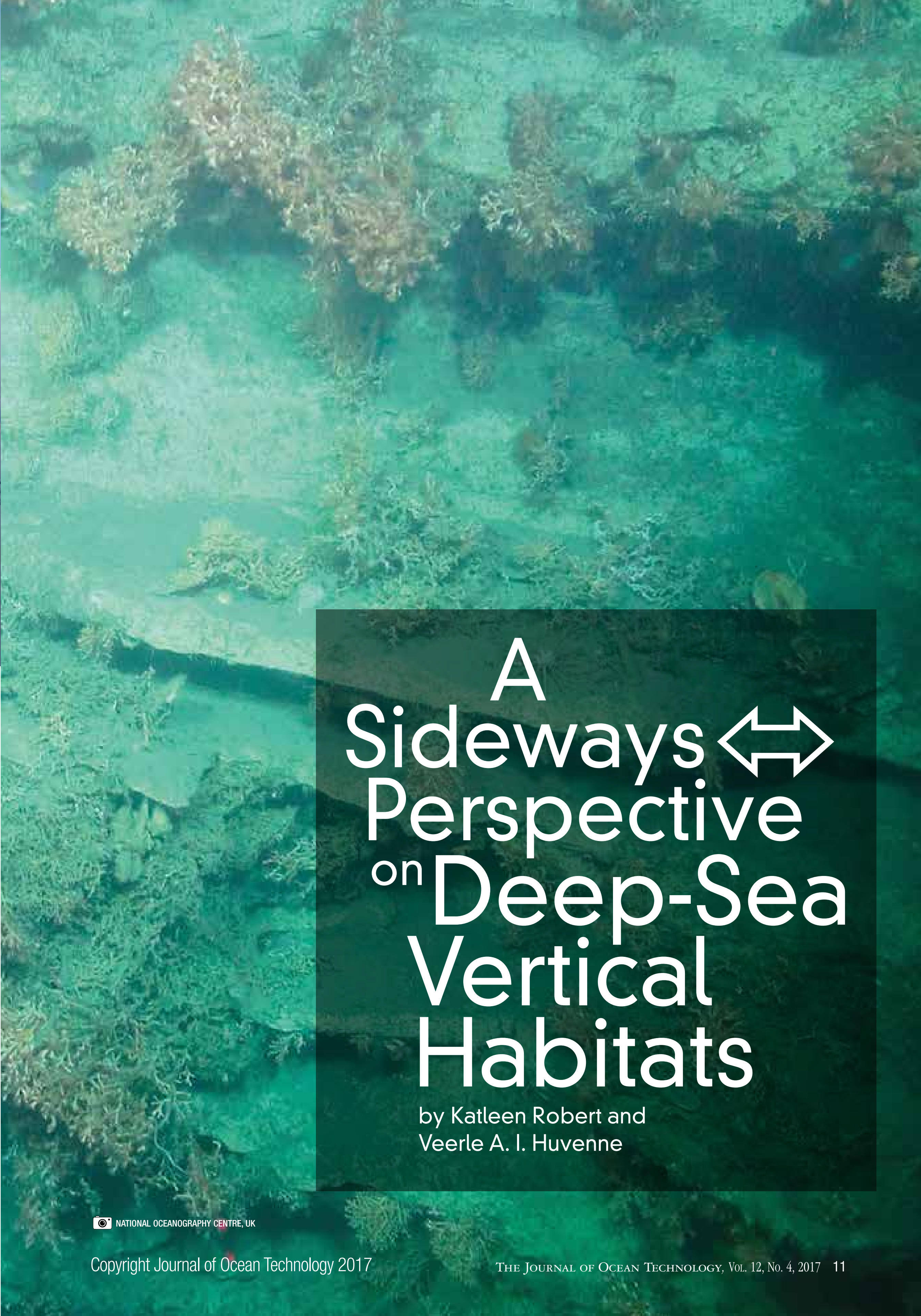

A Sideways ⇔ Perspective on Deep-Sea Vertical Habitats

by Katleen Robert and
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Our understanding of the ocean has always been influenced, and somewhat limited, by our perspective, looking down into the abyss from the surface. In terrestrial environments, the arrival of satellites greatly enhanced the amount of spatial information humanity could access, but if only this down-looking view were to be available – without us living on the actual surface – many dramatic landscapes (e.g., steep canyon walls, overhanging cliffs on mountain faces, etc.) and a good deal of understanding of how our planet works would be missed.

