A high-resolution study on the benthic assemblages at South Georgia by remotely operated vehicle: an *in situ* assessment of predictive habitat mapping.

Report on field trip to South Georgia, January 2017, supported by the Antarctic Science Bursary

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Project Background

In 2012 the regional waters surrounding the sub-Antarctic islands of South Georgia and South Sandwich (figure 1) were designated an IUCN category IV marine protected area (MPA), covering an area of over one million km^2 [1]. The MPA was designed to protect and conserve regional marine biodiversity whilst allowing sustainable and regulated fisheries. A 5-year MPA review cycle was established with the latest completing in 2018. As such, a detailed assessment of the benthic biogeography of the region, specifically in terms of key management priorities (i.e. the presence of vulnerable marine ecosystems (VMEs); endemic species; biodiversity hotspots) was paramount if the importance of the region's benthic habitats be reflected in the spatial planning policy for the region.

Biogeographical knowledge of marine environments through *in situ* sampling is typically spatially very patchy, and in some instances, notably the deep sea, virtually non-existent. Consequently, previous MPA designation tended to be scientifically underpinned by the data that are available, but not scientifically driven in their design. To address this limitation, in 2016, interdisciplinary datasets were used to apply an objective statistical approach to hierarchically partition and map the benthic environment around South Georgia into ecologically-relevant physical habitats [2] (Figure 2). These abiotic landscape maps were subsequently integrated with the South Georgia biodiversity dataset [3] to assess the application of physical habitat classifications as proxies for biological structuring, and as such the application of habitat mapping for informing on large-scale marine spatial planning [4].

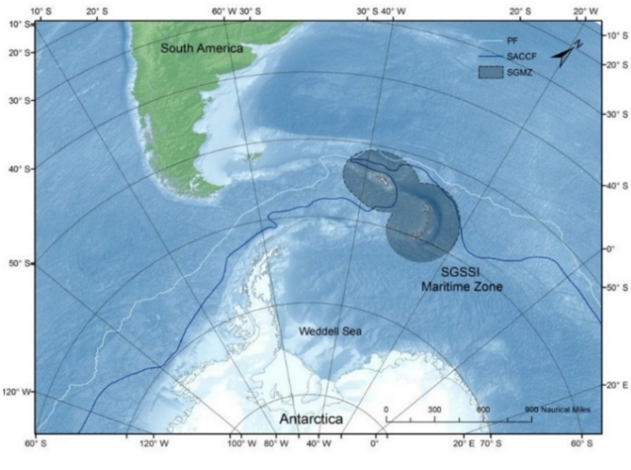

Figure 1. Position of South Georgia and South Sandwich Islands maritime zone relative to the Polar Front (white line) and the South Antarctic Circumpolar Current Front (SACC) (blue line).

Through involvement in the fieldwork campaign M134, using a remotely operated vehicle (ROV) we aimed to, (i) assess the *in situ* benthic assemblages at South Georgia and compare them with modeled faunal distribution predictions; and (ii) add the presence of methane seeps as an abiotic layer to the South Georgia landscape map and to test if the seeps have an effect of benthic assemblage distributions. In addition, the newly collected data provided an opportunity to enable a more comprehensive assessment of the marine biodiversity and habitats of the SGSSI MPA. As part of my PhD thesis this would facilitate assessment of the interaction between biodiversity data and these habitat classifications, and predictively model the presence of VMEs and species rich zones to create a map of conservation priorities for the region.

