Exploring the Azores deep sea using a custom-made low-cost imaging tool: how much have we achieved with the Azor drift-cam?

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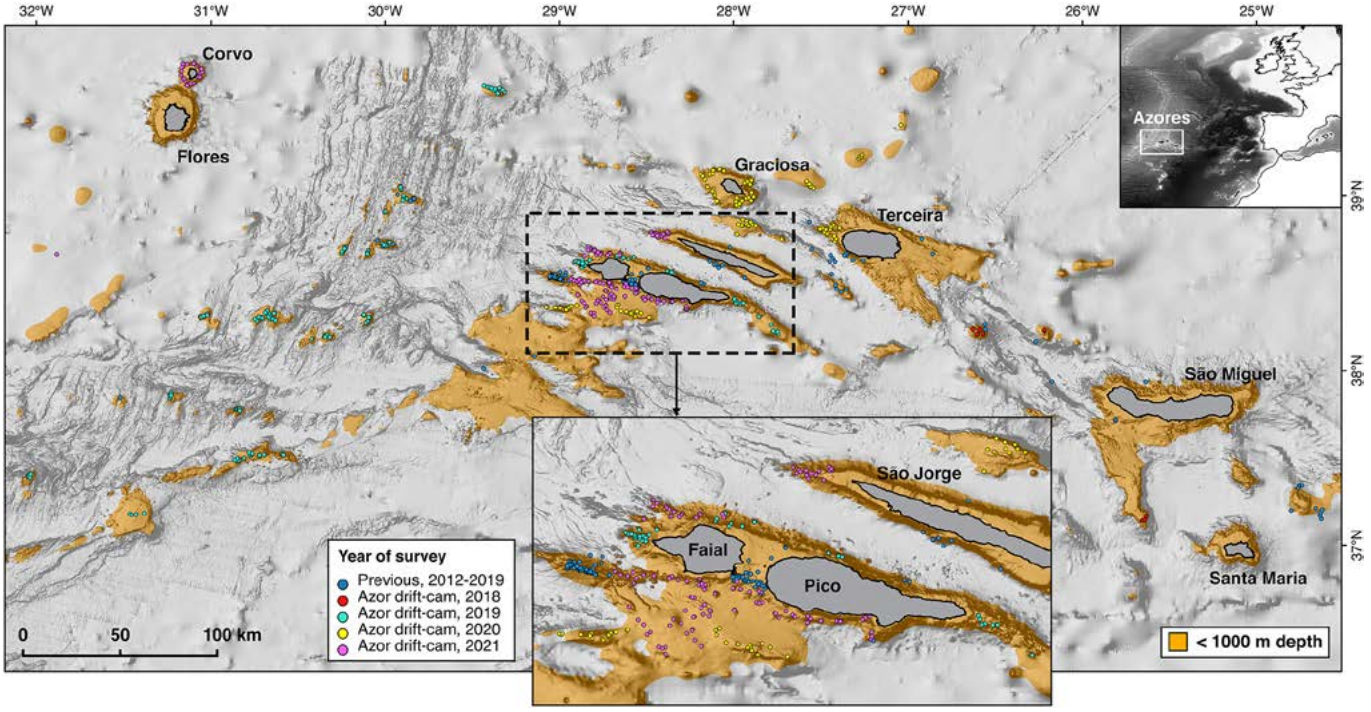
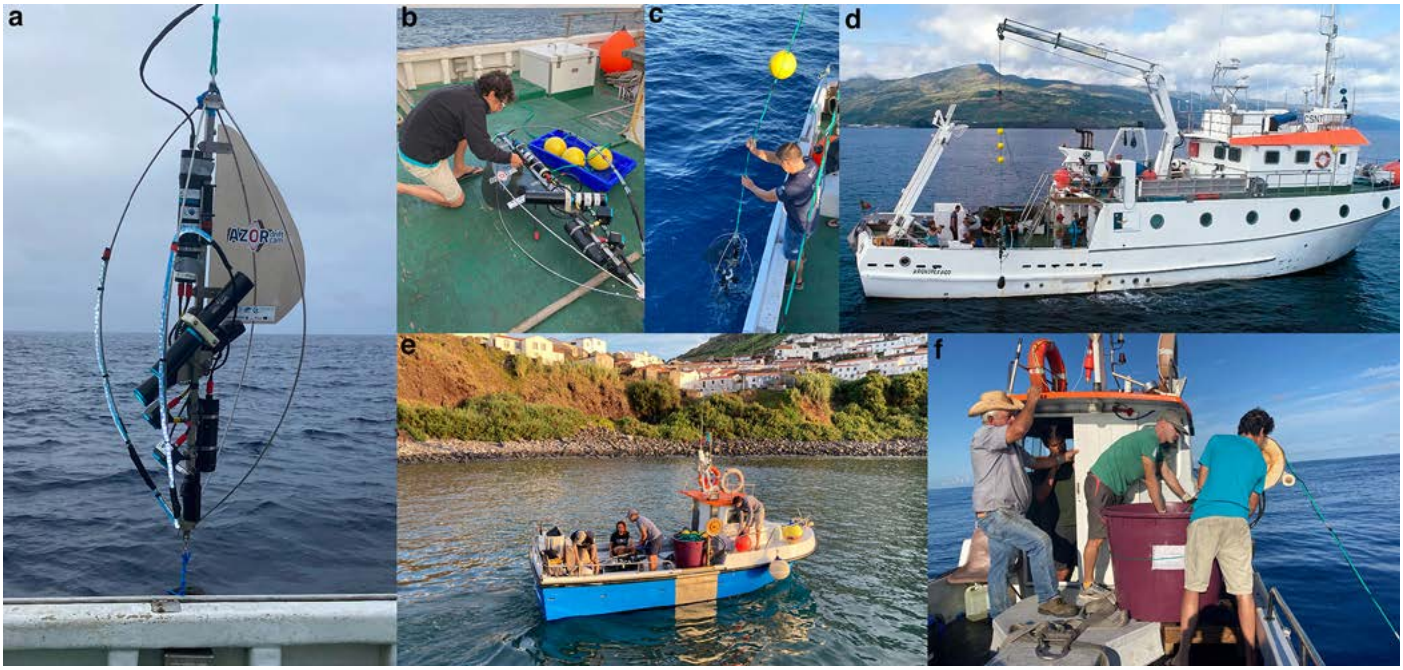
Deep-sea exploration has advanced immensely since the beginning of the 20th century, when manned submersibles started to be used to investigate the diversity of life dwelling at the bottom of the ocean. The development of marine technology has provided us with a series of underwater imaging tools that can gather high-quality images of the seabed thousands of metres below the surface. Although deep-sea imaging devices such as Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs) and towed camera systems have now become essential tools for the study of deep-sea benthic habitats, they still remain inaccessible to many research teams due to their elevated costs, and are generally associated with large oceanographic vessels and specialised crews in order to be fully operational.