So far though, the seafloor has been observed and sampled using instruments launched from boats bobbing at the surface. First weighted lines, then single beam and later multibeam echo sounders have been employed on board vessels to obtain depth soundings and create seafloor maps. In the deeper areas of our oceans, these soundings remain far apart, which limits map resolution and underestimates the steepness of slopes. Dropped-down or towed-camera systems have been employed to study the biological communities inhabiting the seafloor, but their configuration is ill suited to the investigation of vertical habitats.

However, as scuba divers know, vertical and overhanging walls are often covered in organisms, often representing completely different assemblages to the surrounding area. This is because environmental factors, such as sunlight and currents, and biological ones, such as predation and competition, influence which species can thrive in any given location. For example, sunlight is required by algae, and depending on the orientation, walls may provide shade which limits algal growth and allows other organisms such as corals, bryozoans or sponges to dominate.

In the deep sea, the use of human-occupied submersibles supplied the first opportunity to carry out similar observations. Thriving communities of anemones, sponges, barnacles and bivalves were found in a Newfoundland fjord by Haedrich and Gagnon in the 1980s. However, as submersible time is highly limited and extremely expensive, such observations have thus far remained limited.

Technological Advancements

Luckily, a range of tools are now becoming available to study complex vertical habitats, and researchers working as part of CODEMAP (Complex Deep-sea Environments: Mapping habitat heterogeneity As Proxy for biodiversity, European Research Council Grant #258482) at the National Oceanography Centre in Southampton, UK, have employed both remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) to increase our understanding of these habitats by creating three dimensional detailed maps of deep-sea cliffs (Figure 1).

Instead of using echo sounders in the traditional down-looking position, multibeam systems were mounted in different configurations. In the first configuration, a multibeam system was mounted on the front of an ROV and with the ROV pilots staying at specified distance from the wall, the vehicle moved carefully sideways along deep-sea cliffs. The closer to the wall, the higher the resolutions obtained. Following data processing, coordinate rotation routines repositioned the soundings back to their correct location in space, which resulted in high resolution point clouds that were employed to characterize the geomorphology of the walls. The use of point clouds allows overhangs to be reproduced in 3D: such features would normally be lost if rasters (x-y-z grids with only one z value per x-y cell) were used instead.

Geomorphological descriptions were supplemented by high definition video observations captured while the ROV flew in very close proximity to the cliffs (less than 3 m). Using photogrammetry techniques, either involving stereo-cameras or structure-from-motion (a technique which allows for 3D reconstructions from a single camera moving

