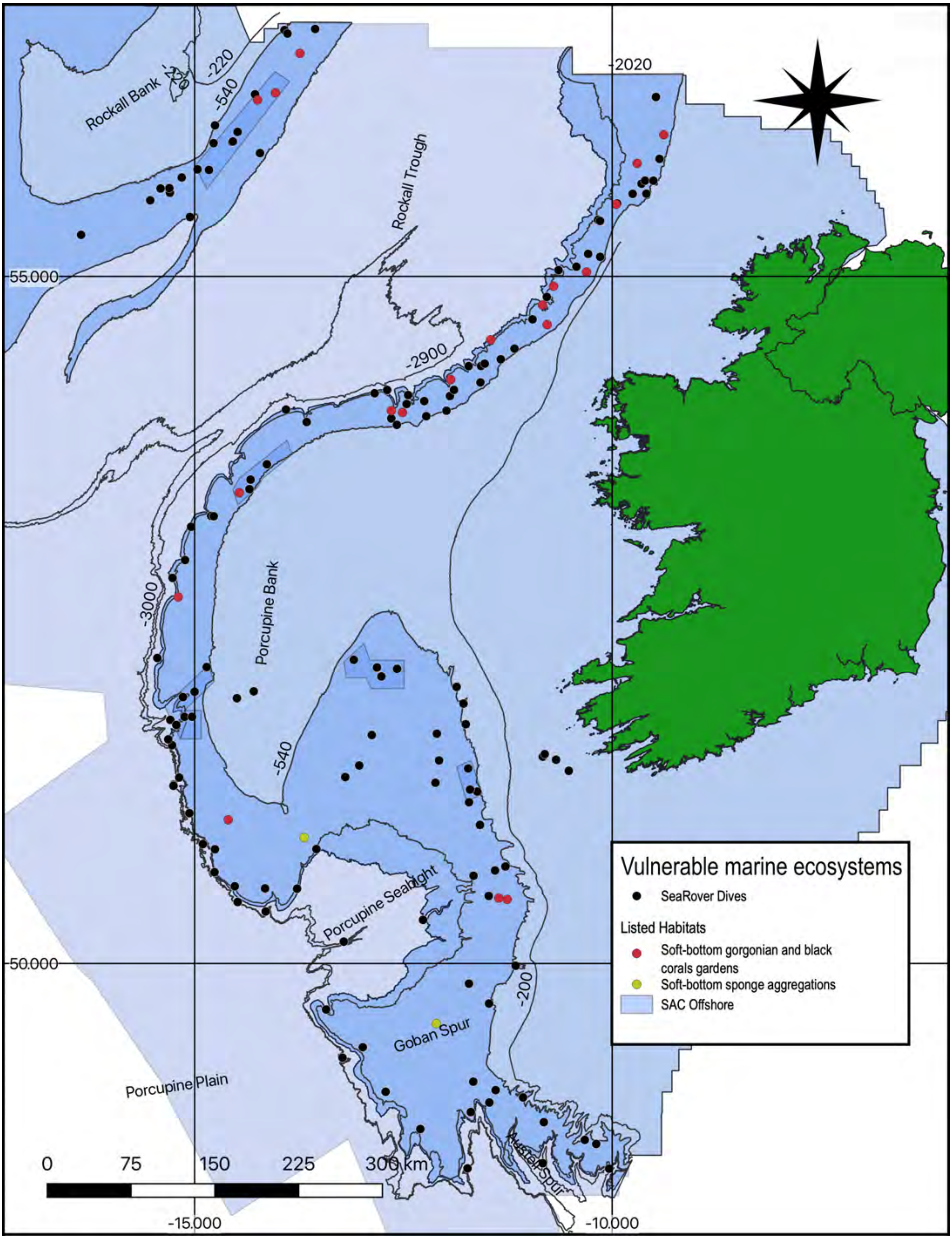

Figure 113. Vulnerable marine ecosystems (VMEs). Map to show distribution of habitats classified as soft bottom gorgonian and black coral gardens and sponge aggregations on mud and sand seabeds. The two categories were mutually exclusive within the dataset.

4. Discussion

4.1 Policy Drivers

Ireland's continental margin is home to some of the most fragile and diverse ecosystems in the world. Habitats range from coral reefs and gardens to glass sponge reefs and sea pen fields. Ireland currently has six offshore Special Areas of Conservation (SACs) (Figure 39, p. 22), aimed at protecting biogenic and geogenic reef habitat as listed in Annex 2 of the Habitats Directive (NPWS, 2013). There is a ban on bottom trawling in four of these SACs. The 2013 Article 17 report by NPWS on the status of EU-listed habitats and species in Ireland showed the conservation status of reef and associated communities as "Unfavourable/Bad with on-going decline" and reported fisheries as the most significant pressure in our offshore marine ecosystems. The 2019 report was able to report reef as "inadequate" on the basis of SeaRover data. Below we list the main policy drivers for the protections of marine habitats and species. Table 8 summarises the main conservation initiatives aimed at protecting Vulnerable Marine Ecosystem (VME) habitats and species.

Maritime Spatial Planning Directive

The Maritime Spatial Planning Directive (MSP) (2014/89/EU) establishes a framework for maritime spatial planning. The main purpose of MSP is to enable the relevant public authorities to organise human activities within the maritime area so as to meet various ecological, economic and social objectives. In Ireland the relevant authority is the Department of Housing, Planning, Community and Local Government. The regulation was transposed into Irish law on 18th September, 2016. Under this Directive, Ireland is required to draw up a national maritime spatial plan by March 2021.

Table 7. Listed Vulnerable Marine Ecosystems and number of records of each category in SeaRover database.

Listed Habitat	Number of records
Carbonate mounds (OSPAR)	**13**
Cold water coral reef (ICES)	**35**
Lophelia pertusa reefs (OSPAR)	13
Lophelia pertusa/Madrepora oculata reef	14
Madrepora oculata (ICES subcategory)	1
Solenosmilia variabilis reef (ICES subcategory)	13
Coral gardens (ICES/OSPAR)	**69**
Hard-bottom coral garden	47
Hard-bottom gorgonian and black coral gardens	37
Colonial scleractinians on rocky outcrops	21
Non-reefal scleractinian aggregations	2
Stylasterid corals on hard substrata (ICES subcategory)	6
Soft-bottom coral garden (ICES subcategory)	30
Soft-bottom gorgonian and black corals gardens	18
Soft-bottom cup-coral fields (ICES subcategory)	4
Cup-coral fields (ICES subcategory)	11
Deep-sea sponge aggregations (ICES/OSPAR)	**32**
Hard bottom sponge aggregations	15
Soft-bottom sponge aggregations (ICES subcategory)	2
Sea-pen fields (ICES)	**15**
Sea-pen and burrowing megafauna communities (OSPAR)	18
Anemone aggregations (ICES)	**8**
Hard bottom anemone aggregations	1
Soft-bottom anemone aggregations (ICES subcategory)	3
Mud and sand emergent fauna (ICES)	**114**
none	7
Total VME habitats recorded	**553**

Table 8. A summary of the main conservation initiatives aimed at protecting VME habitats and species.

Habitats Directive (92/43/EEC)	Requires Member States to designate Special Areas of Conservation (SACs) to protect some of the most threatened habitats and species across Europe.
OSPAR Convention Annex V	Protection and Conservation of ecosystems and biological diversity of the maritime area.
Common Fisheries Policy	A number of spatial closures aimed at protecting biodiversity.
Marine Strategy Framework Directive Article 13	Requires member states to develop a strategy to achieve Good Environmental Status (GES) in their marine water by 2020.
UN Convention on Biological Diversity	Legal requirement for the conservation of biological diversity.
UNGA Resolution 61/105 (2006)	RFMOs to close areas of high-seas bottom fishing where VMEs are known or likely to occur.
FAO 2009	Guidelines on marine protected areas and fisheries.
International Council for the Exploration of the Sea (ICES)	Advice on the implementation regulations fixing the fishing footprint
EU Deep-Sea Access Regime	Restrictions on the fishing of deep-sea species in EU waters

Habitats Directive (92/43/EEC)

Requires Member States to designate Special Areas of Conservation (SACs) to protect some of the most threatened habitats and species across Europe. It gives legal protection for habitats and species listed as important in a European context. Currently, Ireland has designated six offshore SACs (Figures 59–64) for the protection of biogenic and/or geogenic reef (NPWS, 2014a–f).

Articles 6(3) and 6(4) detail the procedure to be followed in cases where a plan or project, not directly connected with or necessary to the management of the site, is likely to have a significant effect thereon, either individually or in combination with other plans or projects. Such plans or projects shall be subject to an appropriate assessment of its implications for the site in view of the site's conservation objectives.

Environmental Impact Assessment Directive

The EIA Directive (2011/92/EU) is recognised as a central tool for environmental management. The main aim of the directive is to ensure that plans, programmes and projects likely to have significant effects on the environment are made subject to an environmental assessment before any decisions are made. Consultation with the public is a key feature of the environmental assessment procedures. The EIA process aims to facilitate the best environmental outcome and to provide as much information as possible to the consenting authority.

OSPAR Convention

The Oslo and Paris Conventions for the Protection of the Marine Environment of the North East Atlantic (the 'OSPAR' Convention) (OSPAR, 1992). The Convention entered into force in March, 1998. The first ministerial Meeting of the OSPAR Commission adopted Annex V to the Convention to cover all activities that might adversely affect the marine environment of the North East Atlantic. The main aim of the OSPAR Convention is the Protection and Conservation of ecosystems and biological diversity of the maritime area. Under this convention, Ireland is committed to establishing marine protected areas to safeguard its marine biodiversity.

Marine Strategy Framework Directive

The Marine Strategy Framework Directive Article 13 (MSFD) (2008/56/EC) (Council Directive, 2008) is a major piece of EU legislation that requires member states, including Ireland to adopt an ecosystem approach for the management of their marine environment. Under the Directive Member States are required to develop a strategy to achieve Good Environmental Status (GES) in their marine waters by 2020 at the latest. Following the first cycle of management which ended in 2020, new programmes of measures will be set on a six-yearly basis. The Directive stretches from the coast to the deep sea and applies to all marine organisms from unicellular algae to large cetaceans, environmental aspects from ecosystem functions to chemical properties, and assessing anthropogenic effects from tourism to commercial fisheries bottom trawling. This is a key piece of legislation that protects and preserves marine biodiversity and its habitats and will be important in helping Ireland to reach its 30 % by 2030 target for biodiversity. The European Commission adopted a report on the MSFD which stated that whilst the framework for marine environmental protection was one of the most comprehensive and ambitious on a world scale, persistent problems such as excess nutrients, underwater noise, plastic litter, and other types of pollution as well unsustainable fishing remained (Anon., 2020a).

UN Convention on Biological Diversity

The Convention on Biological diversity (CBD) is an international legal requirement with three main goals: the conservation of biological diversity; the sustainable use of biodiversity and the fair and equitable sharing of the benefits arising from the use of genetic resources (CBD, 1992). The convention was opened for signature at the Earth Summit in Rio de Janeiro in 1992 and came in to force in 1993 and has been ratified by 196 nations.

United Nations General Assembly

Most deep sea ecosystems are characterized by slow-growing, long-lived species, traits which limit their potential for resilience and recovery from activities such as bottom fishing (Ramirez-Llodra et al., 2011). In 2006, the United Nations called on all states to implement measures aimed at protecting Vulnerable Marine Ecosystems (VMEs) in the deep sea (Resolution 61/105) (UNGA, 2006; FAO, 2009) to address international concerns over the negative impacts of deep-sea fishing on vulnerable benthic ecosystems and species. The Food and Agriculture Organization (FAO) of the United Nations International Guidelines for the Management of Deep-sea fisheries in the High Seas (FAO DSF Guidelines) provide details on VMEs for fisheries management. This also applies to areas beyond national jurisdiction, otherwise known as ‘the High Seas’. Once a VME has been designated, the FAO DSF Guidelines recommend specific conservation and management measures. The resolution made regional fisheries management organisations (RFMOs) responsible for identifying VMEs in their territorial waters and implementing management measures to regulate impacts from bottom fishing.

International Council for the Exploration of the Sea (ICES)

In 2019 a workshop was organised by ICES (ICES, 2019) to review the data and information on the fishing footprint and the location of vulnerable marine ecosystems (VMEs) in order to advise the Commission on the implementation of regulations fixing the fishing footprint and the location of VMEs. ICES (2020) advised that existing areas which had been closed for purposes other than the protection of (VMEs) should remain closed to fishing based on the evidence of the presence of VMEs within the closed area. This applies to the Rockall Haddock box area which was designated to protect juvenile haddock. Table 7 lists the VMEs recorded by the SeaRover surveys and Figure 75 is a map of these sites.

Common Fisheries Policy

Regulation (EU) 1380/2013 established a Common Fisheries Policy (CFP) aimed at the conservation and sustainable exploitation of fisheries resources (Anon. 2016). The CFP states that ‘the impact of fishing on the fragile marine environment is not fully understood. For this reason, the CFP adopts a cautious approach which recognises the impact of human activity on all components of the ecosystem’.

Regulation (EU) 2016/2336

Legislation regarding access to deep-sea fisheries was enacted by the EU in 2016 (EU 2016/2336). This required member states to list areas where VMEs are known to occur or are likely to occur and the determination of the areas where deep sea fishing occurs. Regulations EU 2016/2336 and EC 734/2008 set out conditions for fishing deep sea stocks in the northeast Atlantic. EC 734/2008 applies to bottom gears including bottom trawls, dredges, bottom-set gillnets, bottom-set loglines, pots and traps fishing at depths >400m. The regulations prohibit bottom trawling at depths >800 m. The aims of this regulations are, ‘a) improving scientific knowledge on deep-sea species and their habitats; (b) preventing significant adverse impacts on Vulnerable Marine Ecosystems (VMEs) within the framework of deep-sea fishing and ensuring the long- term conservation of deep-sea fish stocks; (c) ensuring that European Union measures for the purpose of sustainable management of deep-sea fish stocks are consistent with the Resolutions adopted by the General Assembly of the United Nations, in particular Resolutions 61/05 and 64/72.’

Integrated Maritime Policy

The Integrated Maritime Policy aims to co-ordinate policies on specific maritime sectors. It seeks to provide a more coherent approach to issues that do not fall under a single sector, e.g. maritime spatial planning; blue growth; marine data and knowledge; Integrated maritime surveillance and sea basin strategies (Anon., 2016).

