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Title **DETECTION OF VULNERABLE MARINE ECOSYSTEMS IN THE SOUTHERN SCOTIA ARC (CCAMLR SUBAREAS 48.1 AND 48.2) THROUGH RESEARCH BOTTOM TRAWL SAMPLING AND UNDERWATER IMAGERY**

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ABSTRACT

High densities of vulnerable marine ecosystem (VME) indicator taxa were encountered in 17 areas off the northern Antarctic Peninsula and 11 areas off the South Orkney Islands (CCAMLR Subareas 48.1 and 48.2). These areas, which have been proposed for inclusion in the CCAMLR VME registry, were detected during the 2006 and 2009 U.S. Antarctic Marine Living Resources Program surveys. The VMEs were detected in most cases utilizing occurrence and abundance of VME indicator taxa in research bottom trawl samples, as well as by way of *in situ* observations with an underwater photographic/video imaging system. Using standardized densities of VME taxa from bottom trawl samples, we propose one possible trigger level that could be used to provide a basis for notification of a VME, based on CCAMLR Scientific Committee deliberations and current CCAMLR Conservation Measures. We further present a breakdown of 'heavy' vs. 'light' VME indicator taxa with consequences on the proposed trigger, as well as the rationale for potential additional VMEs in Subarea 48.2 (not notified), based on rarity of taxa and/or uniqueness of community.

SUMMARY OF FINDINGS AS RELATED TO NOMINATED AGENDA ITEMS

Agenda Item	*Findings*
5.1	The rationale for the 28 VMEs notified to CCAMLR in Subareas 48.1 and 48.2, based on occurrence in research trawl catches and direct underwater imagery, is described. A VME indicator taxa density threshold of 10kg/1200 m^2 is proposed as a possible trigger for notification of VMEs using ANNEX 22-06/B by scientific bottom trawl surveys. For notifications based on occurrence in trawl catches, species within the phylum Porifera and tunicates (Ascidiacea) were the primary VME indicator taxonomic groups. For notifications by way of *in situ* observations with underwater photography, scleractinians, stylastrids, bryozoa, and primnoid gorgonians were the primary VME indicator taxonomic groups.

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DETECTION OF VULNERABLE MARINE ECOSYSTEMS IN THE SOUTHERN SCOTIA ARC (CCAMLR SUBAREAS 48.1 AND 48.2) THROUGH RESEARCH BOTTOM TRAWL SAMPLING AND UNDERWATER IMAGERY

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Abstract

High densities of vulnerable marine ecosystem (VME) indicator taxa were encountered in 17 areas off the northern Antarctic Peninsula and 11 areas off the South Orkney Islands (CCAMLR Subareas 48.1 and 48.2). These areas, which have been proposed for inclusion in the CCAMLR VME registry, were detected during the 2006 and 2009 U.S. Antarctic Marine Living Resources Program surveys. The VMEs were detected in most cases utilizing occurrence and abundance of VME indicator taxa in research bottom trawl samples, as well as by way of *in situ* observations with an underwater photographic/video imaging system. Using standardized densities of VME taxa from bottom trawl samples, we propose one possible trigger level that could be used to provide a basis for notification of a VME, based on CCAMLR Scientific Committee deliberations and current CCAMLR Conservation Measures. We further present a breakdown of 'heavy' vs. 'light' VME indicator taxa with consequences on the proposed trigger, as well as the rationale for potential additional VMEs in Subarea 48.2 (not notified), based on rarity of taxa and/or uniqueness of community.

Introduction

Identification of Vulnerable Marine Ecosystem (VME) risk areas in the Southern Ocean is of escalating importance to the management of bottom fishing activities in the CCAMLR Convention area. This was brought about largely by the requirements of United Nations General Assembly (UNGA) Sustainable Fisheries Resolution (61/105) aimed at avoiding significant adverse impacts of bottom fishing activities on VMEs in high seas areas, which led to the adoption by the CCAMLR Commission of Conservation Measure 22-06 (Bottom Fishing in the Convention Area) and CM 22-07 (Interim measure for bottom fishing activities subject to CM 22-06 encountering potential VMEs in the Convention Area). When the CCAMLR Commission revised Conservation Measure 22-06 (2008), a Notification of Encounter of Vulnerable Marine Ecosystems was included (Annex 22-06/B) as part of the Conservation Measure. This notification is required to be completed when evidence of VMEs are encountered and not otherwise reported under CM 22-07.

The Annex 22-06/B notification allows for VMEs to be reported when encountered through fishery independent research activities. Encounters can be reported via several methods, including *in-situ* photographic observation, and presence of VME-associated organisms in the

catch. The notification requires that the habitat-forming organisms and other VME indicator taxa or habitat feature be provided for each VME that is notified. Fishery-independent Antarctic research surveys provide powerful platforms with great potential to detect and report encounters of VMEs in the CCMALR Convention Area. As notifications are reported to the CCAMLR Secretariat and included into the CCAMLR VME registry the ability of CCAMLR to manage and minimize risk to VMEs in both present and potential future fisheries in the Convention area is greatly improved.