The Azores Exclusive Economic Zone spans more than 1,300 km from east to west, and is home to around 130 seamounts with summits shallower than 1,000 m water depth. For years, local scientists and policy makers had limited access to underwater imaging devices, and deep-sea exploration mostly relied on international research vessels equipped with commercial ROVs visiting the archipelago. A large number of these scientific cruises focused on the study of hydrothermal vents, common features along the Mid-Atlantic Ridge. Most of our knowledge on the biological diversity of the deep sea was based on the study of organisms accidentally collected as fishing by-catch and from the few research cruises that actually targeted benthic habitats. The situation improved with the dives performed by the ROV



Above: Figure 1 - Location of the underwater dives performed with the Azor drift-cam during the summers of 2018 (first trials) throughout 2021 in the Azores region. The orange colour over the bathymetry corresponds to those areas with depths shallower than 1,000 m. The dark blue dots represent the location of the dives carried out in previous years using other underwater video devices (e.g., commercial ROVs, manned submersibles, towed cameras) from which we have information in our database.

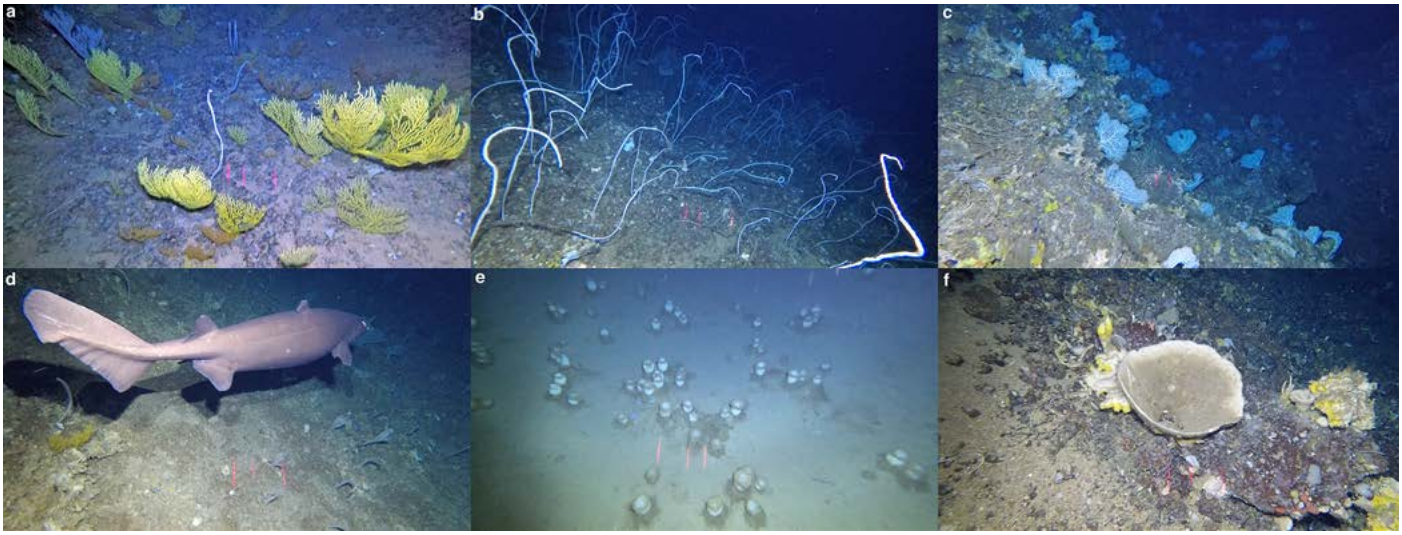


Above: Figure 2 - Images from the exploratory work done in the Azores with the Azor drift-cam over the past three years: (a) The device held with the crane of the vessel NI Arquipélago *ready to be deployed; (b-d) The team getting the system ready and deploying it over the side of the vessel to start surveying the deep sea; (e-f) Images of the survey performed on the slopes and adjacent seamounts of the island of Corvo with the Azor drift-cam deployed from a local fishing vessel.*

Luso as part of Portugal's Continental Shelf Extension Project (https://en.emepc.pt/projeto-rov-luso) and within the frame of national and international projects, such as CoralFish and the Blue Azores programme. Additionally, the Azores-based manned submersible *LULA1000* from the Rebikoff-Niggeler Foundation (https://www.rebikoff.org/) explored some slopes and seamounts around the central group of islands. Knowledge of deep-sea habitats further increased through collaborations with international institutions, such as NIOZ (Netherlands) and IEO-CSIC (Spain), with exploratory surveys using commercial ROVs and towed camera systems conducted in specific areas.

Even with all these recent efforts, the deep-sea area explored in the Azores using visual methods remained relatively small until a few years ago (blue dots in Fig. 1), and comprehensive information regarding the diversity and composition of its benthic communities was only available for a limited number of seamounts. In order to speed up deep-sea exploration in the region and better inform policymakers, in 2018 researchers at IMAR/Okeanos (University of the Azores) started to develop an affordable and easy-to-use underwater video system for a rapid appraisal of benthic habitats. A year later, following prototype testing, a low-cost video device to obtain images from the deep seafloor down to 1,000 m was completed. It was named 'Azor drift-cam', since it takes advantage of the drift of the vessel to 'fly' over the seabed. This system was developed to reflect the reality of the Azores setting, aiming to be cost-effective, cover large areas in short periods of time, perform well over rough seafloor terrain, be operational from small vessels and have high chance of escaping lost long-lines, the most common fishing gear in the region. The device is composed of off-the-shelf components, taking advantage of the powerful action cameras now available on the market. It has an oval steel structure that protects all electronic components from potential collision with rocks and from entanglement with fishing lines, reducing the likelihood of losing equipment. It has two action cameras (one of which provides a live feed to the surface), powerful LED lights, a parallel laser system for image scaling, and a temperature/depth sensor (Fig. 2a). All electronic components are battery-powered to avoid sending electricity through the cable, further decreasing the risks associated with its use. Being aware of the expensive nature of marine technology, the design and functioning of the Azor drift-cam was recently shared in an open access article in the journal *Methods in Ecology and Evolution* in order to allow other research teams interested in the field of deep-sea exploration to benefit from this technology (https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.13617).