EU Deep-Sea Access Regime

The EU Deep-Sea Access Regime regulates which kind of operators are allowed to target deep sea species and sets the conditions under which member states can issue licences for deep sea fisheries. In 2016 the Council and the European Parliament agreed on revised rules for the fishing of deep-sea species in EU waters. These included:

- an 800 meter depth limit below which it will not be possible to fish with bottom trawls
- the setting of a geographical footprint based on historical criteria by which vessels will only be able to fish in those areas where they have done so during the reference period
- special protection measures for vulnerable marine ecosystems which apply to operations with bottom gears below a depth of 400 m

4.2 Significance of the SeaRover survey

Ireland's vast continental shelf remains relatively unexplored for its biological and geological potential. The SeaRover survey has provided snapshots of this area, however only 0.001% of Ireland's continental slope and 0.000127% of Irish territorial waters was surveyed. Even with this small amount of sampling, SeaRover uncovered species that are likely to be new to science, species that were reported for the first time from Ireland as well as new biotopes. Half of the biotopes recorded were either variants of existing biotopes or entirely new, and were not able to be matched with the EU's MHBI biotope classification. By comparison with other groups, the fish are relatively well known, however even amongst the fish species, the survey recorded the pink frogmouth (*Chaunax pictus*), for which there was only a single previous record in Ireland from farther south, (off Goban Spur). Whilst the pink frogmouth is a southern species, the cauliflower coral (*Drifa glomerata*), which was reported for the first time for Ireland, is boreal-arctic in distribution; ranging to Connecticut in the west and the Barents Sea in the north. It is a large, reef-forming soft coral and the SeaRover records are the most southerly in the eastern Atlantic. Ireland is probably at an interface between northern species and southern species and the bathymetry, with deeper water to the south where the Rockall Trough descends onto the Abyssal Porcupine Plain interacts with the surface flow of water and deep flows of water which constitute the North Atlantic Conveyor current system. Canyons south of the Porcupine Seabight, such as Whittard Canyon, descend to -4000 m whilst the canyons on the NW descend into the Rockall Trough at -2500 m. The fact that the SeaRover cruises found species and biotopes which were previously unreported from Irish waters indicates that it is a frontier that for the most part remains relatively unexplored.

Figure 114. Chaunax pictus, the pink frogmouth.

For many of the species that were encountered by SeaRover it was not possible to attribute identifications to the species level and operational taxonomic unit (OTU) system was used. Table 9 lists the use of OTU to species ratio across the different groups within the SeaRover dataset. Cnidarians (corals, anemones, hydrozoans etc.) represent the most diverse group with 142 OTUs recorded yet only 13% of these could be identified to species level. More fish (Chordata) were identified to species level than any other group, this reflects the amount of scientific research that has centred on fish and fish identification relative to the other groups.

For the vast majority of invertebrates relying only on their identification to OTU makes it difficult to understand these records in a wider context. The species name is the anchor on which we attach all other information such as habitat preferences, distribution data, biology, chemistry, conservation status etc. and underpins all other studies. The species name is also the link to the historical surveys of the deep-sea and the taxonomic work that was done on these groups. The fact that we don't have names for so many of these species hinders deep-sea research and is a bottleneck to future high impact scientific studies.

Table 9. A list of the Operational Taxonomic Unit (OTU) to named species ratio for the various groups recorded by SeaRover.

Phylum	Species	OTUs	% Identified to Species
Cnidaria	19	142	13.380%
Echinodermata	35	105	33.333%
Porifera	10	88	11.364%
Chordata	56	83	67.470%
Crustacea	10	27	37.037%

For groups such as cnidarians and Porifera, there are only very few active taxonomists in the world. These taxonomists conduct revisions of species, genera and families. For example, the genus *Thouarella* (an octocoral) currently has 38 species according to the World Register of Marine Species (Cordeiro et al. 2020), 23 of which were described before 1932 and 15 since 2006. In 2019, *Thouarella porcupinensis* Altuna & López-González, 2019 was described from the Porcupine Bank and in 2020 three new species were described with molecular evidence from Antarctica. Of the 15 species described since 2006, Pablo López-González (Biodiversidad y Ecología Acuática, Departamento de Zoología, Facultad de Biología, Universidad de Sevilla, Seville, Spain) has described nine, and Stephen Cairns (Department of Invertebrate Zoology, Smithsonian Institution, NMNH W-326, MRC-163, Washington, D.C., United States of America) the other six.

Taxonomists now have new weapons in their armoury, namely DNA sequencing and scanning electron microscopy (SEM), to add to traditional morphology, but there are very few universities or museums conducting taxonomic research. Without accurate identification and accurate species level taxonomy it is impossible to know whether species have narrow or broad ranges or how important their populations within the Irish seas are to the survival of the species. Many of the finds by SeaRover are potentially new species, especially for groups such as Cnidaria (anemones, burrowing and tube-dwelling anemones, sea fans, sea-pens, black corals) and sponges.

4.3 Maps are foundational tools

The EMODnet bathymetry of Ireland's seas has unlocked a vast range of possibilities for exploration and education. Previously many conservation questions in relation to seabed species and habitats have been attempted to be answered by modelling on the basis that it would be too expensive to collect detailed data. MPAs to protect coral mounds and living cold water coral reefs were created as a matter of urgency where these features were known to be deteriorating due to fishing pressures. The 2018 EMODnet bathymetry reveals small scale habitat heterogeneity and positions of complex topographic features in enormous detail. SeaRover ground truthing of this bathymetry reveals habitat heterogeneity at a scale of metres, with escarpments being revealed as linear sites with completely different habitats rich in epifaunal life completely different to the adjacent sediment slopes.

The continued evolution of deep-diving autonomous underwater vehicle (AUV) technology is making the world's oceans more accessible. Despite being the Earth's largest habitat, the deep sea is relatively understudied (Tyler 2003; Glover et al. 2010). It was not until the 1960s and 1970s that the deep sea was appreciated to contain diverse habitats and fauna with a multitude of abyssal hills and seamounts emerging from abyssal plains (Ramirez-Llodra et al. 2011). Relationships between this biological diversity and environmental factors have a poorly understood dependence on analytical scale (Chase & Knight, 2013). Only by gathering data across scales in the range of 1 m^2 to 100 km^2, often referred to as a landscape scale (Forman, 1995), can a greater understanding of the functional relationships and heterogeneity within and between habitats be attempted. Such knowledge is now critical to our ability to manage and conserve deep-sea environments (Ruhl et al. 2011).

Current methods for the study of deep-sea megafauna include trawl sampling and photographic and video surveys. Trawls have been useful in determining some long-term and large-scale patterns in invertebrate and fish ecology (Billett et al. 2001; Haedrich & Merrett 1988). However, each trawl amalgamates specimens collected over its entire length into a single sample, limiting spatial interpretation, and it is often difficult to quantify the true seafloor area sampled. Furthermore, trawls may disturb the habitat under study, and the resultant samples are often damaged with soft-bodied organisms in poor condition or lost. Evidence from time-lapse photography suggests that trawls substantially underrepresent some fauna, particularly the smaller size classes (Bett, 2001).

SeaRover demonstrates that there is small scale habitat heterogeneity in the deep sea in areas with complex topography. All of the continental slope has complex topography which is only recently revealed by high resolution bathymetry. Bathymetry is still not sufficiently fine-grained in areas such as canyons, where steep and overhanging surfaces create distinct habitats containing biotopes such as the oyster-*Acesta* biotope described from Whittard Canyon area by (Johnson et al. 2013). If modelling of the type attempted by Howell is to be of any predictive value it needs to be much more fine-grained. Figure 64 demonstates that the modelled distribution of *Lophelia* is out of scale compared with the real world, where living reef is only in a relatively small patch on the top of carbonate mounds. The carbonate mounds are now visible on EMODnet bathymetry and are topped by living *Lophelia* if it has not been swept away by bottom fishing. The *Lophelia* only thrives on upward facing surfaces where there is sufficient current to provide enough food. On the continental slope coral mounds form in the inner parts of wider canyons and on spurs between canyons.

The resuspension of sediment by bottom fisheries is a serious threat to coral reefs in marginal habitats and has a negative effect on associated organisms such as glass sponges. Grant et al., (2019) demonstrated that glass sponges stop feeding in moderate turbidity and recommended a buffer of 30 km around glass sponge communities.

Currents in submarine canyons on the continental margin are mostly tidal. The orientation of sand waves on the continental shelf, south west of Ireland are clearly defined by the flow in and out of the English Channel. Water flowing in and out with tides rising and falling in the North Sea and Irish Sea generate currents in the canyon systems which mixes the water from top to bottom, bringing nutrient rich water from the abyssal areas to the surface and stimulating plankton growth and the start of the foodchain. Fishing for pelagic fish is concentrated in these areas of high productivity, with fishing activity forming a pattern related to the canyons 4000 to 1000m below, see Figures 51-52, page 28.

4.4 SeaRover Data Dissemination

Self Service Web Delivery

The website is the hub for the dissemination of the SeaRover data and crucial for the end users listed below. It should be both visible and accessible with a user friendly interface. The video files are currently hard to access as they are large files. They could be converted to MP4 compressed files which are one tenth in size, then split into short clips of 3-4 minutes. These clips would then be very easily linked to for annotation or downloaded for use elsewhere. One possibility would be to allow registered users to login and be able to add further descriptors such as species identifications. This would have the potential to add value to the SeaRover dataset. A demonstration website has already been created based on Ireland's Marine Atlas. Filtering of layers showing species distributions of SeaRover discovered OTUs and biotopes could create a very heavily populated portal. Many existing portals are attractive in design but actually host very little data.

A website hosting the SeaRover will need to address the lack of public knowledge of how to access and interpret a GIS system. The website should be designed to be intuitive in its use. It could do this by creating some explanatory YouTube videos walking through how to configure a map to display detailed information. GIS layers are frequently hosted within systems which allow download of data but are full of GIS jargon. SeaRover data could ideally be made available for use by a range of users from geography students to scientists and GIS professionals. The free availability of QGIS will increase the audience for GIS layers and MI could encourage use of the data by providing educational material and self-help guidelines, videos, etc. which explain how to download data and create maps. The SeaRover datasets are heavily and consistently georeferenced with many attributes which can be categorised or filtered in multiple ways to answer questions about species and habitat distributions on both narrow and broad scales in the deep sea which are completely unknown to date. In order to maximise the use of SeaRover data a prize could be offered to schools or more advanced students for projects making most creative use of the dataset.

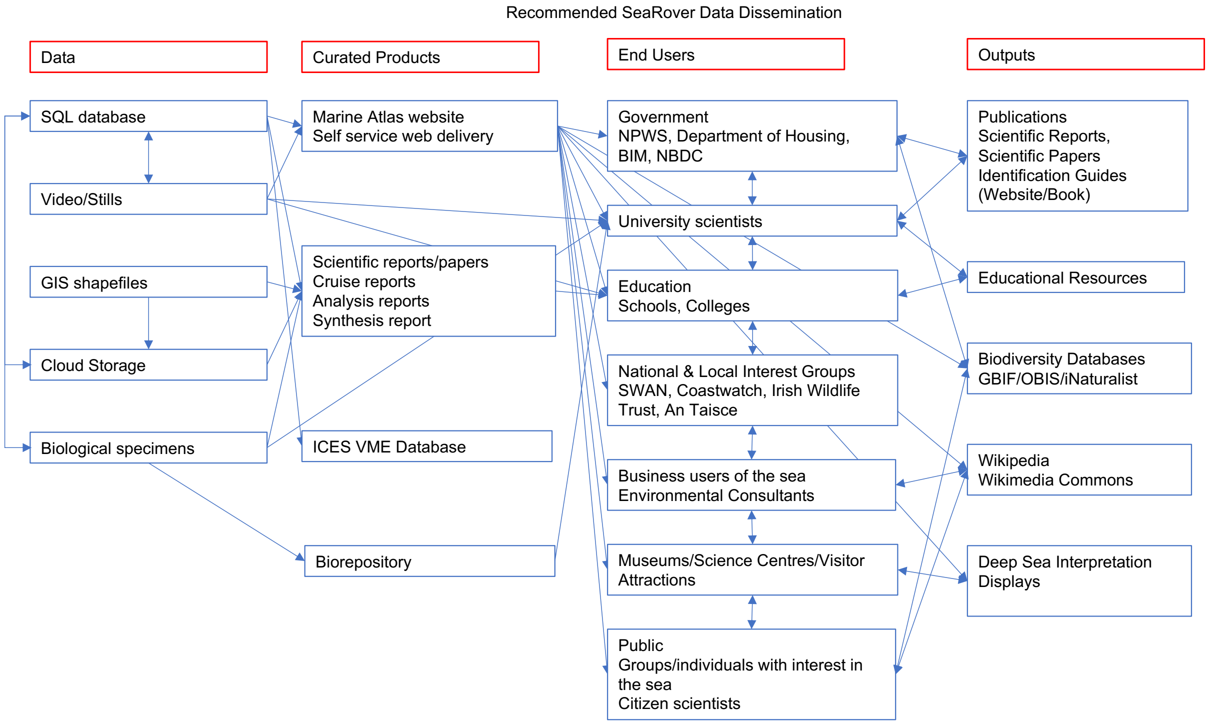

Figure 115. A diagram summarising how the data from SeaRover can be used in the future.

Government

National Parks & Wildlife Service; Department of Housing; Bord Iascaigh Mhara; National Biodiversity Data Centre – The SeaRover data will inform and facilitate decisions on the location and extent of offshore Marine Protected Areas. More widely, it will inform and facilitate marine spatial planning for the Irish Continental Margin.

ICES VME Database

The SeaRover survey recorded 532 conservation listed habitats (Table 7), being either designated an ICES Vulnerable Marine Ecosystem, and/or an OSPAR Threatened and/or Declining Habitat. These VME records should be submitted to the ICES VME Database. This is the central portal for data on the distribution of VMEs in the North Atlantic.

University Scientists

The SeaRover survey obtained a wealth of data on Ireland's deep sea habitats and species which can be mined by university researchers and students for an array of scientific studies and potentially lead to high impact publications.

Detailed seabed bathymetry data could be used in conjunction with the considerable amount of video data to give ecological context to some of the larger, long lived structures such as corals, sea fans, black corals and sponges that were present. This would enable a refinement of the habitat parameters for these species and allow better predictive models of where we can expect species to occur. This might also allow us to assess potential damage for areas where they are not found, but where suitable habitat may be restored by removal of pressures such as bottom fishing.

Some of the SeaRover data indicates that there is both an Arctic as well as a southern component to the Irish fauna. This is exemplified by records of the cauliflower coral *Drifa glomerata* which is an Arctic species and the pink frogmouth fish (*Chaunax pictus*), for which the Searover record is the furthest north this species has ever been recorded. Potentially the data could be used to map the range in distribution of northern and southern species and contribute to our understanding of the confluence between colder Arctic and warmer, Atlantic waters.