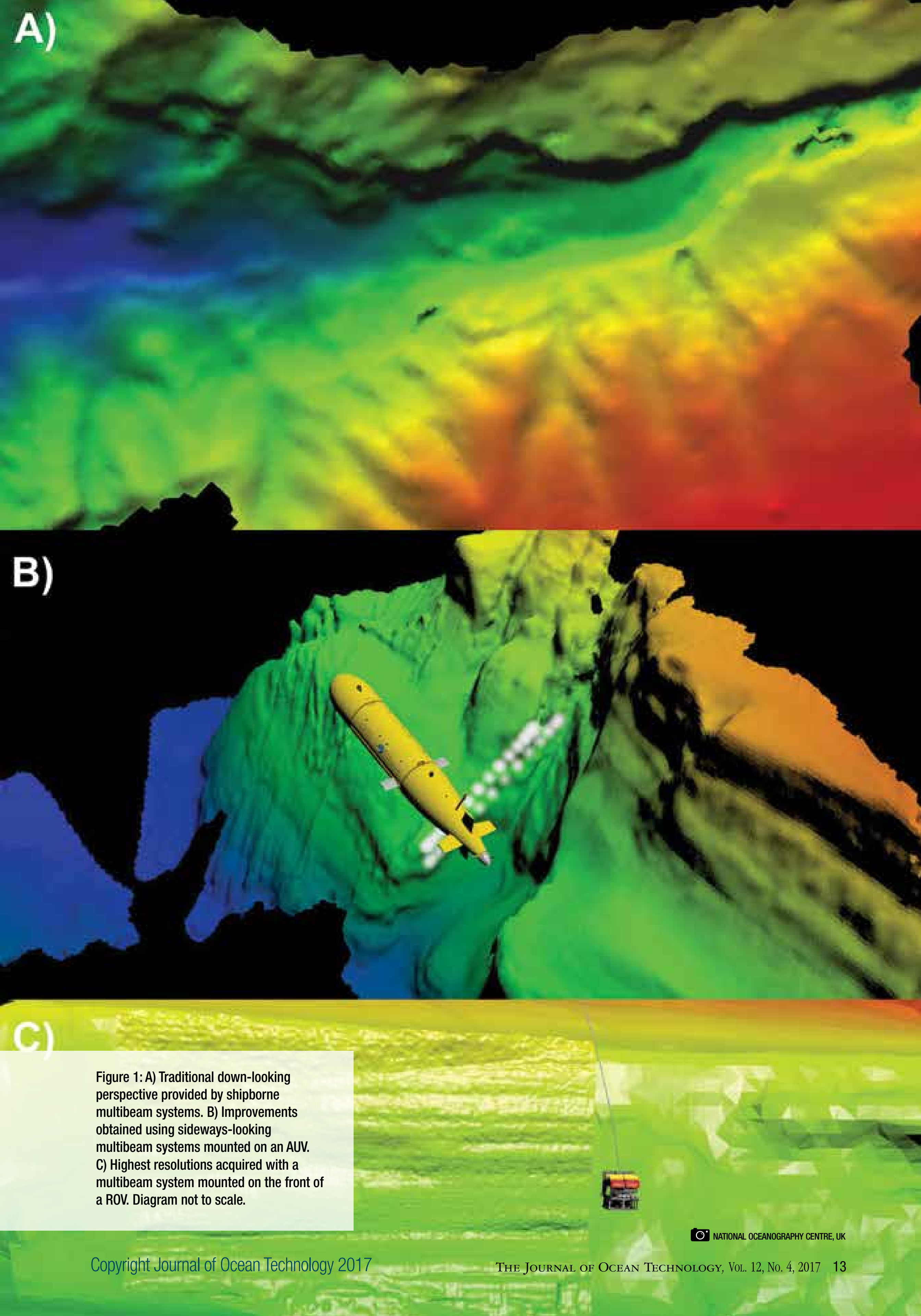

Figure 1: A) Traditional down-looking perspective provided by shipborne multibeam systems. B) Improvements obtained using sideways-looking multibeam systems mounted on an AUV. C) Highest resolutions acquired with a multibeam system mounted on the front of a ROV. Diagram not to scale.