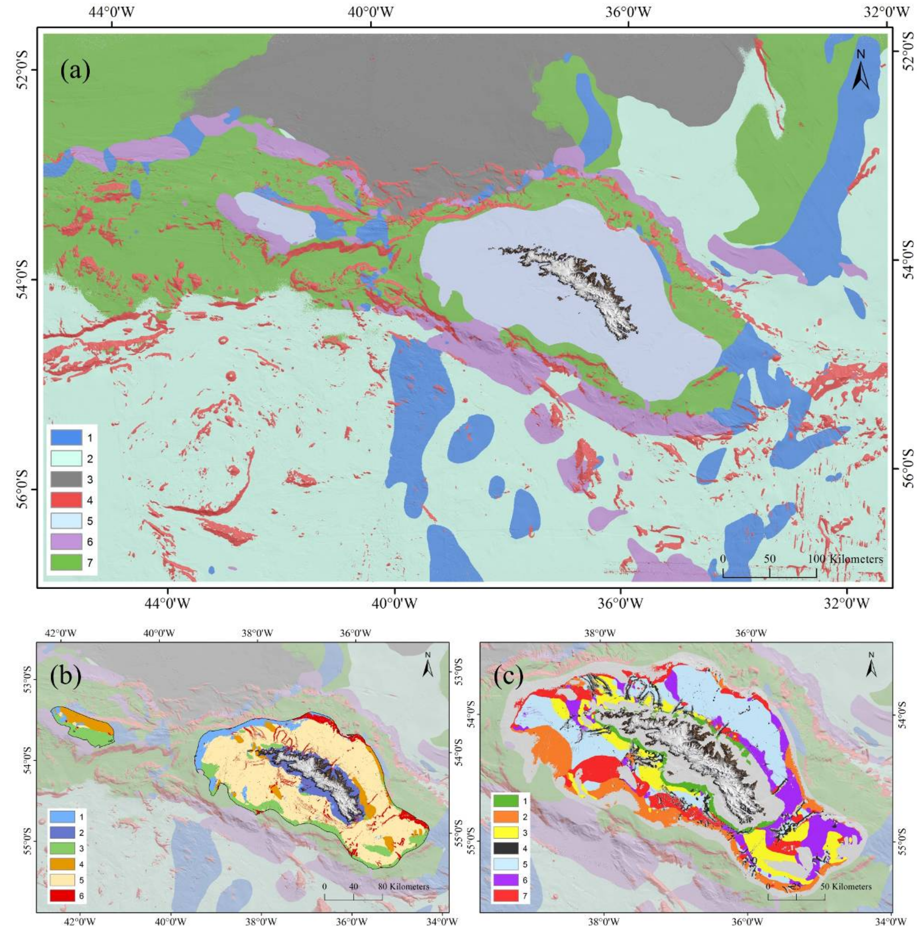

Figure 2. Nested hierarchical marine landscape maps showing (a) distribution of 7 cluster classes across the whole study region as defined by k-means cluster analysis; (b) re-clustering of cluster 5 taken from first k-mean partition (figure 2a) whereby the shelf (previously a single cluster) is now split into 6 sub-clusters; and (c) re-clustering of cluster 5 - sub-cluster 5 (figure 2b) whereby sub-cluster 5 is partitioned into 7 further third-tier clusters. Figure adapted from Hogg et al. (2016) [2].

Sampling

The primary objective of M134 was to investigate emissions of free gas from cross-shelf troughs at South Georgia. During the expedition the MARUM-SQUID ROV (figure 4) conducted 10 dives with a total of 52 hours bottom time. These dive sites were at Church Trough, Icefjord Trough, King Haakon Trough, Annenkov Trough and Cumberland Bay (Figure 3). Operation depths ranged between 230m and 800m water depth.

The start of each dive involved the detection of methane flares using sonar and camera systems. Where detected, gas samples were taken using a gas bubble sampler. At the conclusion of these deployments the remaining ROV time was then be used to address the goals of this project. The ROV was equipped with 5 cameras including a high-resolution stills camera, a pan and tilt HD video camera and two line lasers for size measurements of objects on the seafloor. These camera systems were used to characterise and record the biotic and abiotic attributes of the benthic environment. In general, this involved undertaking a direct transect from the methane sites in South Georgia's cross shelf troughs, up the trough flanks onto the shallower regions of the continental shelf. The rationale for this was to try to cover as much ground as possible to maximise the chances of observing as wide a range of predicated habitat types (As described in Hogg et al. 2016 [2]) as possible.