The SeaRover data could be combined with data from previous scientific cruises; Irish Fisheries data (including historical data) and data held in museums, together with specimens. This would give greater context to the significance of the SeaRover data and enable us to see what has changed since we first started exploring Ireland's deep sea habitats.

The wealth and accuracy of the georeferenced data within the SeaRover dataset will enable transects to be revisited for targeted collection of particular specimens to facilitate further studies on population genetics, barcoding, phylogenetics, biodiscovery and naming species.

Importantly, this georeferenced dataset will enable future monitoring programmes to revisit the surveyed transects to see how they change over time.

Biorepository

Specimens are data and the collection, curation, storage and accessibility of these data is important. *The Taxonomic Data Working Group (TDWG)* established a set of international standards to facilitate the sharing of information about biological diversity, these are referred to as 'Darwin Core'. Various institutions and organisations e.g., Naturalis in Leiden, Senckenberg Institute in Frankfurt, Smithsonian Museum in Washington, have established biorepositories for deep sea biological samples. Currently, there is no central repository for deep sea specimens in Ireland and specimens are distributed across a range of institutions and individuals. The establishment of a repository for biological specimens and a team to curate it, would greatly facilitate a wide range of scientific studies such as DNA barcoding, taxonomy, biodiscovery, population genetics and naming of species.

Schools and Colleges

The SeaRover data can be used by educators to produce a wide range of dissemination products to inform and inspire students and public about Ireland's deep sea natural resources. Video and images could be used by students to create short movies interpreting Ireland's deep sea habitats. The GIS data could also be used by students to experiment with mapping and the use of GIS.

National & Local Interest Groups

Organisations such as Coastwatch, Irish Wildlife Trust, SWAN, Seas At Risk and Client Earth all have an interest in marine biodiversity and conservation. As such the SeaRover data will be of interest to these groups.

Business users of the sea

There are a range of businesses with an interest in the deep sea e.g. the energy sector (exploration of oil and gas, offshore wind); fishing industry; deep sea mining; telecommunications and environmental consultants. The SeaRover data should be made visible and accessible for all of these interest groups.

Museums, Science Centres, Visitor Attractions

The considerable video data and images captured during the SeaRover cruises could be used as part of interpretative displays to raise awareness and appreciation of Ireland's deep sea natural heritage.

Citizen Scientists

By making the SeaRover data accessible and findable, interested members of the public and citizen scientists can greatly add value to this dataset. Individuals with specialist interests in particular groups can use images captured through video and stills to create biological records. These records can be uploaded to biological records databases such as iNaturalist and from there they can flow to large international databases such as the Global Biodiversity Information Facility (GBIF) and the Ocean Biodiversity Information System (OBIS).

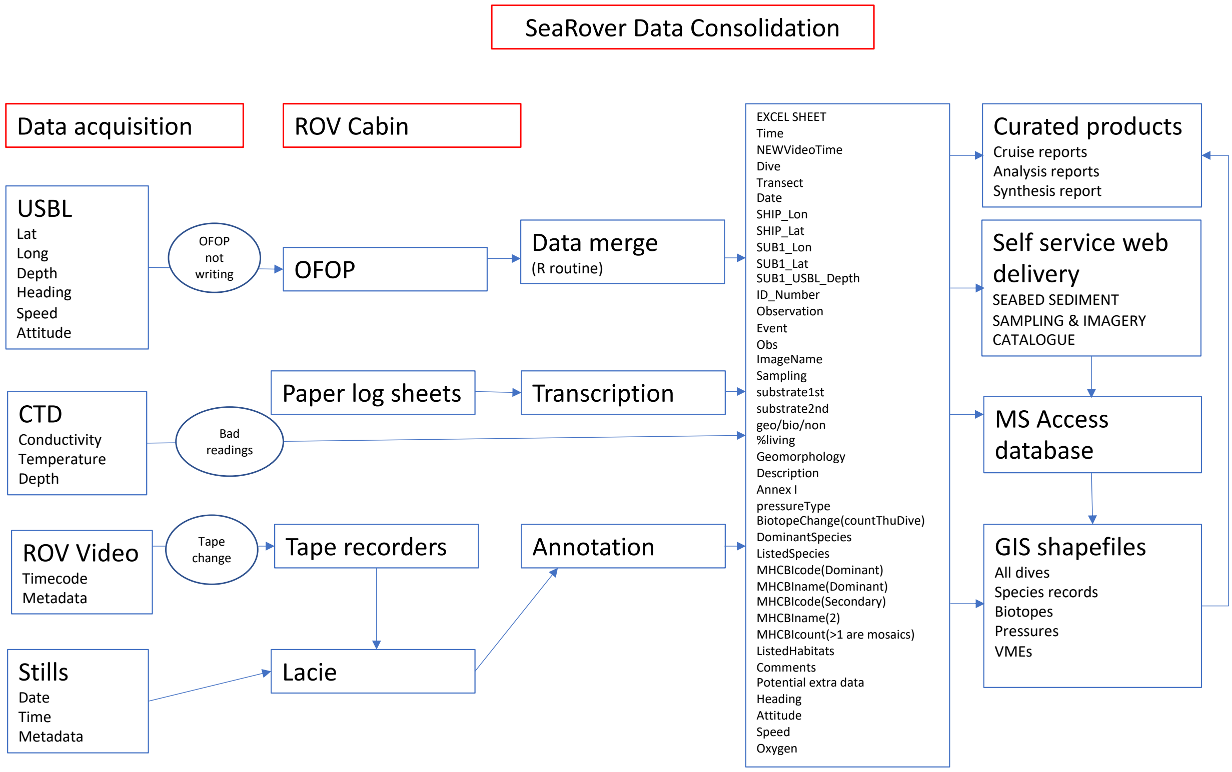

Figure 116. A diagram summarising how the data from the HD video of the seabed, the still photography, CTD and USBL has been captured, stored and analysed.

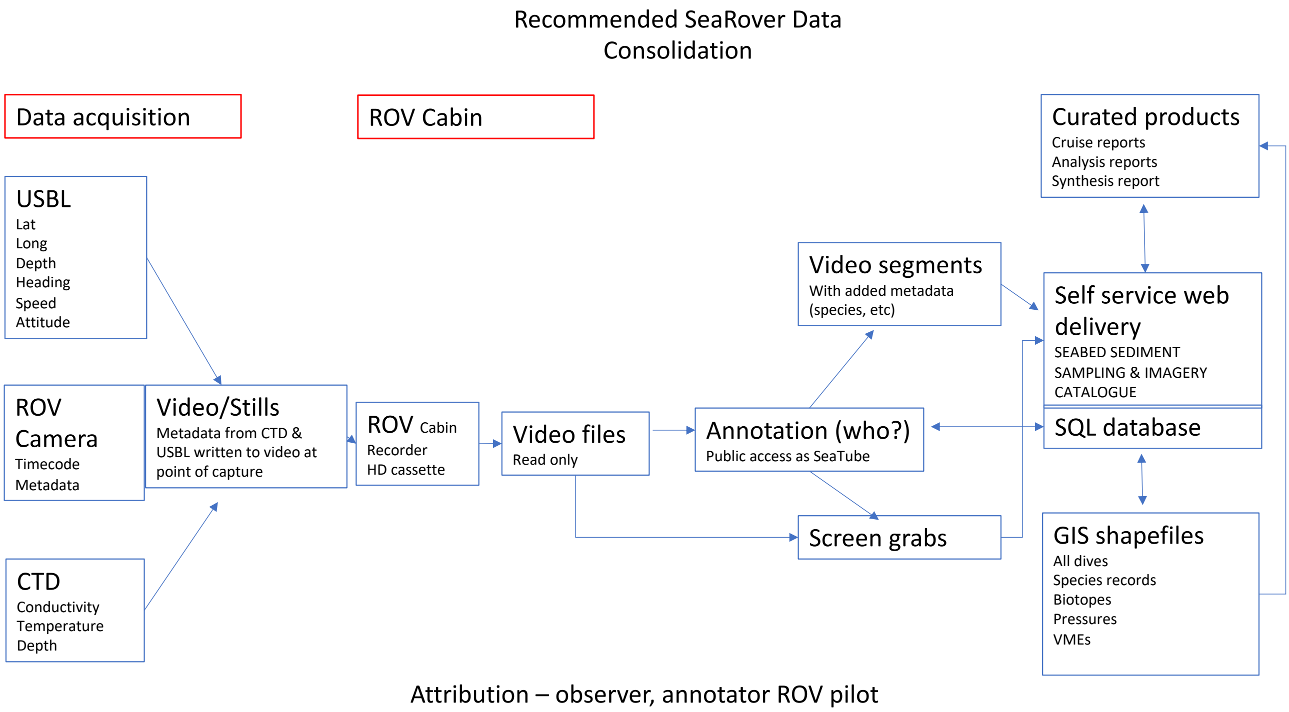

Figure 117. Recommendations for the capture of seabed data.

This diagram addresses potential points of failure e.g. the reliance on OFOP, need for change of recorder cassette, and recommends an updated camera system for the ROV which enables metadata from the CTD & USBL to be stored to video at point of capture.

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Appendix 1. Recommendations for review

Standard operating procedures

Standard Operating Procedures (SOPs) are currently designed by and for the principal investigator (PI) running the cruise. All scientific staff on each cruise should attend a training workshop before departing to sea and an apprenticeship scheme would benefit individuals who would be running cruises in the future. SeaRover developed expertise and methods which should be captured as training courses.

The SOPs at present are checklists which are often very specific for certain items of equipment such as the current camera, current logging software and purpose of the cruise. They are only meaningful to a PI who has already run into problems and solved them and is familiar with the ROV and ship's systems, preparation of samples for particular purposes, etc.

Being at Sea

Once at sea things will go wrong and there are limited possibilities for repair of systems. There are multiple points of failure ranging from:

- Loss of ROV or catastrophic damage (ISIS)
- CTD malfunctioning and giving random readings amongst good ones
- OFOPs data not recorded or not saved to main disk storage
- Main disk storage not backed up

Curation and data curation

Biological recording is based on standards which are part of Darwin Core.

SeaRover data is mostly anonymous. It is recommended that all data are attributed to recorders in order to give appropriate credit for both rare and routine observations and motivate staff to strive for excellence, folllow up on collected specimens and feel a shared ownership of the data.

Table 10. The four tenets of biological recording

Who?	What?	When?	Where?
Observer	Species	Date	GPS position
Sample preparator	OTU	Time (UTC)	Position of start of transect
Identifier	Biotope		Position of observation/ collection event
ROV pilot	VME		

Database structure

- Data was stored in multiple Excel files. It was imported to and cleaned in Microsoft Access
- Main tables: Dives, Observations, Species records
- Lookup tables: Taxa, Biotopes, Listed Habitats

Numbers of records

- Observations are based on OFOP recording one event per second
- SeaRover recorded over 1.2 million observations and 310 hours of video on the HD camera alone
- An observations subset was created by saving one out of 60 chronologically and adding one-off events generated by OFOP button presses, resulting in 47085 observations
- 154 Stations - ROV dives
- 1151 Biotope segments documented
- 7570 OTU records
- 546 VME records

Cameras

Holland I was using a camera based on a Canon G5 chip shooting 2592 x 1944 pixels and with a maximum sensitivity of 400 ISO. It was set on 50 ISO throughout the SeaRover cruises and had no strobe lighting so exposures were typically 1/8 to 1/30th second at f2.8 aperture and the images were jpegs, limiting the possibility of colour correction, exposure correction and enhancement. This resulted in many exposures being unsharp due to camera shake or subject or ROV movement. If the camera system for the Holland I is to be updated, we recommend a ROV stills camera such as the SubC imaging Rayfin or STR SeaSpyder. These cameras can shoot RAW images at 3 fps with resolution of 5344 x 4008 pixels (21Mp) or 6000 x 4000 (24 Mp).

Modifications and upgrades suggested for Holland I camera systems

Digital camera technology has progressed quickly in the last 15 years. Ideally the minimum specification for work like SeaRover would use a camera or cameras recording to a 20-24 Mp sensor at 25600 ISO with existing lighting on ROV. ROVs now often have a camera mounted on the manipulator arm which can get closer to the subject and provide feedback to the pilot (wrist camera).

Table 11. ISO shutter speed aperture table

Cruise/camera	ISO	Shutter	Aperture f-stop	Comment
SeaRover Kongsberg oe-14-208	50	1/8 to 1/30	2.0-2.8	Camera shake evident
CE10008	200	1/50	2.0	Poor depth of field, camera shake
oe-14-208 max ISO	400	1/50	2.8	Strobe needed
+ 1 stop sensitivity	800	1/100	2.8	
+ 1 stop sensitivity	1600	1/100	4	
+ 1 stop sensitivity	3200	1/100	5.6	
+ 1 stop sensitivity	6400	1/100	8	
Sony Exmor RS BSI sensor	12800	1/100 or 1/200	11 or 8	Sweet spot
	25600	1/100 0r 1/200	16 or 11	

Table 12. Resolution of digital cameras

Sensors	Still image size pixels	Max ISO	Physical size mm	Year	Pixel density MP/cm^2	Video
Current (oe-14-208)	2592 x 1944	400	7.11 x 5.33	2003	13.16	HD
Nikon Z6	6048 x 4024	51200	35.9 x 23.9	2018	2.85	4K
Nikon Z7	8256 x 5504	25600	35.9 x 23.9	2018	5.32	4K
Nikon Z50	5568 x 3712	51200	23.5 x 15.7	2020	5.68	4K
SubC Rayfin	5344 x 4016	51200?	7.487 diag.	2014		4K
CathX	4096 x 2304					4K

Modern cameras use a Back Side Illuminated (BSI) sensor, earlier sensors were built with the photo receptors behind the wiring inside the chip, limiting the amount of light which could fall on the individual photosites. In BSI sensors the wiring is behind the photosites.

For example the SubC imaging Rayfin addresses many issues relevant to deep-sea photography. Video is compressed within the camera, allowing a connection by ethernet to have the bandwidth to handle the 4K video data stream to the surface. Internal storage of stills is on an SSD providing sufficient storage for the high resolution images gathered on a single dive. Sensitivity is high enough to shoot 3 frames per second at 21 MP resolution using the ROV's continuous lighting. The camera is rated to 6000 m and is available with corrected optics designed specifically for its role. It logs NMEA data in real time which provides GPS position, heading, depth and other data linked by timecode to the recorded video and still images.