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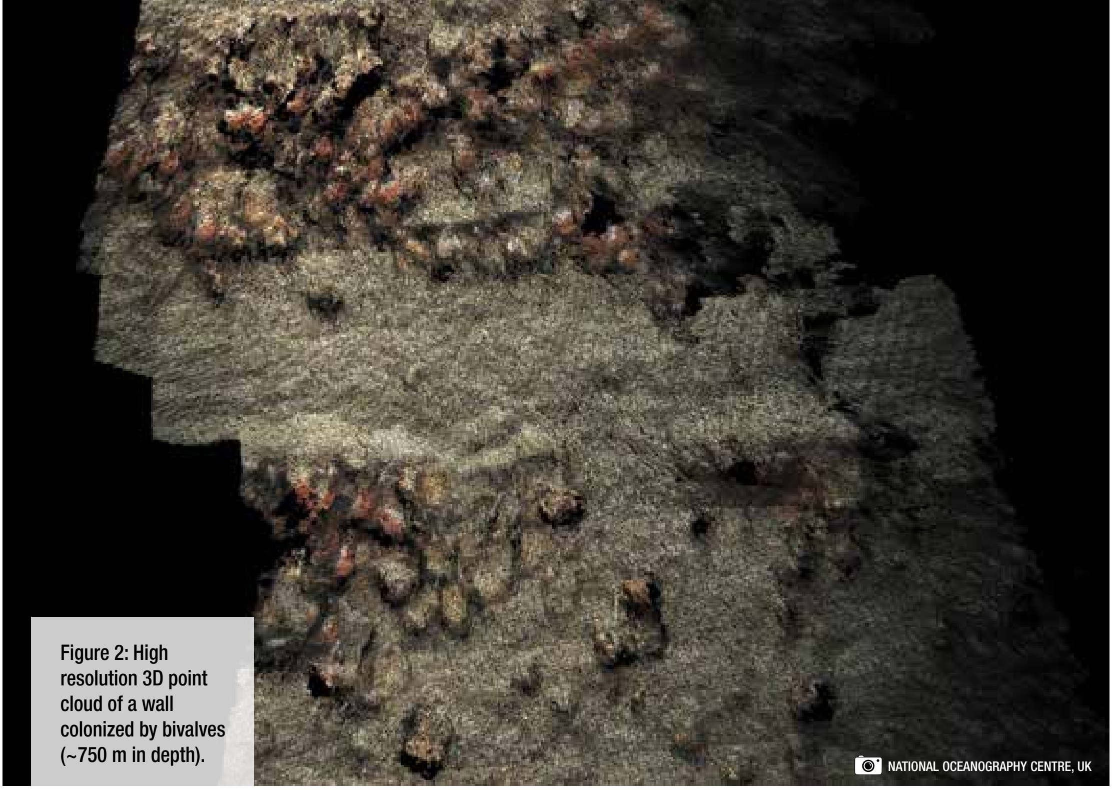

Figure 2: High resolution 3D point cloud of a wall colonized by bivalves (~750 m in depth).

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around a scene), we created further high-resolution, coloured 3D point clouds of these walls (Figure 2). Once these reconstructions are georeferenced, using the positioning system of the vehicle, and scaled, using scaling lasers present in the imagery, individual organisms can be positioned in space with a high degree of accuracy. The resolutions obtained (<1 cm) are such that if multiple repeated video surveys are available, growth of organisms can be estimated and species coverage (e.g., of cold-water corals) can be monitored.

ROVs are, however, often relatively slow moving (~0.5 knots) and can really struggle in areas of stronger current. AUVs, on the other hand, can reach much higher speeds (~3 knots) and cover larger distances. In a recent cruise on board the RRS *James Cook*, a multibeam sonar was mounted sideways on the AUV Autosub6000 to map steep sections of a submarine canyon. Although slightly lower resolutions were generally obtained as compared to the ROV mapping (0.5 m-5 m versus 0.1 m-0.5 m, as a result of the greater distance from the wall), more than 30 times the coverage could be achieved in a similar amount of time, allowing for both sides of the canyon to be mapped.

Biological Diversity

These tools allowed us to obtain high resolution maps, but to understand the ecology of vertical habitats, we had to analyze the acquired video to extract valuable biological information. Individual organisms were, whenever possible, identified and counted to obtain abundance estimates for each species. In the Northeast Atlantic, walls have been found to be colonized by both soft and hard cold-water corals, limid bivalves, deep-sea oysters and sponges. These species are arranged in different assemblages so that individual walls can be quite distinct from each other. Imagine step-like walls with hanging gardens formed by large branching orange or pink coral colonies, or shear walls with small overhangs under which grow 10-15 cm-sized clams with bright orange gills and pale pink solitary corals (Figure 3). As one zooms in, smaller organisms such as brittle stars or feather stars can be seen in the thousands, nestled among coral polyps, while small fish, octopus, crabs, shrimps and sea urchins can also be seen going about their daily business among the sessile (non-moving) fauna.