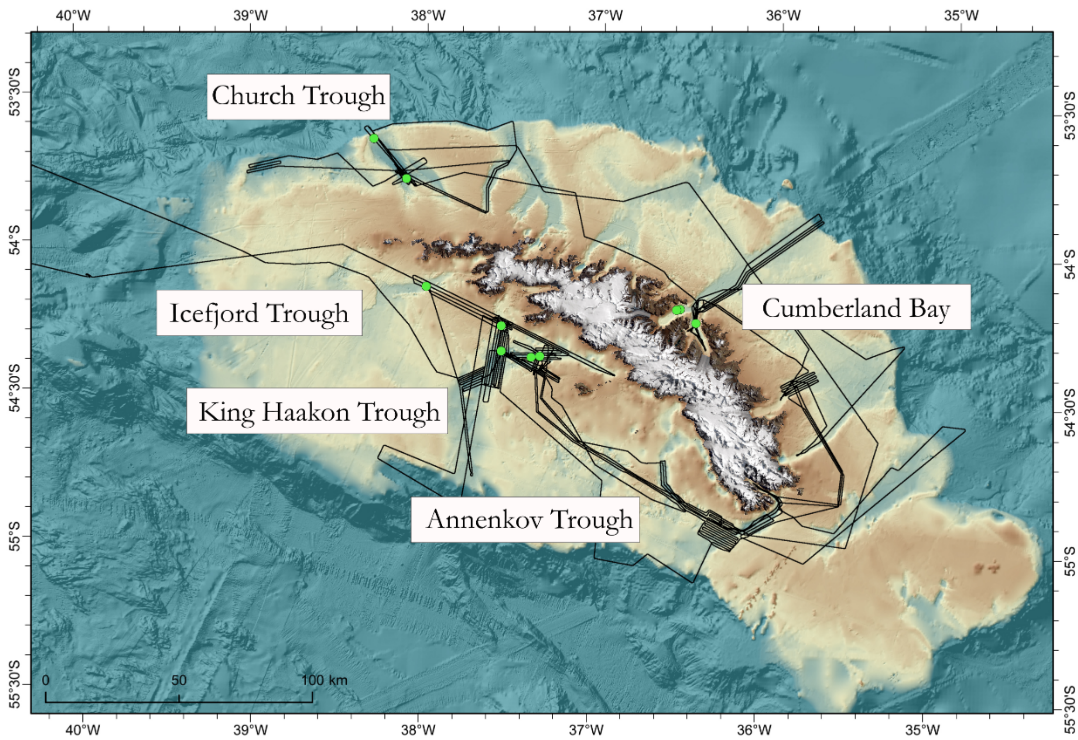

Figure 3. Cruise track around South Georgia, showing ships track (denoted in black), sampling stations (denoted in green) and cross-shelf troughs investigated during cruise M134. Figure adapted from Bohrmann et al. (2017) [5].

There were two notable limitations associated with the ROV work undertaken during M134. The ROV often malfunctioned in the cold-water environment due to hydraulic issues. This resulted in an inability to use the manipulator arm and thus often limited our ability to collect physical macrofaunal and push cores samples. A further limitation was that for most ROV dives, biological dive time was coupled to geochemistry work on methane seeps. As such dives were limited to cross shelf troughs which proved to be relatively homogenous landscape in terms of geomorphology and substrate.

Analysis

The work undertaken during M134 represents one of the first times an ROV has been deployed at South Georgia, providing an insight into benthic environments previously not seen. The data collected provides us with a better understanding of South Georgia's benthic fauna, with georeferenced data filling spatial gaps in the South Georgia biodiversity dataset. Many of the sites surveyed during M134 had never been sampled before leading to exciting discoveries of vulnerable marine habitats. One such example is the discovery of a tectonic uplift zone in Annenkov Trough to the South of the island. Here large vertical hard rock walls were discovered with complex benthic communities and covered in incredibly rich in marine life (figure 5). A full description of ROV deployments and all other aspects of the M134 can be accessed in the cruise report [5].

The data collected will now be collated with pre-existing biodiversity datasets [3]. The M134 data will be split, enabling its use as both a testing and training dataset. The testing data will be used to assess the accuracy and robustness of ecological niche models and large-scale habitat mapping models developed for the region. The training dataset can then be integrated into the models to help improve their predictive capabilities (manuscript in prep [6]). Furthermore, it is anticipated that this project will lead to future collaboration with both MARUM (research leads on M134) and the Centre for Environment, Fisheries and Aquaculture science (Cefas) to combine ROV and camera lander data for South Georgia and South Sandwich Islands to further optimise predictive models for the region.