Procedure for deploying ROV (scientists)

Pre-flight checks:
The pilots have an extensive pre-flight checklist. However, their main focus is on technical issues related to the ROVs proper functioning rather than our science issues, so it is worth checking:

1. **The pilots have synced all the clocks**
2. The bioboxes have the dividers as required (see ROV log sheets)

When the ROV goes in the water:

1. Log full details of the dive on the record sheet
2. Start the CTD if in use (see separate instructions)

When the ROV is on the bottom:

1. Turn on the laser lights. Lasers should remain on for the duration of the dive. **Do not turn them off**.
2. Set the white balance on the camera. Ask the pilots for help.
3. Insert a new high def cartridge and record time and cartridge letter (A, B, C, D etc) on the logsheet
4. **At the same time**, request the pilots to start the recording of the composite video. Composite video feed should have time, depth, lat and long overlays. Recorded outputs should include 1) a low res version of the high def video and 2) the video stream from the digital stills. Other cameras at the discretion of the scientists on watch.
5. Set your phone to a 2 hour countdown
6. Start OFOPS (see separate instructions)

During the Dive

1. Change the high def cartridge every 2 hours (i.e., when the lab time alarm goes) and reset the timer. If necessary, delete previous data from the cartridge.
2. Check that the composite video clips have restarted at this time too (they should be set to start a new clip every 30 mins)
3. High def cartridge immediately sent to dry lab for copying to Lacie
4. Record times of any cores taken using diagram on main dive logsheet
5. Record details of any fauna collected on “samples collected” logsheets. Record time and depth of collection. All fauna collected **MUST** have a series of digital still photographs taken and a close-up zoom with the video too. The bioboxes and their quadrants are illustrated visually (as they appear through the ROV cameras) on the log sheets. Simply circle the appropriate box.
6. Record details of all digital stills taken on the “photographs taken” logsheets
7. Take photos and zoomed video of any fauna that need to be identified (all corals and sponges).

Sample collection:
The focus of the NUIG SFI project is corals and sponges. Experience suggests that the easiest way to collect these is:

1. **Sponges.** Sponges are usually fairly robust, but they can 'tear'. They always need to be collected using the manipulator arms. They have a horrible tendency to block the slurp although sponges that stick out from ledges like tree fungi can be collected with the slurp.
2. **Octocorals**. It should be possible to collect octocorals by grabbing them near the base, closing the jaws of the manipulator arms, and twisting.
3. **Sea pens** (yes technically these are corals too). Some sea pens are sensitive to touch and withdraw into the sediment as soon as the robotic arm touches them. Therefore, it is important to line the robotic arm carefully at the base of the stem and then make a grab for them. Pull the sea pen out of the sediment with the robotic arm. Large specimens can be dropped directly in a biobox. It is often easier to feed small specimens into the slurp sampler. Do not attempt to slurp sea pens out of the sediment. It won't work and it fills the slurp chamber with sediment spoiling all other specimens therein.
4. **Black corals**. Black corals are mostly very robust and can be collected with the robotic arms. Black corals are best placed in the bioboxes.

Notes on the slurp:
The wash through of the slurp is fierce. It is not great for collecting delicate samples. If you do wish to collect something delicate with it, instruct the pilots to have the power on for the shortest possible time. THEN: move the slurp chamber on and do not put another collecting in this chamber. You can put multiple robust samples in a single chamber (e.g., lots of Kophobelemnon), but if you try to put two Umbellula in a slurp, the turbulence formed by the second collection will mash the first sample.

Notes on the front buckets:
These are best not used. They are there for in emergency, when something big and heavy is collected that won't fit in the bioboxes. Note that if the samples aren't heavy they will wash out of these buckets on the surface. If you do put something in these, it's worth lying one of the arms above the bucket for the ascent. **Do NOT use routinely: you will lose your samples.**

On leaving the seafloor:

1. Turn off OFOPS and copy the files to USB stick
2. Stop the high def video and send the cartridge to the dry lab immediately for copying to Lacie/Drobo

ROV on the surface:

1. Stop the CTD (if in use), copy the files to a USB stick
2. Take the USB stick with the CTD files and OFOPs files to the dry lab and copy to the Lacie/Drobo
3. Complete the ROV summary sheet.

ROV on Deck:
Always wait until the pilots say it is safe to approach the ROV. Then:

1. Empty the bioboxes and slurp chambers into the 11 labeled buckets. Note that there is a separate laminated diagram which shows how the bioboxes are labeled. Great care is required because when emptying them you are approaching the boxes from the other side to that from which you view them during the dive so left is right, and right is left; front is back and back is front!!
2. When the pilots have finished their essential jobs, request that the digital stills camera be brought to the dry lab so that the scientists can download the images.

Samples in the wet lab:

NOTE: THIS IS A BRIEF OVERVIEW ONLY. THERE IS A SEPARATE LABEL SOP WITH DETAILED INSTRUCTIONS FOR HOW TO LABEL

1. Label and preserve faunal specimens collected by ROV as directed in the separate SOP.
2. All collected specimens should be photographed in the wet lab prior to preservation. Make sure that a label with the specimen number is visible in the photograph.
3. Enter details of the samples preserved in a lab book or on log sheets.
4. On the "samples collected" logsheet, match your sample up with the collection event, and add the specimen number (SFI_xxx) into the last column of this logsheet.

In the dry lab

5. Work through the digital stills adding the sample numbers to the end of the files names (e.g., change IMG_7234.jpg to IMG_7234_SFI398.jpg. If you do this immediately after each dive, it is fairly easy to work out (from the times) which images are of which collected samples.
6. Enter the data from the "samples collected" logsheet and the "samples preserved" logsheet/labbook into the Excel files that will be on computers in the dry lab.
7. Make sure the event log is up to date.

ROV data checklist:

1. **High def video**. This should be copied from the Ki Pro cartridge as soon as a cartridge has 2 hours of video on it. The last cartridge should be copied directly after the dive, so that each dive starts with a new cartridge. When a cartridge has been copied, return it to the ROV shack. **It is important not to leave cartridges lying around as this becomes very confusing.** Check that the number of files for each dive matches what is expected from the log sheets.
2. **Digital stills.** Digital still images should be downloaded from the camera after each dive, although if there is a quick turnaround this can wait until after a second dive. However, remember that the images are stored on the camera, so if the camera floods during the second dive… There is a computer in the dry lab with the camera software. Karl (ROV pilot) is familiar with this and can show scientists how to download the images. Copy the images onto a USB drive and transfer them to the Lacie. **Do NOT carry the camera back to the ROV shack**. Ask a pilot to collect it. You cannot afford the bill if you slip…!
3. **Composite video.** This is recorded in the ROV shack and a feed from this hard drive will be available in the dry lab. The composite video files should be copied to the Lacie at the end of every dive. Check that the number of files for each dive matches what is expected from the log sheets.
4. **Laboratory stills.** When all specimens are preserved after a dive (i.e., the work in the wet lab is finished), the photographs should be transferred from the camera in the wet lab to the Lacie.
5. **OFOPS data.** This should be transferred from the OFOPs computer in the ROV shack to the Lacie at the end of every dive
6. **ROV CTD (if used) data.** This should be transferred from the CTD computer in the ROV shack at the end of every dive.
7. **CTD data.** A CTD will be conducted prior to every dive to provide speed of sound data for the USBL system. The CTD files should be copied to the Lacie at the end of the cruise
8. **Sonardyne data**. The output from the Sonardyne system (with lat/long/depth information for the ROV) should be copied to the Lacie after each dive.

Connecting the KiPro dock to the Lacie:
The Lacie has two thunderbolt ports, and a 'daisy chain' set up is most efficient. With all the equipment plugged in but turned off at the plug, connect the Lacie to the iMac with a thunderbolt cable, then use the second thunderbolt cable to connect the KiPro dock direct to the Lacie (i.e., the KiPro dock is not connected directly to the iMac). If you have two Lacie's (for double back up), daisy chain the Lacie's together and put the KiPro dock on the end of the chain. Then turn everything on (remembering that the Lacie 'on switch' is the big blue light at the front).

NEVER remove a KiPro cartridge without dismounting it first. Either use the mouse to pick up the image of the cartridge on the desktop and drop it in the waste basket or click on the eject arrow next to the cartridge's name on the left menus of Finder. The same applies to the Lacie, although there should not be any reason to dismount it.

Starting OFOPS:

1. Open up OFOPS in the ROV shack
2. Go to the menu 'GPS & Logging'. Select Ship and Sub data connection. Then for Ship (1st position) tick Read data on COM port and for Sub (2nd position RVO) tick Read data on COM port
3. Go to the menu 'Map'. Select Set UTM Zone. Change to '29' and hit Apply.
4. Go to the menu 'GPS & Logging'. Click Start logging position.

Stopping OFOPS:

1. Go to the menu 'GPS and logging'. Click 'stop logging'.
2. Close down OFOPS
3. Copy the generated files to USB stick and take to dry lab for transfer to Lacie / Drobo

Starting the ROV CTD:

1. Ask the pilots to turn on the CTD pump.
2. Open the Seabird software
3. Go to the menu 'Real time data'. Click on Start
4. Change output data file name to the dive number (or other appropriate file name)
5. Click Start and OK.
6. Check that the CTD is pumping properly and sensible data are scrolling. If the CTD does not appear to be working properly, inform the pilot. Often a 'power cycle' of the CTD will be sufficient to solve the problem.

Stopping the ROV CTD:

1. Go to the menu 'Real time data'. Click on Stop
2. Shut down the Seabird software
3. Copy the generated files to USB stick and take to dry lab for transfer to Lacie / Drobo

From the ROV to the laboratory

Step 1. Just before the ROV starts its ascent, place buckets with seawater in a cold room (ideally at 5°C but it can be in the -20°C). There should be a bucket for each compartment of the ROV where specimens were put.

At most, the ROV can have 13 different compartments:

- left biobox divided in 4
- right biobox divided in 4
- 3 slurp chambers
- 2 front white buckets

Depending where the specimens were put during the dives, prepare the right number of buckets with cold seawater.

Label each bucket with the compartment name.

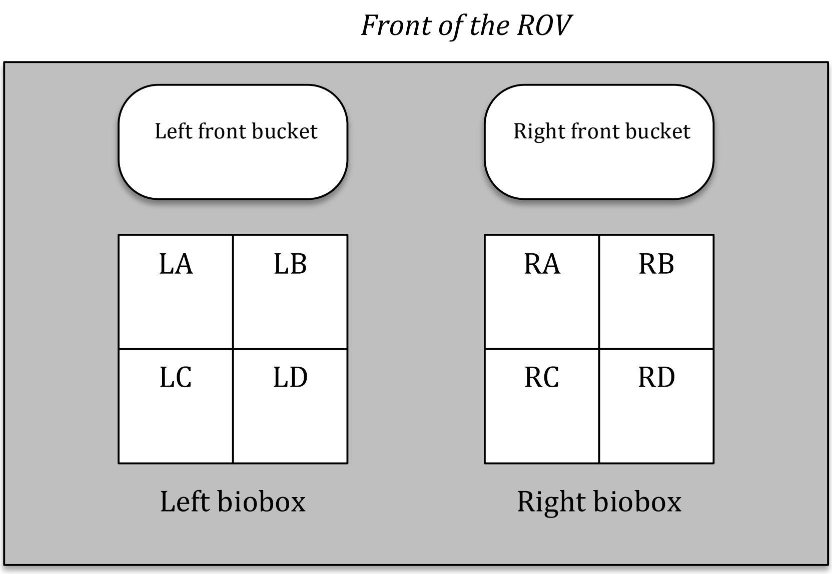
- slurp chamber: 1 (SC1), 2 (SC2) and 3 (SC3)
- the white front buckets: we call them left front bucket (LFB) and right front bucket (RFB)
- left biobox: we call the compartment A (LA), B (LB), C (LC) and D (LD)
- right biobox: we call the compartment A (RA), B (RB), C (RC) and D (RD)

Step 2. Once the ROV is on deck and the pilots are happy for us to approach, take the specimens out of the ROV. Be careful when putting the specimen from the ROV to the bucket. You have a mirror image to what you see from the ROV shack, so left is right, and right is left. There is a printed card to help you with this!

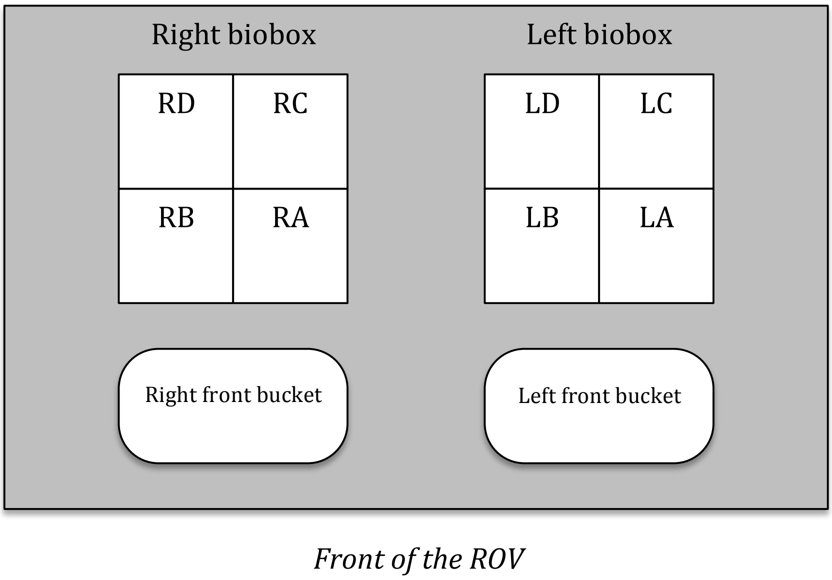
Step 3. Once each compartment of the ROV has been emptied carried the bucket back in a cold temperature room.

[Granuaille Notes: I don't think there is a walk-in freezer on Granuaille, so it will not be possible to prefreeze water. Therefore, I recommend that you fill the buckets immediately before use, using deck hoses, but let the deck hoses run through for a considerable amount of time before use so that cold water from the sea (rather than warm water that has been sitting in the system) fills the buckets.]

ROV shak/video view:



View when the ROV is back on deck:



Note that the log sheets present the view as shown from the ROV shack, and a separate laminated sheet is available giving the view from the front of the ROV for use in emptying the bioboxes.

D	C
B	A

RIGHT

D	C
B	A

LEFT

Correct labels for the ROV bioboxes as seen from standing in front of the ROV
***remember the view in the shack which (we use to label) is from behind the boxes so left and right have to be reversed)

Laboratory work for SFI project: Octocorallia, Antipatharia and Porifera

1) Wear gloves and change them periodically to avoid cross-contamination of samples.