Thanks to the Azor drift-cam, we have now collected a large amount of new video footage from across the whole Azores region. During the past three summers, almost 400 dives have been performed on several seamounts along the Mid-Atlantic Ridge (most of which never visited before) and on the seamounts and island slopes around the islands of Faial, Pico, São Jorge, Terceira, Graciosa and Corvo (Fig. 1). This sampling effort represents more than 300 hours of new deep-sea imagery, adding up to more than 200 linear kilometres of seabed. One of the key aspects of the system is that it can be operated from medium-sized research vessels, such as NI *Arquipélago* (Fig. 2b-d), as well as from small fishing boats (Fig. 2e,f). This versatility massively increases our capacity to survey areas close to shore at low operational cost, and benefits from the knowledge of local fishers that has been



Above: Figure 3 - Some examples highlighting the diversity of species and communities found in the Azores deep sea that have been recorded with the Azor drift-cam: (a,b) coral gardens characterised by the presence of large octocorals; (c) aggregation of the hydrocoral Errina dabneyi*; (d) a deep-sea shark on a coral garden; (e-f) sponge fields. More images recorded with the Azor drift-cam can be viewed at www.youtube.com/channel/UCrUCCk9866Ym8voq7ZwwZoQ.*

gathered through years of experience. Two full surveys have now been carried out on board fishing vessels, targeting the slopes and adjacent seamounts of the islands of Graciosa and Corvo. In both cases, the equipment was shipped to those islands using regular ferry lines, proving the capacity of the Azor drift-cam to be easily moved between areas when needed.

The images recorded over the past three years have provided a significant amount of new information regarding the composition and, especially, the spatial distribution of deep-sea benthic communities in the Azores. Several of the seamounts and island slopes explored so far are home to structurally complex assemblages, which include diverse cold-water coral gardens, sponge grounds and a wide variety of associated fish species (examples in Fig. 3). Some of the communities observed likely fulfill the criteria set by FAO to describe Vulnerable Marine Ecosystems due to their high structural complexity and functional significance of their main constituents, as well as their vulnerability to human activities and potentially slow recovery after disturbance. Our improved knowledge on the location of such diverse benthic communities, most of which had remained unknown until now, have increased our capacity to develop area-specific management plans that should lead to a more sustainable use of deep-sea natural resources and a better long-term conservation of the natural heritage of the Azores region.

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WANTED: Your innovation stories!

As well as being a low-cost and easy-to-use system for deep-sea exploration, the Azor drift-cam is also a perfect example of scientific innovation that iAtlantic is keen to promote. With the support of iAtlantic's recently-appointed Innovation and Exploitation Manager, Theoni Massara, we will be communicating the drift-cam's innovation potential to the greater public as well as seeking ways to facilitate exploitation discussions with industry.

However, we have a keen interest in the broader aspects of innovation too: not only do we want to hear about new technology developed in the project, but also other innovative uses of project data and imagery, novel protocol development, or forward-thinking collaborations with external partners. Innovation exists in the maps and assessments developed by iAtlantic scientists, as well as in the industrial collaborations that have facilitated iAtlantic's access to new environmental datasets of interest. We are interested to hear about your participation in platforms that maximise iAtlantic's visibility outside the marine science community, as well as development of new project proposals that build on iAtlantic research. Check out the article on p25 to read how iAtlantic has collaborated with a textile designer!

These are just a few examples of "innovation" in its broadest sense; it is important that we think outside the box to really capture all the fantastic ways that iAtlantic research finds its way into the wider world and makes an impact. If you have an innovation/exploitation story to share or would like to discuss an idea, please get in touch with iAtlantic's Innovation and Exploitation Manager, Theoni Massara (theoni.massara@ed.ac.uk).