One of the key initial findings from the work is that the ROV data has highlighted the weakness of large-scale top-down modelling approach previously applied at South Georgia [2], as significant habitat heterogeneity and corresponding beta diversity occur at finer spatial scales than realised in these models. Understanding and adapting models to account for such limitations will be the focus of future work.

Acknowledgements

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Islands and Chile. In addition, I thank Prof. Gerhard Bohrmann (MARUM) for the opportunity to participate in this multidisciplinary research cruise.

Figure 4. Deployment of SQUID remotely operated vehicle during cruise M134.

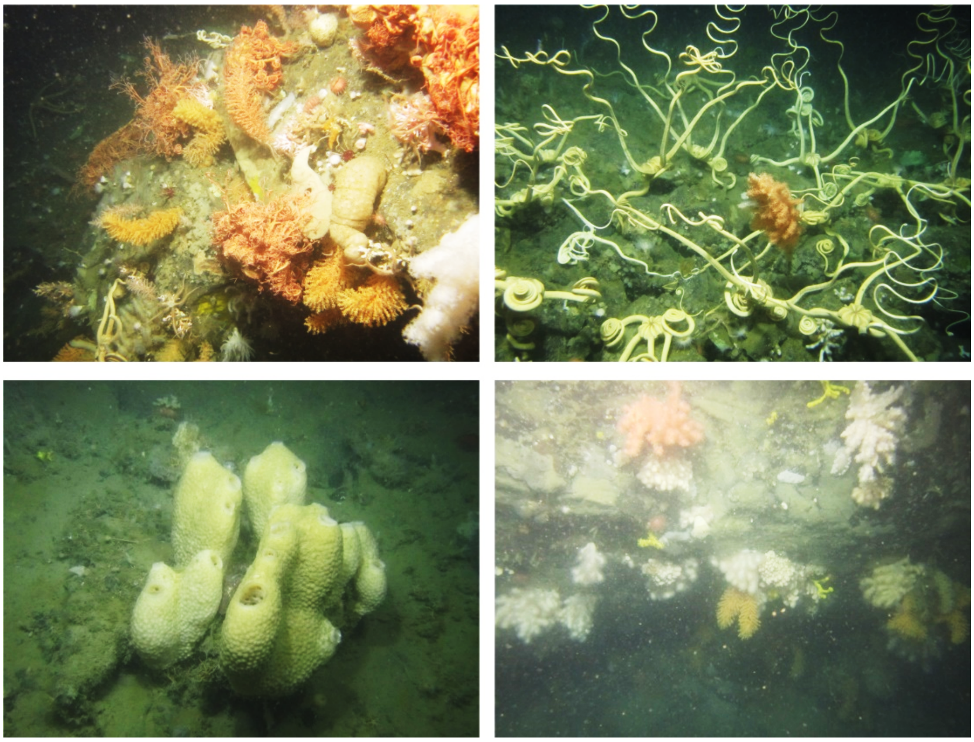

Figure 5. Hard rock vertical wall of Haakon Trough showing, Top left: dense aggregations of benthic invertebrates, including but not limited to, basket stars (Astrotoma agassizii and Gorgonocephalus chilensis), fan shaped gorgonian soft corals (Briareopsis aegeon), bottle brush octocorals (Primnoidea), Sterechinus urchin, hydrocorals, Sea anemones, brittlestar, pencil urchin, nudibranch, stony cup corals (Scleractinia), bryozoans (encrusting and fleshy growth forms), ascidians and hydrozoans. Top Right: Dense aggregations of Astrotoma basket stars on the shelf on top of the wall. Bottom left: Demosponge (possibly of the family Hymedesmiidae) at the base of the wall. Bottom Right: High benthic richness often recorded on the lip and underside of overhangs on the wall, here manifest in a high diversity of fleshy soft corals, bottlebrush octocorals, gorgonians, bryozoans and anemones. All images curtesy of MARUM.

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