2) Process each bucket one at a time, leaving the other in the cold room temperature.

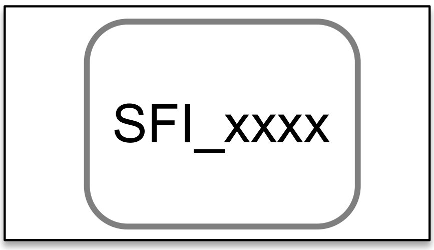
3) When using forceps, do not use serrated forceps to avoid tissue build up in serrations.

4) Clean any tools (forceps, scissors, pliers….) between samples.

5) For each specimen, we take 3 different samples: the specimen itself, a taxonomic voucher and a tissue sample for DNA. Use the SFI_xxxx sequentially (ie: first specimen will be SFI_378, the second SFI_379 …..).

Step 1. Take the next-in-sequence preprinted loose waterproof label. These have printed cruise details on the front and a sticker with the SFI number on the back. Complete the date and fill in Dive/Station number.

Front view



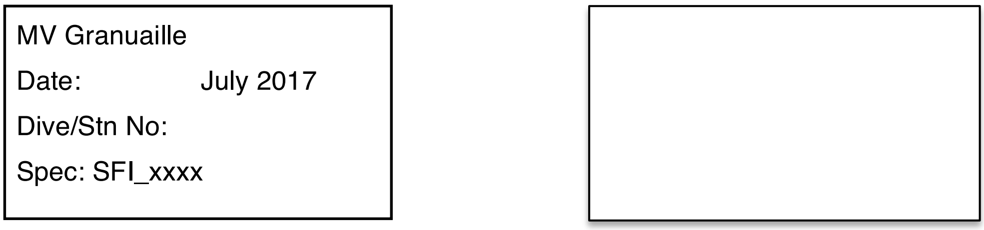
Back view

Step 2. Take a photograph of the specimen, which includes a ruler (for size) and the **front side of the label that you just filled in**, both visible on the picture. It's absolutely essential that the lable is in this photo.

Step 3. Remove all epifauna from the specimen if any.

Step 4. Take a taxonomic voucher.

Take the 10 mL vial labelled with the same SFI number as you used in step1. Fill in the label in the vial with date and dive/station number (note that the label is a duplicate of the one in step 1 but does not have a sticker in the back – rather the sticker is on the outside of the vial).



Front view *Back view*

Cut a small piece of the specimen:

- for octocorals, ensure a piece of a branch with 5-6 polyps
- for black corals, the base of the specimen and a piece of branch with 5-6 polyps
- for sponges, a piece

It is important that the voucher is large enough to be informative, but small enough to ensure sufficient material is left for the chemistry analysis.

Put the piece in the 10 mL vial labeled with the same SFI_xxxx number and fill in with 96% ethanol.

Then put the vial in the -20°C freezer or if no space, in the coolest place that you can find onboard.

Step 5. take a DNA sample.

Take the 2 ml tube with the same SFI_xxxx number as in step 1 (note that it ll labeled and that you do not need to label it).

Cut a very small piece of the specimen (3-4 polyps for corals and a small piece for sponge) and put it in the 2mL tube with 96% ethanol.

Then put the pot in the -20°C freezer.

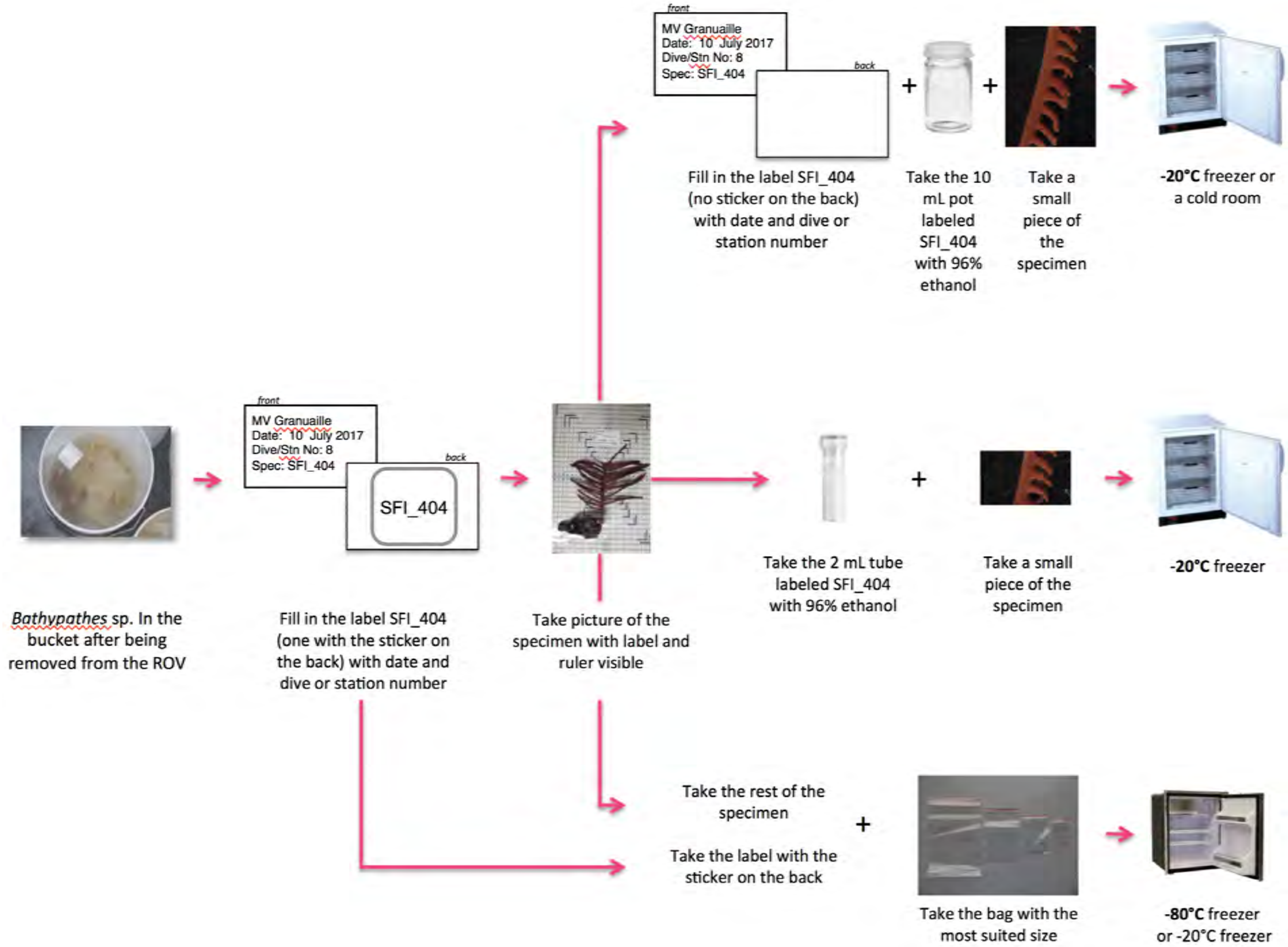
Step 6. Bag the main sample.

Use the labels that you made in step 1.

Place the whole specimens (after pieces were removed for voucher and DNA) in a bag (use the most appropriate bag size) with the label but without any fixative.

Store in -80°C freezer or if no room, in -20°C freezer.

Example of the protocol (*Bathypathes* sp. SFI_404 collected the 10th July 2017 during dive 8



Dive Plan	

Dive location

Cruise	
Dive/Event #	
Holland dive	
Date	
Time (UTC)	
Lat	
Long	
Depth (m)	
Time on bottom	

New media insertion

Time (UTC)	HiDef (tick)	Composite (details)

ROV push cores

(Insert UTC time in circle)

ROV LHS

ROV RHS

Biobox labels

--------(front of ROV)--------

A	B
C	D

Left

A	B
C	D

Right

Event/ Dive #	

Granuaille 2017 Samples collected

Sheet No.	

Time (UTC)	Depth	Slurp Chamber (tick)			Left Biobox (circle)		Right Biobox (circle)		Description	Number of photos taken	High def video zoom (tick)	Photograph file names (filled in later)	Specimen No (filled in later)
		1	2	3									
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					
					A	B	A	B					
					C	D	C	D					

DIVE SUMMARY

Cruise	Granuaille 2017
Dive/Event #	
Holland dive	
Date	
Time off Bottom	
Bottom depth at dive end	
Time out of water	
Reason for ending dive	
Narrative summary of dive (for cruise report)	
No of cores taken	
No of HD video files	
Any issues with composite video files	
Any issues with ROV:	

Granuaille 2017 Samples collected

SFI No.	Event No.	ROV Box	ID by…	Samples	Species (Latin name if possible)	Higher Taxonomy (If species not known: give lowest higher taxon possible)	Description (particularly important if not identified)
				Frozen ☐ Morph ☐ DNA ☐			
				Frozen ☐ Morph ☐ DNA ☐			
				Frozen ☐ Morph ☐ DNA ☐			
				Frozen ☐ Morph ☐ DNA ☐			
				Frozen ☐ Morph ☐ DNA ☐			
				Frozen ☐ Morph ☐ DNA ☐			

Appendix 2. List of biotopes observed

Segments are a count of times the biotope was encountered on SeaRover cruises. Biotopes are listed by depth zone, C Circalittoral 50 - 200 m, UB Upper bathyal 200 - 600 m, MB Mid bathyal 600 - 1200 m, LB Lower bathyal 1200-2000 m, Upper abyssal - 3000 - 4000 m, MA Mid abyssal 4000 - 6000 m. Potential new or variant biotopes are marked with an asterisk* and the rationale is explained in section 2.4 of this review and the individual analysis reports.

Biotope	Biotope segments
C: CR.FCR.FouFa	**2**
Fouling faunal communities	2
C: CR.LCR	**5**
Low energy circalittoral rock	5
C: SS.SCS	**1**
Sublittoral coarse sediment (unstable cobbles, pebbles, gravels and coarse sands)	1
C: SS.SMu	**8**
Sublittoral cohesive mud and sandy mud communities	8
C: SS.Ssa	**3**
Sublittoral sands and muddy sands	3
UB: M.AtUB.Bi.CorRee	**3**
*(variant of) Atlantic upper bathyal cold water coral reef (biogenic structure)	2
Atlantic upper bathyal cold water coral reef (biogenic structure)	1
UB: M.AtUB.Co	**2**
Atlantic upper bathyal coarse sediment	2
UB: M.AtUB.Co.UrcCom	**5**
Urchin dominated community on Atlantic upper bathyal coarse sediment	5
UB: M.AtUB.Co.UrcCom.CidUrc	**4**
Cidarid urchin assemblage on Atlantic upper bathyal coarse sediment	2
Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	2
UB: M.AtUB.Mu	**21**
Atlantic upper bathyal mud	21
UB: M.AtUB.Mu.CriCom	**1**
*(variant of) Crinoid dominated community on Atlantic upper bathyal mud	1
UB: M.AtUB.Ro	**9**
Atlantic upper bathyal rock and other hard substrata	9
UB: M.AtUB.Ro.BarCom	**2**
*(lower bathyal variant) Barnacle dominated community on Atlantic upper bathyal rock and other hard substrata	2
UB: M.AtUB.Ro.DeeSpo	**11**
*(encrusting variant of) Deep sponge aggregation on Atlantic upper bathyal rock and other hard substrata	2
*(lower bathyal variant) Deep sponge aggregation on Atlantic upper bathyal rock and other hard substrata	1
*(mid bathyal encrusting variant of) Deep sponge aggregation on Atlantic upper bathyal rock and other hard substrata	2
*(Mid Bathyal variant of) Deep sponge aggregation on Atlantic upper bathyal rock and other hard substrata	1
*(Mycale) Deep sponge aggregation on Atlantic upper bathyal rock and other hard substrata	1
*(variant of) Atlantic upper abyssal rock and other hard substrata	1
*(variant of) Deep sponge aggregations on Atlantic upper bathyal rock and other hard substrata	3

Biotope	Biotope segments
UB: M.AtUB.Ro.DeeSpo.SpoSty	**1**
*(lower bathyal variant) Lobose sponge and stylasterid assemblage on Atlantic upper bathyal rock and other hard substrata	1
UB: M.AtUB.Ro.MixCor	**17**
*(canyon/escarpment variant) Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	2
*(canyon/escarpment variant) Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	2
*(sparse, canyon/escarpment variant) Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	1
*(sparse, canyon/escarpment variant) Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	3
*(variant of) Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	3
Mixed cold water coral community on Atlantic upper bathyal rock and other hard substrata	6
UB: M.AtUB.Ro.SpaEnc	**5**
Sparse encrusting community on Atlantic upper bathyal rock and other hard substrata	5
UB: M.AtUB.Ro.SpaEnc(.HydBry)	**13**
*(variant) Sparse encrusting community on Atlantic upper bathyal rock and other hard substrata (dominated by Hydrozoans [e.g. Stylaster/Pliobothrus] and Bryozoans [e.g. Reteporella])	13
UB: M.AtUB.Sa.UrcCom.CidUrc	**4**
Cidarid urchin assemblage on Atlantic upper bathyal sand	4
MB: M.AtMB.Bi.CorRee	**34**
Atlantic mid bathyal cold water coral reef (biogenic structure)	34
MB: M.AtMB.Bi.CorRee.LopFra	**20**
Mixed coral assemblage on Atlantic mid bathyal Lophelia pertusa reef framework (biogenic structure)	20
MB: M.AtMB.Bi.CorRee.LopPer	**7**
Atlantic mid bathyal live Lophelia pertusa reef (biogenic structure)	7
MB: M.AtMB.Co	**10**
Atlantic mid bathyal coarse sediment	9
Syringammina fragilissima field on Atlantic mid bathyal mud	1
MB: M.AtMB.Co.MixCor	**4**
Mixed cold water coral community on Atlantic mid bathyal coarse sediment	4
MB: M.AtMB.Co.MixCor.DisLop	**6**
Discrete Lophelia pertusa colonies on Atlantic mid bathyal coarse sediment	6
MB: M.AtMB.Co.SpaEnc	**1**
Sparse encrusting community on Atlantic mid bathyal coarse sediment	1
MB: M.AtMB.Co.UrcCom	**9**
*(carbonate rock variant of) Urchin dominated community on Atlantic mid bathyal coarse sediment	1
*(mixed sediment variant) Urchin dominated community on Atlantic mid bathyal coarse sediment	1
Urchin dominated community on Atlantic mid bathyal coarse sediment	7
MB: M.AtMB.Co.UrcCom.CidUrc	**1**
Cidarid urchin assemblage on Atlantic mid bathyal coarse sediment	1
MB: M.AtMB.Co.UrchCom.CidUrc	**6**
Cidarid urchin assemblage on Atlantic mid bathyal coarse sediment	6
MB: M.AtMB.Mu	**39**
*(variant of) Atlantic mid bathyal mud	2
Atlantic mid bathyal mud	37