Overall, these walls are mainly colonized by filter/suspension feeders, because the steep

Figure 3: Examples of a range of communities inhabiting deep sea walls (700-2,000 m).

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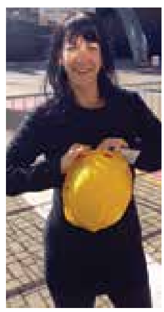
topography can lead to complex current regimes which may serve to bring down more food and keep it in suspension for longer. Other factors such as depth, wall orientation or the nature of the rock are also likely to play a role in determining the dominant species. Both depth and wall orientation are likely to affect the quantity of food which may reach these organisms from the productive upper layers while the geology of the wall may limit the size of colonies, with more fragile rock unable to give a strong foothold to large colonies of cold-water corals.

Not all deep-sea walls are an oasis of life and detailed maps are needed in order to understand the factors driving such patterns. As such, from the maps, fine-scale terrain characteristics, such as slope, aspect (direction of steepest slope) and roughness, are derived and used to identify potential drivers. For example, on certain walls with high densities of cold-water corals (~1,300 m in depth), increased biodiversity is associated with the high roughness created by those colonies. Other organisms (e.g., soft corals, basket stars, feather stars) tend to associate with the coral colonies, and grow on their skeletons, further away from the wall where the current regime is likely more beneficial to their specific requirements. On the other hand, on a deeper (~1,500 m) wall located 1,100 km to the northwest, sponges are a much more important component of the community and higher diversity is associated with the smoother portions of the wall where corals are absent.

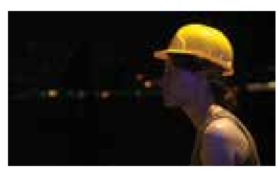
Future Perspective

We are only just beginning to understand the ecology of deep-sea vertical habitats and only a few walls have so far received any attention, but as the technology develops, such investigations will be facilitated. Advancements in deep-water navigation systems should improve the accuracy and quality of the acoustic maps as well as allow autonomous vehicles to fly closer to the cliffs, achieving even higher resolutions. Similarly, the use of hovering AUVs will permit them to be in close enough proximity to enable acquisition of good quality imagery. Having autonomous systems collect imagery will greatly increase the amount of biological information available, but without computer systems similarly able to extract species level information automatically, manual interpretation will remain a significant bottle neck, limiting the study of multiple systems.

Being able to study walls throughout our ocean is crucial to determine how such areas contribute to regional biodiversity patterns. Moreover, as these walls can provide shelter to vulnerable long-lived coral species, they may play a crucial role as sources of larvae to recolonize damaged surrounding areas. It is only through more studies aiming to understand their distribution and the connectivity patterns of the species they harbour that we will be able to gain an overview of vertical habitats in the deep sea and be in a position to inform their management.



Katleen Robert did her PhD followed by a post-doc at the National Oceanography Centre, Southampton, UK, as part of the seafloor and habitat mapping team. Her research focused on finding relationships between species distributions and environmental drivers in deep-sea habitats, particularly biodiversity hotspots in submarine canyons. After six years in the UK, Dr. Robert is now returning to her native Canada to take up a position in ocean mapping at the School of Ocean Technology, Fisheries and Marine Institute of Memorial University of Newfoundland. She will be working on improving spatial characterization of the ocean to monitor habitat changes over time.



Veerle Huvenne is head of the seafloor and habitat mapping team at the National Oceanography Centre, Southampton, UK. She was the lead investigator of the ERC funded research project CODEMAP, which aimed at developing techniques to map heterogeneity at multiple spatial scales in complex deep-sea environments. Dr. Huvenne has participated and led over 30 scientific expeditions, totalling over two years at sea. Her main scientific interests are the spatial structure of benthic ecosystems such as cold-water coral reefs, submarine canyons, seamounts and hydrothermal vents.