Biotope	Biotope segments
MB: M.AtMB.Mu.BurAne	**14**
*(lower bathyal variant) Burrowing anemone field in Atlantic mid bathyal mud	4
*(lower bathyal variant) Burrowing anemone field in Atlantic mid bathyal sand	2
*(mixed sediment variant) Burrowing anemone field in Atlantic mid bathyal mud	1
*(sparse, lower bathyal variant) Burrowing anemone field in Atlantic mid bathyal mud	1
*(variant of) Burrowing anemone field in Atlantic mid bathyal mud	2
Burrowing anemone field in Atlantic mid bathyal mud	4
MB: M.AtMB.Mu.BurOph	**5**
Burrowing ophiuroid community on Atlantic mid bathyal mud	5
MB: M.AtMB.Mu.CriCom	**18**
*(lower bathyal stalked variant) Crinoid dominated community on Atlantic mid bathyal mud	18
MB: M.AtMB.Mu.DeeSpo	**1**
*(variant of) Deep sponge aggregation on Atlantic mid bathyal mud	1
MB: M.AtMB.Mu.DeeSpo.PheCar	**2**
Pheronema carpenteri field on Atlantic mid bathyal mud	2
MB: M.AtMB.Mu.EreCor	**2**
Erect coral field on Atlantic mid bathyal mud	2
MB: M.AtMB.Mu.EreCor.AcaArb	**8**
*(Coarse sediment/sparse variant of) Acanella arbuscula assemblage on Atlantic mid bathyal mud	2
*(Mixed sediment variant of) Acanella arbuscula assemblage on Atlantic mid bathyal mud	3
*(sparse, Mixed sediment variant of) Acanella arbuscula assemblage on Atlantic mid bathyal mud	1
*(variant of) Acanella arbuscula assemblage on Atlantic mid bathyal mud	1
Acanella arbuscula assemblage on Atlantic mid bathyal mud	1
MB: M.AtMB.Mu.InfPol	**2**
Mixed infauna dominated by polychaetes in Atlantic mid bathyal mud	2
MB: M.AtMB.Mu.SolScl	**1**
Solitary scleractinian field on Atlantic mid bathyal mud	1
MB: M.AtMB.Mu.SpnMeg	**27**
*(lower bathyal variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	10
*(lower bathyal, sand, variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	1
*(sparse, lower bathyal mixed substrate variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	1
*(sparse, lower bathyal variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	2
*(sparse, upper abyssal variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	3
*(sparse, upper abyssal, coarse variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	3
*(upper abyssal, coarse variant) Sea pens and burrowing megafauna on Atlantic mid bathyal mud	2
Sea pens and burrowing megafauna on Atlantic mid bathyal mud	5
MB: M.AtMB.Mu.UrcCom	**3**
*(Mixed substrate variant) Urchin dominated community on Atlantic mid bathyal mud	1
Urchin dominated community on Atlantic mid bathyal mud	2
MB: M.AtMB.Mu.XenCom	**1**
Xenophyophore dominated community on Atlantic mid bathyal mud	1
MB: M.AtMB.Mu.XenCom.SyrFra	**7**
*(sparse) Syringammina fragilissima field on Atlantic mid bathyal mud	1
Syringammina fragilissima field on Atlantic mid bathyal mud	6
MB: M.AtMB.Mx	**5**

Biotope	**Biotope segments**
Atlantic mid bathyal mixed sediment	5
MB: M.AtMB.Mx.XenCom.SyrFra	**4**
Syringammina fragilissima field on Atlantic mid bathyal mixed sediment	4
MB: M.AtMB.Ro	**15**
Atlantic mid bathyal rock and other hard substrata	15
MB: M.AtMB.Ro.BarCom	**17**
*(Lower bathyal variant of) Barnacle dominated community on Atlantic mid bathyal rock and other hard substrata	1
*(lower bathyal variant) Barnacle dominated community on Atlantic mid bathyal rock and other hard substrata	12
Barnacle dominated community on Atlantic mid bathyal rock and other hard substrata	4
MB: M.AtMB.Ro.BraCom	**6**
*(variant of) Brachiopod dominated community on Atlantic mid bathyal rock and other hard substrata	5
Brachiopod dominated community on Atlantic mid bathyal rock and other hard substrata	1
MB: M.AtMB.Ro.MixCor	**26**
*(sparse) Mixed cold water coral community on Atlantic mid bathyal rock and other hard substrata	1
Mixed cold water coral community on Atlantic mid bathyal rock and other hard substrata	25
MB: M.AtMB.Ro.MixCor.DisLop	**13**
*(canyon/escarpment variant) Discrete Lophelia pertusa colonies on Atlantic mid bathyal rock and other hard substrata	4
*(Madrepora oculata variant of) Discrete Lophelia pertusa colonies on Atlantic mid bathyal rock and other hard substrata	2
*(sparse) Discrete Lophelia pertusa colonies on Atlantic mid bathyal rock and other hard substrata	1
Discrete Lophelia pertusa colonies on Atlantic mid bathyal rock and other hard substrata	6
MB: M.AtMB.Ro.SpaEnc	**5**
*(lower bathyal variant) Sparse encrusting community on Atlantic mid bathyal rock and other hard substrata	3
*(lower bathyal, non Psolus variant) Sparse encrusting community on Atlantic mid bathyal rock and other hard substrata	1
Sparse encrusting community on Atlantic mid bathyal rock and other hard substrata	1
MB: M.AtMB.Ro.SpaEnc.PsoAno	**9**
*(lower bathyal vairant of) Psolus squamatus, Anomiidae, serpulid polychaetes and Munida on Atlantic mid bathyal rock and other hard substrata	1
Psolus squamatus, Anomiidae, serpulid polychaetes and Munida on Atlantic mid bathyal rock and other hard substrata	8
MB: M.AtMB.Sa	**19**
Atlantic mid bathyal sand	19
MB: M.AtMB.Sa.BurAne	**4**
*(coarse sediment variation of) Burrowing anemone field in Atlantic mid bathyal sand	3
Burrowing anemone field in Atlantic mid bathyal sand	1
MB: M.AtMB.Sa.SolScl	**1**
Solitary scleractinian field on Atlantic mid bathyal sand	1
MB: M.AtMB.Sa.UrcCom	**13**
*(coarse sediment variant of) Urchin dominated community on Atlantic mid bathyal sand	1
*(coarse variant of) Urchin dominated community on Atlantic mid bathyal sand	2
*(sparse) Urchin dominated community on Atlantic mid bathyal sand	2
Urchin dominated community on Atlantic mid bathyal sand	8
MB: M.AtMB.Sa.UrcCom.CidUrc	**1**
*(mixed sediment variant) Cidarid urchin assemblage on Atlantic mid bathyal sand	1

Biotope	Biotope segments
MB: M.AtMB.Sa.UrchCom.CidUrc	**4**
Cidarid urchin assemblage on Atlantic mid bathyal sand	4
LB: *(var nov) M.AtLB.Mu(.BurMeg)	**4**
*(suggested temporary new variant) Atlantic lower bathyal mud (with burrowing megafauna)	4
LB: M. AtLB.Ro.MixCor	**1**
Mixed cold water coral community on Atlantic lower bathyal rock and other hard substrata	1
LB: M.AtLB.Bi.CorRee	**12**
Atlantic lower bathyal cold water coral reef (biogenic structure)	12
LB: M.AtLB.Bi.CorRee.SolFra	**13**
Mixed coral assemblage on Atlantic lower bathyal Solenosmilia reef framework (biogenic structure)	13
LB: M.AtLB.Bi.CorRee.SolVar	**18**
Atlantic lower bathyal live Solenosmilia variabilis reef (biogenic structure)	18
LB: M.AtLB.Co	**10**
Atlantic lower bathyal coarse sediment	10
LB: M.AtLB.Co.MixCor	**1**
Mixed cold water coral community on Atlantic lower bathyal coarse sediment	1
LB: M.AtLB.Co.MixCor.DisSol	**1**
Discrete Solenosmilia variabilis colonies on Atlantic lower bathyal coarse sediment	1
LB: M.AtLB.Co.SolScl	**1**
Solitary scleractinian field on Atlantic lower bathyal coarse sediment	1
LB: M.AtLB.Co.XenCom.SyrFra	**1**
Syringammina fragilissima field on Atlantic lower bathyal coarse sediment	1
LB: M.AtLB.Co.XenCom.SyrFra/ M.AtLB.Mu.EreCor.AcaArb	**2**
Syringammina fragilissima field on Atlantic lower bathyal coarse sediment/ (patchy) Acanella arbuscula assemblage on Atlantic lower bathyal mud	1
Syringammina fragilissima field on Atlantic lower bathyal coarse sediment/ Acanella arbuscula assemblage on Atlantic lower bathyal mud	1
LB: M.AtLB.Mu	**57**
*(var) Atlantic lower bathyal mud	2
Atlantic lower bathyal mud	55
LB: M.AtLB.Mu.BurOph	**3**
*(var) Burrowing ophiuroid community on Atlantic lower bathyal mud	3
LB: M.AtLB.Mu.EreCor	**9**
*(variant of) Erect coral field on Atlantic lower bathyal mud	2
Erect coral field on Atlantic lower bathyal mud	7
LB: M.AtLB.Mu.EreCor.AcaArb	**8**
Acanella arbuscula assemblage on Atlantic lower bathyal mud	8
LB: M.AtLB.Mu.EreCor.AcaArb/ M.AtLB.Co.XenCom.SyrFra	**3**
Acanella arbuscula assemblage on Atlantic lower bathyal mud/ Syringammina fragilissima field on Atlantic lower bathyal coarse sediment	3
LB: M.AtLB.Mu.InfPol	**1**
Mixed infauna dominated by polychaetes in Atlantic lower bathyal mud	1
LB: M.AtLB.Mu.SolScl	**8**
Solitary scleractinian field on Atlantic lower bathyal mud	8
LB: M.AtLB.Mu.UrcCom	**13**
*(variant of) Urchin dominated community on Atlantic lower bathyal mud	1
Urchin dominated community on Atlantic lower bathyal mud	12

Biotope	Biotope segments
LB: M.AtLB.Mu.UrcCom.GraAcu	**2**
Gracilechinus acutus norvegicus assemblage on Atlantic lower bathyal mud	2
LB: M.AtLB.Mu.XenCom	**2**
Xenophyophore dominated community on Atlantic lower bathyal mud	2
LB: M.AtLB.Mu.XenCom.SyrFra	**39**
*(patchy) Syringammina fragilissima field on Atlantic lower bathyal mud	8
*(sometimes sparse) Syringammina fragilissima field on Atlantic lower bathyal mud	1
Syringammina fragilissima field on Atlantic lower bathyal mud	30
LB: M.AtLB.Mu.XenCom.SyrFra/ M.AtLB.Mu.SolScl	**2**
Syringammina fragilissima field on Atlantic lower bathyal mud/ Solitary scleractinian field on Atlantic lower bathyal mud	2
LB: M.AtLB.Mx	**1**
Atlantic lower bathyal mixed sediment	1
LB: M.AtLB.Mx.SurOph	**1**
*(upper abyssal variant) Surface dwelling ophiuroid community on Atlantic lower bathyal mixed sediment	1
LB: M.AtLB.Mx.SurOph.OphCer	**30**
*(variant with very few cerianthids, mostly mud) Ophiomusium lymani and cerianthid anemone assemblage on Atlantic lower bathyal mixed sediment	5
Ophiomusium lymani and cerianthid anemone assemblage on Atlantic lower bathyal mixed sediment	25
LB: M.AtLB.Mx.XenCom.SyrFra	**17**
*(upper abyssal variant) Syringammina fragilissima field on Atlantic lower bathyal mixed sediment	1
Syringammina fragilissima field on Atlantic lower bathyal mixed sediment	16
LB: M.AtLB.Ro	**24**
Atlantic lower bathyal rock and other hard substrata	24
LB: M.AtLB.Ro.DeeSpo	**3**
*(variant of) Deep sponge aggregations on Atlantic lower bathyal rock and other hard substrata	3
LB: M.AtLB.Ro.MixCor	**73**
*(sparse) Mixed cold water coral community on Atlantic lower bathyal rock and other hard substrata	2
*(Stalked crinoids, sponges, and) Mixed cold water coral community on Atlantic lower bathyal rock and other hard substrata	3
Mixed cold water coral community on Atlantic lower bathyal rock and other hard substrata	68
LB: M.AtLB.Ro.MixCor.DisSol	**13**
Discrete Solenosmilia variabilis colonies on Atlantic lower bathyal rock and other hard substrata	13
LB: M.AtLB.Sa	**4**
Atlantic lower bathyal sand	4
LB: M.AtLB.Sa.SolScl	**5**
*(sparse) Solitary scleractinian field on Atlantic lower bathyal sand	2
Solitary scleractinian field on Atlantic lower bathyal sand	3
LB: M.AtLB.Sa.SolScl/M.AtLB.Co.XenCom.SyrFra	**6**
Solitary scleractinian field on Atlantic lower bathyal sand/ Syringammina fragilissima field on Atlantic lower bathyal coarse sediment	6
LB: M.AtLB.Sa.UrcCom	**5**
Urchin dominated community on Atlantic lower bathyal sand	5
UA: M.AtUA.Bi	**11**
*(variant of) Atlantic upper abyssal cold water coral reef (biogenic structure)	11
UA: M.AtUA.Co	**4**
Atlantic upper abyssal coarse sediment	4

Biotope	Biotope segments
UA: M.AtUA.Mu	**49**
*(variant of) Atlantic upper abyssal mud	1
Atlantic upper abyssal mud	48
UA: M.AtUA.Mu.HolCom	**31**
?*(lower bathyal) Holothurian dominated community on Atlantic upper abyssal mud	1
*(Lower bathyal variant) Holothurian dominated community on Atlantic upper abyssal mud	14
*(mixed sediment variant) Holothurian dominated community on Atlantic upper abyssal mud	5
*(variant of) Holothurian dominated community on Atlantic upper abyssal mud	7
Holothurian dominated community on Atlantic upper abyssal mud	4
UA: M.AtUA.Mu.InfPol	**2**
Mixed infauna dominated by polychaetes in Atlantic upper abyssal mud	2
UA: M.AtUA.Mu.UrcCom	**11**
*(mixed sediment variant of) Urchin dominated community on Atlantic upper abyssal mud	3
Urchin dominated community on Atlantic upper abyssal mud	8
UA: M.AtUA.Mx	**5**
Atlantic upper abyssal mixed sediment	5
UA: M.AtUA.Ro	**83**
*(Stalked crinoids, sponges, and corals on) Atlantic upper abyssal rock and other hard substrata	23
Atlantic upper abyssal rock and other hard substrata	60
UA: M.AtUA.Sa	**14**
Atlantic upper abyssal sand	14
MA: M.AtMA.Mu	**1**
*(burrowing echinoid dominated) Atlantic mid abyssal mud	1
MA: M.AtMA.Mu.HolCom	**2**
Holothurian dominated community on Atlantic mid abyssal mud	2

Appendix 3. Species and OTU list

OTU or Taxon	Number of occurrences
Annelida	
Polychaeta	107
Echiuroidea	20
Bonelliidae	20
267 Bonellia viridis	20
(unclassified)	1
(unclassified)	1
1104 Echiura sp	1
Phyllodocida	23
Aphroditidae	23
146 Aphroditidae sp 1	23
Sabellida	59
Sabellidae	5
54 Sabellidae sp 1	5
Serpulidae	54
106 Serpulidae sp 1	51
1148 Serpulidae sp (black)	2
228 Serpulidae sp 2	1
Terebellida	4
Terebellidae	4
262 Lanice sp 1	4
(unclassified)	1
(unclassified)	1
(unclassified)	1
967 Annelida sp 5	1
Arthropoda	548
Hexanauplia	37
(unclassified)	37
(unclassified)	37
1209 Cirripedia sp 2	3
82 Cirripedia sp 1	34
Malacostraca	450
Decapoda	385
Chirostylidae	40
1054 Chirostylidae sp 2 (indet)	20
285 Chirostylidae sp 1 (indet)	20
Geryonidae	28
254 Chaceon affinis	28
Homolidae	22
304 Paromola cuvieri	22
Lithodidae	12
1063 Neolithodes grimaldii	12
Majidae	7
11 Majidae sp 1	7
Munididae	54
200 Munida sarsi	12
339 Munida tenuimana	42
Munidopsidae	20
1126 Munidopsis sp	28
1144 Galacantha sp	20
Nephropidae	2
1300 Homarus gammarus	1
443 Nephrops norvegicus	1
Paguridae	76
205 Paguridae	76
Pandalidae	4
57 Pandalus borealis	4
Polybiidae	
235 Bathynectes sp	27
(unclassified)	120
1077 Caridea (indet)	83
1121 Majoidea sp	7
543 Decapoda sp 3	3
Isopoda	16
Munnopsidae	16
1102 Munnopsidae	15
152 Munnopsurus giganteus	1
Mysida	11
(unclassified)	11
1026 Mysida (indet)	11
(unclassified)	38
(unclassified)	38
1106 Eucarida sp	19
1138 Eucaridea sp (redDeep)	19
Pycnogonida	59
Pantopoda	59
Colossendeidae	59
1059 Colossendeis sp 1	56
1201 Colossendeis sp 2	3
Brachiopoda	10
(unclassified)	10
(unclassified)	10
(unclassified)	10
34 Brachiopoda sp 1	10
Bryozoa	19
Gymnolaemata	19
Cheilostomatida	19
Phidoloporidae	19
204 Reteporella	19

OTU or Taxon	Number of occurrences
Chordata	1553
Actinopterygii	1280
Chondrichthyes	18
Rajiformes	15
Rajidae	15
1067 Leucoraja sp	15
Squaliformes	3
Oxynotidae	3
9984 Oxynotus paradoxus	3
Anguilliformes	114
Congridae	3
1100 Conger conger	3
Synaphobranchidae	111
440 Synaphobranchus kaupii	111
Argentiniformes	6
Argentinidae	6
1188 Argentinidae sp1	6
Aulopiformes	30
Bathysauridae	4
1112 Bathysaurus ferox	4
Ipnopidae	26
1078 Ipnopidae sp	26
Beryciformes	40
Berycidae	9
1025 Beryx decadactylus	9
Trachichthyidae	31
651 Hoplostethus atlantica	31
Gadiformes	591
Gadidae	24
1019 Merlangius melangus	16
1302 Pollachius pollachius	4
1316 Gadus morhua	1
439 Micromesistius poutassou	2
9983 Pollachius virens	1
Lotidae	62
1175 Molva macrophthalma	1
174 Gaidropsarus argentatus	3
245 Molva dypterygia	4
258 Brosme brosme	22
654 Molva molva	32
9985 Lotidae	1
Macrouridae	286
1003 Nezumia aequalis	36
1105 Coryphaenoides armatus	16
1172 Macrouridae sp (cf Coelorhinchus)	23

OTU or Taxon	Number of occurrences
303 Coelorhinchus coelorhinchus	17
446 Trachyrincus sp	48
566 Coryphaenoides rupestris	72
577 Coryphaenoides guentheri	71
593 Coelorinchus labiatus	3
Moridae	176
1160 Lepidion cf guentheri	27
1166 Guttigadus latifrons	15
1301 Antimora sp	5
249 Lepidion eques	75
349 Mora moro	54
Phycidae	42
1020 Phycis blennoides	42
(unclassified)	1
1014 Gadiformes sp 1	1
Lophiiformes	28
Chaunacidae	1
9991 Chaunax pictus	1
Lophiidae	28
273 Lophius piscatorius	28
Notacanthiformes	149
Halosauridae	21
1113 Halosauridae sp	21
Notacanthidae	93
1009 Notacanthidae sp 1	18
552 Polyacanthonotus rissoanus	75
(unclassified)	35
1012 Notacanthiformes sp 1	31
1034 Notacanthiformes (indet)	4
Ophidiiformes	21
Bythitidae	21
1111 Cataetyx laticeps	21
Osmeriformes	29
(unclassified)	29
1074 cf Rouleina attrita	29
Perciformes	83
Epigonidae	13
1018 Epigonus telescopus	13
Trichiuridae	29
1016 Trichiurus lepturus	7
1097 Aphanopus carbo	9
1303 Trichiuridae	13
Zoarcidae	41
259 Zoarcidae sp 1	23
291 Zoarcidae sp 2	18

OTU or Taxon	Number of occurrences
Pleuronectiformes	5
Scophthalmidae	5
441 Lepidorhombus boscii	5
Scorpaeniformes	59
Psychrolutidae	11
128 Cottunculus microps	11
Sebastidae	47
1216 Trachyscorpia cristulata	10
227 Helicolenus dactylopterus	37
Triglidae	1
1312 Chelidonichthys cuculus	1
Zeiformes	40
Oreosomatidae	40
563 Neocyttus helgae	40
(unclassified)	85
(unclassified)	85
1006 Actinopterygii sp 4	17
930 Actinopterygii sp 3	68
Ascidiacea	49
(unclassified)	49
(unclassified)	49
20 Ascidiacea sp 2	37
591 Ascidiacea sp (clear)	11
8 Ascidiacea (yellow)	1
Elasmobranchii	125
Carcharhiniformes	49
Pentanchidae	45
1005 Galeus melastomus	26
1082 Apristurus profundorum	2
1131 Apristurus sp (indet)	6
1305 Galeus sp	9
568 Apristurus cf microps	2
Pseudotriakidae	3
1071 Pseudotriakidae microdon	3
Scyliorhinidae	1
1304 Scyliorhinus canicula	1
Hexanchiformes	1
Hexanchidae	1
1306 Hexanchus griseus	1
Rajiformes	30
Rajidae	3
382 Rajidae sp 2	3
(unclassified)	27
1159 Rajiformes (indet)	7
652 Rajiformes sp 1 (Neoraja caerulea?)	20

OTU or Taxon	Number of occurrences
Squaliformes	45
Centrophoridae	20
1048 Centrophorus squamosus	16
1139 Deania calcea	4
(unclassified)	25
569 Squaliformes	25
Holocephali	95
Chimaeriformes	95
Chimaeridae	83
1024 Chimaera opalescens	23
1039 Hydrolagus cf affinis	22
265 Chimaera monstrosa	20
653 Chimaera opalescens	18
Rhinochimaeridae	12
1185 Harriotta haeckeli	2
936 Harriotta raleighana	10
Myxini	4
Myxiniformes	4
Myxinidae	4
383 Myxine glutinosa	4
Cnidaria	2517
Anthozoa	2403
Actiniaria	549
Actinernidae	45
554 Actinernus sp	45
Actiniidae	52
12 Bolocera tuediae	29
41 Actiniidae sp (sand Bolocera)	23
Actinoscyphiidae	31
1047 Actinoscyphiidae sp 1 (pink)	31
Actinostolidae	44
132 Actinostolidae sp 1	44
Edwardsiidae	1
3 Edwardsiidae sp	1
Halcampoididae	10
23 Halcampoididae sp 1	10
Hormathiidae	137
1066 Adamsia sp	39
1098 Hormathiidae sp	4
255 Phelliactis sp 1	78
499 Actinauge richardi	16
Liponematidae	8
1055 Liponema sp	8
Relicanthidae	2
1207 Relicanthus sp1	2

OTU or Taxon	Number of occurrences
(unclassified)	219
1118 Sagartiidae sp (wide oral disc)	21
109 Actiniaria sp 4	2
1099 Actiniaria sp 30	2
1120 Actiniaria sp (large Red)	13
217 Actiniaria sp 6	1
344 Actiniaria sp 10	1
4 Actiniaria sp 1	39
478 Actiniaria sp 13 (pink/ purple)	12
582 Actiniaria sp 18	28
605 Actiniaria sp 20	104
900 Actiniaria sp 21	2
907 Actiniaria sp 24	6
976 Actiniaria sp 27	7
980 Actiniaria sp 28	2
Alcyonacea	527
Acanthogorgiidae	29
331 Acanthogorgia sp	4
544 Acanthogorgia granulata	1
608 Acanthogorgia cf armata	24
Alcyoniidae	103
1080 Pseudoanthomastus sp	15
140 cf. Drifa Alcyonacea sp 2	4
278 Anthomastus grandiflorus	84
Anthothelidae	30
311 Anthothela grandiflora	30
Chrysogorgiidae	78
1200 cf Chrysogorgiidae	2
1008 Chrysogorgiidae sp 1	48
1044 Radicipes cf gracilis	18
994 Metallogorgia, Iridogorgia or Cirripathes	9
9997 Iridogorgia	3
Coralliidae	5
1202 Corallium sp 1	3
1203 Corallium sp 2	2
Isididae	172
1037 Isididae sp (white sparse branching)	1
1064 Isididae sp (fine branching)	16
1157 Keratoisis sp (fine branching)	12
557 Lepidisis sp	30
578 Keratoisis sp 2	14
585 Acanella arbuscula	68

OTU or Taxon	Number of occurrences
649 Eknomisis sp	21
991 Acanella arbuscula (firtree)	10
Nephtheidae	7
1022 Gersemia sp 3	7
Paragorgiidae	21
1065 Paragorgia (twiggy) (poss Swiftia)	21
Plexauridae	66
1050 Paramuricea sp	57
1165 Plexauridae sp (rigidFan)	1
1192 Plexauridae sp (deep)	2
661 Swiftia	6
Primnoidae	14
1193 Primnoidae sp (unbranching)	4
280 Callogorgia verticillata	10
(unclassified)	2
343 Alcyonacea sp 3	2
Antipatharia	325
Antipathidae	59
1187 Antipathes dichotoma	11
283 Stichopathes cf gravieri	18
560 Stichopathes sp	30
Aphanipathidae	10
1081 Phanopathes sp	3
330 Phanopathes sp	7
Cladopathidae	16
540 Chrysopathes sp Trissopathes sp	16
Leiopathidae	45
305 Leiopathes sp	40
612 Leiopathes sp (dense)	5
Myriopathidae	3
320 Antipathella sp	3
Schizopathidae	184
1015 Dendrobathypathes (prev Stauropathes sp 1)	13
1042 Parantipathes sp	35
1043 Telopathes sp	7
1161 Parantipathes sp (branched)	9
1181 Telopathes sp 2 (red)	8
1208 Stauropathes sp 2	4
284 Bathypathes sp (brown)	37
328 Bathypathes sp 1	27
547 Stauropathes arctica	41
561 Bathypathes sp 2	3
(unclassified)	8

OTU or Taxon	Number of occurrences
592 Antipatharia sp 4 cf Stauropathes	8
Corallimorpharia	28
Corallimorphidae	28
39 Corallimorphidae sp 1	15
43 Corallimorphidae sp 2	13
Gorgonacea	40
(unclassified)	40
1070 Gorgonacea sp (pink, SolenoAssoc) (Jasonisis)	17
307 Gorgonacea sp 7 (pink) cf Isidella	23
Pennatulacea	281
Anthoptilidae	30
1107 Anthoptilum sp	18
594 Anthoptilum grandiflorum	12
Halipteridae	21
622 Halipteris cf finmarchica	21
Kophobelemnidae	22
442 Kophobelemnon stelliferum	22
Pennatulidae	63
1046 Pennatula aculeata	38
1083 Pennatula cf inflata	17
1183 Pennatula inflata	8
Protoptilidae	22
1108 Distichoptilum gracile	18
434 Protoptilum sp	4
Umbellulidae	61
581 Umbellula sp	61
Virgulariidae	2
385 Virgularia mirabilis	2
(unclassified)	60
1060 cf Halipteris sp	10
1114 Pennatulacea (indet)	22
1191 Pennatulacea sp 3 (submergedAxis)	22
1196 Pennatulacea sp 6	5
486 cf Pennatula phosphorea (deep)	1
Primnoidae	6
(unclassified)	6
1086 cf Thouarella sp	6
Scleractinia	281
Caryophylliidae	199
250 Lophelia pertusa	42
335 Desmophyllum cf dianthus	16

OTU or Taxon	Number of occurrences
584 Caryophyllia sp 5 (bullseye)	33
6 Caryophyllia sp 2	81
700 Solenosmilia variabilis	27
Dendrophylliidae	1
1093 Enallopsammia sp (?)	1
Flabellidae	52
1056 Flabellum sp	52
Oculinidae	26
251 Madrepora oculata	26
(unclassified)	3
9974 yellow coral	1
1130 Scleractinia sp (mud Butterfly)	3
Spirularia	46
Cerianthidae	46
458 Pachycerianthus multiplicatus	46
Zoantharia	50
Epizoanthidae	30
317 Epizoanthus sp 1 (Paguridae Associated)	30
Zoanthidae	17
1217 Zoanthidae	1
122 Zoanthidae sp 1	1
586 Zoanthidae sp 2	15
(unclassified)	3
293 Zoantharia sp 6 (=Hexacorallia)	3
Zoanthidea	21
(unclassified)	21
1149 Zoanthidea sp	20
925 Zoanthidea sp 3 (HyalonemaAssoc)	1
(unclassified)	226
(unclassified)	226
1028 Unknown anthozoa (yellow)	4
1057 Caryophyllidae sp (tentative)	3
1058 Caryophyllidae/Fabellidae (indet)	20
1069 Ceriantharia sp (giant)	13
1133 Anthozoa white branching	1
1215 Unknown anthozoa (red)	1
2 Cerianthidae sp 1	118
289 cf Clavulariidae sp	25

OTU or Taxon	Number of occurrences
400 cf Edwardsiidae/ Halcampoididae/ Haloclavidae	1
984 cf Halcampoididae sp	40
Hydrozoa	101
Anthoathecata	51
Corymorphidae	10
120 Corymorphidae sp	8
1204 Corymorpha sp 2	2
Stylasteridae	40
207 Pliobothrus sp	27
361 Stylaster sp 1	11
449 Stylaster sp 1	2
Tubulariidae	1
127 Tubularia sp 2	1
Leptothecata	1
Plumulariidae	1
1310 Nemertesia ramosa	1
Siphonophorae	16
1135 Siphonophorae sp (indet)	2
Rhodaliidae	16
1079 Rhodaliidae sp	5
950 Rhodaliidae sp	11
(unclassified)	33
(unclassified)	33
50 Hydrozoa (bushy)	7
56 Hydrozoa (flat branched)	24
903 Hydrozoa sp 3	2
Scyphozoa	13
Coronatae	1
Periphyllidae	1
1023 Periphylla periphylla	1
(unclassified)	12
(unclassified)	12
1134 Scyphozoa (indet)	12
Echinodermata	1649
Asteroidea	530
Brisingida	87
Brisingidae	87
1087 Novodinia sp	7
274 Brisingidae	80
Forcipulatida	91
Asteriidae	5
231 Asterias rubens	5
Pedicellasteridae	3
1143 Ampheraster alaminos	3
Stichasteridae	43

OTU or Taxon	Number of occurrences
198 Stichastrella rosea	43
Zoroasteridae	40
988 Zoroaster fulgens	40
Paxillosida	67
Luidiidae	2
448 Luidia	2
Pseudarchasteridae	65
433 Pseudarchaster sp 1	65
Spinulosida	42
Echinasteridae	42
1154 cf Henricia sp (deep)	25
208 Henricia sanguinolenta	17
Valvatida	147
Goniasteridae	50
1002 Goniasteridae sp	7
1184 Goniasteridae sp	1
234 Ceramaster/Peltaster/ Plinthaster sp 1	24
388 Ceramaster/Peltaster/ Plinthaster sp 2	15
542 Hippasteria phrygiana	3
Poraniidae	51
263 Porania	51
Solasteridae	46
1061 Solasteridae sp (7 arm)	4
1089 Lophaster furcifer	3
573 Solaster endeca	27
9977 Solasteridae sp (white)	9
9978 Solasteridae sp	3
Velatida	75
Myxasteridae	1
1182 cf Pythonaster sp	1
Pterasteridae	63
1110 Hymenaster cf pellucidus	10
1115 Pterasteridae sp	22
1174 cf Hymenaster (yellow)	13
299 Pterasteridae sp	15
983 Hymenaster membranaceus	3
(unclassified)	11
1068 Velatida sp 2	2
199 Velatida sp 1	9
(unclassified)	21
(unclassified)	21
1171 Asteroidea sp (pinkDeepSed)	6

OTU or Taxon	Number of occurrences
1173 Asteroidea (cf Ceramaster/Hymenaster, red/pink)	5
1186 Asteroidea cf Spinulosida	7
1189 Asteroidea sp (yellowDeep)	1
9992 Asteroidea sp	2
Crinoidea	259
Comatulida	136
Antedonidae	2
437 Leptometra celtica	2
Bathycrinidae	53
1041 Bathycrinidae sp 1	20
1045 Bathycrinidae sp 2 cf Porphyrocrinus thalassae	17
1141 Bathycrinidae sp	16
Pentametrocrinidae	38
436 Pentametrocrinus atlanticus	38
Phrynocrinidae	1
9998 Porphyrocrinus thalassae	1
Rhizocrinidae	18
1103 Democrinus sp	18
Thalassometridae	24
315 Koehlermetra porrecta	24
Hyocrinida	25
Hyocrinidae	25
1031 Anachalypsicrinus nefertiti	25
(unclassified)	98
(unclassified)	98
1072 Crinoidea sp	27
1210 Pentametrocinidae	2
131 Crinoidea sp 1	69
Echinoidea	348
Camarodonta	122
Echinidae	122
1052 Echinus sp (deep, white/pink)	13
1119 Echinidae sp (dark)	7
1129 cf Echinus (deepPinkSpine)	34
194 Echinidae sp (pink)	18
445 Echinus sp	26
559 Echinidae sp (white)	24
Cidaroida	57
Cidaridae	54
211 Cidaris cidaris	54
Histocidaridae	3

OTU or Taxon	Number of occurrences
1092 cf Histocidaris purpurata (deep)	3
Echinothurioida	81
Echinothuriidae	31
1125 Hygrosoma sp	31
Phormosomatidae	50
555 Phormosoma placenta	50
Echinothuroidea	29
Echinothuridae	29
188 Araeosoma fenestratum	29
Spatangoida	3
Spatangidae	3
537 Spatangus raschi	3
(unclassified)	56
(unclassified)	56
1094 Echinothuroidea sp	13
279 Echinoidea sp 1	14
572 Echinoidea sp 5	29
Holothuroidea	289
Dendrochirotida	39
Psolidae	39
1049 cf Psolus sp	27
252 Psolus squamatus	12
Elasipodida	138
Elpidiidae	59
1116 Elpidiidae sp	10
1122 Elpidiidae (indet)	7
1167 Peniagone sp	16
628 cf Amperima sp	26
Laetmogonidae	72
432 Benthogone sp	56
574 cf Benthogone sp (white)	16
Psychropotidae	7
1169 Psychropotes depressa	5
1170 Benthodytes sp	2
Holothuriida	39
Mesothuriidae	39
1206 Mesothuria sp	5
536 Mesothuria intestinalis	34
Persiculida	10
(unclassified)	10
1124 Benthothuria	9
1211 cf Hansenothuria sp	1
Synallactida	29
Deimatidae	5
1153 Oneirophanta mutabilis	5
Stichopodidae	24

OTU or Taxon	Number of occurrences
266 Parastichopus tremulus	24
(unclassified)	34
(unclassified)	34
1179 Holothuroidea sp (pink Deep)	29
1190 Holothuroidea sp (muddy)	3
963 Holothuroidea sp 5	2
Ophiuroidea	218
Amphilepidida	5
Ophiactidae	3
100 Ophiactis abyssicola	3
Ophiotrichidae	2
451 Ophiothrix fragilis	2
Euryalida	56
Asteronychidae	26
471 Asteronyx loveni	26
Gorgonocephalidae	15
214 Gorgonocephalus sp 1	15
(unclassified)	15
1307 Euryalida	15
Ophiacanthida	1
Ophiotomidae	1
1308 Ophiocomina nigra	1
Ophiurida	78
Ophiomusaidae	78
551 Ophiomusa lymani	78
(unclassified)	78
(unclassified)	78
1036 Ophiuroidea sp 11 (red disc)	12
1076 Ophiuroidea (indet)	37
26 Ophiuroidea sp 1	7
340 Ophiuroidea sp 7 - yellow	12
640 Ophiuroidea sp 10	6
646 Ophiuroidea sp (orangeDeep)	4
(unclassified)	5
(unclassified)	5
(unclassified)	5
216 Heliometra glacialis	1
9986 Holothuroidea sp	1
9988 Forcipulatida	3
Foraminifera	55
Monothalamea	55
(unclassified)	55
Syringamminidae	55
261 Syringammina fragilissima	55
Mollusca	229
Bivalvia	18
Limida	12
Limidae	12
1062 Acesta excavata	12
Pectinida	5
Anomiidae	5
32 Anomiidae sp 1	5
(unclassified)	1
(unclassified)	1
9973 Bivalvia sp	1
Cephalopoda	128
Octopoda	86
Enteroctopodidae	12
1194 Muusoctopus johnsonianus	12
Megaleledonidae	33
973 Graneledone verrucosa	33
Octopodidae	2
1000 octopus	1
1311 Octopus vulgaris	1
Opisthoteuthidae	17
1176 cf Grimpoteuthis sp	4
918 Opisthoteuthis extensa	13
(unclassified)	22
1180 Cirrata sp (indet)	2
659 Octopoda (indet)	20
Sepiida	7
Sepiolidae	7
1095 Sepiolidae sp	7
Teuthida	30
(unclassified)	30
1017 Teuthida sp 1	30
(unclassified)	5
(unclassified)	5
73 Cephalopoda sp	5
Gastropoda	82
Neogastropoda	30
Buccinidae	30
113 Colus sp	30
Pteropoda	1
(unclassified)	1
368 Pteropod sp1	1
Trochida	13
Margaritidae	13
277 Margarites sp 1	13
(unclassified)	38

OTU or Taxon	Number of occurrences
(unclassified)	38
621 Hypsogastropoda	38
Polyplacophora	1
(unclassified)	1
(unclassified)	1
33 Polyplacophora sp	1
Nemertina	1
(unclassified)	1
(unclassified)	1
(unclassified)	1
384 Nemertina	1
Porifera	806
Demospongiae	131
Axinellida	27
Axinellidae	27
202 cf Phakellia ventilabrum	25
403 Axinella infundibuliformis	2
Poecilosclerida	18
Mycalidae	13
171 Mycale lingua	13
(unclassified)	5
1146 Poecilosclerida sp	5
Polymastiida	27
Polymastiidae	27
1030 cf Polymastia boletiformis	19
1137 cf Polymastia penicillus	8
Suberitida	3
Stylocordylidae	3
1212 Stylocordyla borealis	3
Tetractinellida	52
Ancorinidae	5
657 Stryphnus fortis	5
Geodiidae	47
1163 Geodia sp (warty)	1
1205 Geodia atlantica	2
196 Geodia barretti	1
601 cf Geodia baretti (Porifera massive globose sp 11)	25
83 Geodia cf atlantica (Porifera massive lobose sp 6)	18
Verongiida	4
Ianthellidae	4
658 Hexadella dedritifera	4
Hexactinellida	109
Amphidiscosida	39
Hyalonematidae	18
917 Hyalonema sp 1	18
Pheronematidae	21
1084 cf Pheronema sp (Rock poss Aphorme horrida)	10
347 Pheronema carpenteri	11
Lyssacinosida	32
Euplectellidae	4
1198 Euplectella suberea	4
Rossellidae	28
1038 Asconema sp	11
1213 Caulophacus	1
650 Asconema sp (Porifera massive globose 14)	16
Sceptrulophora	37
Aphrocallistidae	27
264 Aphrocallistes beatrix	27
Farreidae	10
1142 cf Farreidae	10
(unclassified)	1
(unclassified)	1
9987 Hexactinellid (glass vase)	1
(unclassified)	566
(unclassified)	566
(unclassified)	566
1 Porifera encrusting sp 1 (white)	69
1004 Porifera lobose cf Polymastia penicillus	1
1010 Porifera lamellate sp 10	27
1029 Porifera lamellate sp X	2
105 Porifera encrusting sp 18 (cream)	7
1051 Porifera massive globose sp 15 (Soleno rubble)	9
1053 Porifera lamellate sp 13	13
1075 Porifera cylindrical sp	18
1090 Porifera massive lobose sp 32	17
1091 Porifera branching glassy	1
1101 Porifera lamellate (escarp)	3
1127 Porifera globose (spikyLoofah)	1
1128 Porifera globose (muddy)	13
1132 Porifera lamellate lobose (fleshy)	9
1145 Porifera bracket deep	1
115 Porifera boring sp 1	2
1151 Porifera lamellate (Hexactinosida)	16

OTU or Taxon	Number of occurrences
1156 Porifera lamellate (bubbles)	12
1158 Porifera massive lobose sp 21 (Hertwigia sp? Yellow)	1
1162 Porifera vase (cf Aphrocallistes)	13
1164 Porifera cylindrical sp (rough)	2
1177 Porifera lamellate (indetWhite)	1
1178 Porifera globose lobose	7
118 Porifera encrusting (black/ red)	5
124 Porifera cup sp 3	2
13 Porifera encrusting (green)	3
1309 Porifera globose sp.	1
1315 Porifera encrusting white (unknown)	2
137 Porifera massive globose sp 6	11
21 Porifera encrusting sp 9	1
281 Porifera branching-erect sp1/Antho dichotoma	1
30 Porifera encrusting sp 10 (yellow)	23
380 Porifera massive globose sp 9	11
387 Porifera massive fig sp 1	1
422 Porifera lamellate sp 7	15
52 Porifera encrusting sp 14	4
532 Porifera encrusting (blue)	6
535 Porifera cup 2	16
558 Porifera cylindrical sp	1
576 Porifera massive lobose sp 18 (cf Farrea sp)	11
58 Porifera encrusting sp 15 (yellow)	33
604 Porifera massive lobose sp 20	1
606 Porifera lamellate sp 9	20
611 Porifera massive lobose sp 21 (Hertwigia sp?)	15
616 Porifera massive lobose sp 22 (yellow cf Hertwigia sp)	6
623 Porifera lamellate sp 10 (Yellow Soleno Assoc)	13
648 Porifera massive globose sp 13	6
7 Porifera encrusting sp 2	11

OTU or Taxon	Number of occurrences
75 Porifera encrusting globose (pale)	16
800 Blue porifera encrusting	58
802 Porifera encrusting green	2
81 Porifera lamellate lobose	7
9 Porifera encrusting (orange)	3
982 Porifera massive lobose sp 30	3
9975 Stalked porifera	5
9976 Sponge yellow sprouts	1
9979 Porifera sprouts shape	1
9980 Porifera small globose	1
9981 Porifera flower	1
9982 Porifera	1
9990 Demospongiae	1
9999 Porifera cup	2
(unclassified)	26
(unclassified)	26
(unclassified)	26
(unclassified)	26
1001 Unknown sp 1	1
1007 Unknown octocoral or annelid	1
1011 Unknown annelida or porifera	1
1027 Unknown hydrozoa or annelida	4
1073 Unknown annelida or foraminifera	3
1088 Unknown Hydrozoa/ Bryozoa	2
1117 Unknown spring (small)?	7
1123 Unknown mud fluff	4
1147 Unknown black dots	1