The U.S. Antarctic Marine Living Resources (AMLR) Program has characterized benthic invertebrate catch from several fishery-independent bottom trawl research surveys throughout the Scotia Arc region, with the goal of better understanding the spatial distribution of epibenthic invertebrate megafaunal communities, as well as elucidating the factors that influence their distribution (Lockhart and Jones, 2008). Research on benthic invertebrate distribution, structure, and factors that drive these patterns has been pursued on various spatial scales in other regions of the Southern Ocean (Clarke et al. 2007, Barry et al. 2003, Gutt and Starmans 1998). However, information from these benthic research endeavors has not specifically been used to notify of the presence of Southern Ocean VME indicator communities. This changed in 2008, when the Delegation of Australia used data from the CEAMARC-CASO 2007/08 research cruise to formally notify two VME encounters in CCAMLR Division 58.4.1 (Australia, 2008) at the CCAMLR WG-EMM meeting in St. Petersburg, Russia. The notifications for both of these VMEs were based on direct underwater video observations, and endorsed by the Scientific Committee as VME encounters (SC-CAMLR-XXVII para. 4.238).

Currently, there is very little guidance on how a VME is defined quantitatively in the Southern Ocean. Although the CCAMLR Scientific Committee agreed during the 2008 meeting that the notifications tabled by Australia were VMEs with clear evidence of biodiversity-rich benthic communities (SC-CAMLR-XXVII para 4.238), the occurrence of VMEs based on indicator taxa in research trawl catches has not been formalized. Currently the only quantitative guidelines set forth by CCAMLR to indicate a VME risk area pertain to indirect evidence observed on commercial longline and pot fishing gear. In 2008, the Scientific Committee agreed that a minimum of 10 indicator units (=10 kg or 10 litres) of sessile benthic invertebrate indicator taxa on a recovered section of line would be evidence of an encounter with a possible VME (SC-CAMLR-XXVII, para 4.256). This advice was taken by the Commission and used as a basis for the VME risk area indicator taxa trigger set out in CM 22-07 (2008), which specifies 10 indicator units on a line segment, meaning a 1000-hook section of line or a 1200 m section of longline (whichever is shorter), and for pot lines a 1200 m section. An interim guide to VME indicator taxa specific to CM 22-07 is set out in the CCAMLR Classification Guide for Potentially Vulnerable Invertebrate Taxa in the Ross Sea Long-line Fishery (Parker et al., 2008), and is available from the CCAMLR Secretariat.

This paper provides details of the VME indicator taxa (as specified by Parker et al., 2008) encountered during the 2006 and 2009 U.S. AMLR bottom trawl research surveys of the Antarctic Peninsula (Subarea 48.1) and South Orkney Islands (Subareas 48.2), respectively. Building on the SC-CAMLR-XXVII deliberations and existing trigger levels set out in CM 22-07, the information on composition and density is then used to detect VMEs in these two Subareas. In addition, we provide direct evidence of VMEs using an underwater

photographic/video imaging system developed for the purpose of ground truthing benthic invertebrate catches and capturing images of VMEs. We also break down 'heavy' (Hexactinellida, Demospongiae, Actinaria, Solitary Tunicates, Colonial Tunicates) vs. 'light' (the remainder of VME taxa) indicator taxa and discuss the consequences of these on the proposed VME trigger. Finally, we consider the need to take into account rare taxa or unique community assemblages when notifying an encounter of a VME (see SC-CAMLR-XXVII para 4.255) as a rationale for potential additional VMEs in Subarea 48.2, which have yet to be formally proposed.

Methods

Bottom Trawl Sampling

Research bottom trawling was conducted in February-March 2009 (South Orkney Islands; Subarea 48.2) and 2006 (Trinity Peninsula; Antarctic Peninsula; Subarea 48.1) during two U.S. AMLR Program field seasons. For both Subareas, stations were set out according to random, depth stratified survey designs conducted primarily along the shelf regions (50-500 m). The total number of stations sampled by bottom trawl was 75 and 67 for the South Orkney Islands and Antarctic Peninsula, respectively. There were five additional hauls completed at slope depths around the South Orkney Islands (mean trawl depth range: 629-798 m) and an additional six slope hauls taken off the Antarctic Peninsula (mean trawl depth range: 623-759 m).

The sampling gear used was the "Hard Bottom Snapper Trawl" with vented V-Doors (Net Systems, Inc. Bainbridge Island, WA), a trawl designed for catching demersal finfish that also has demonstrated the capacity to sample sessile benthic invertebrates (Lockhart and Jones, 2008). The headrope transducer platform of the trawl was instrumented with a SimRad FS25 Trawl sonar system used to monitor the geometry of the mouth of the trawl as it was deployed and record contact with the bottom. For most stations, the trawl was on the bottom for 30 min. The area of seabed sampled during the haul was determined by the latitude longitude coordinates taken with GPS from the start to the end of the trawl's bottom contact, and the average of the trawl mouth width recorded while on the bottom.

Once the trawl catch was secured on deck it was shoveled into fish baskets and moved to the sorting tables. For catches that required subsampling the fish were separated on the back deck and for those that did not the fish were usually separated from the benthos on the sorting tables. At a few locations the biomass of the hauls was so great that only a portion of the invertebrate component could feasibly be put into baskets for weighing. In these cases up to 20 baskets of invertebrates were moved to the sorting area for weighing, while any additional baskets were counted and discarded. In this way, an average weight per basket was calculated for extrapolation. In cases where it was not feasible to sort all baskets of benthic invertebrates that made it to the sorting area, a subsample was randomly chosen (minimum 6 baskets) and the remainder weighed.

Density of megafaunal invertebrates by sampling station was standardized by prorating the VME indicator taxa (Parker et al. 2008) nominal pooled catch of the station's swept area to 1200 m^2. Calculations of total benthic invertebrate density excluded only inorganic matter, pelagics and

algae. During the 2009 survey, the benthic invertebrate catch was compositionally analyzed by sorting into 61 feasible taxonomic groupings or operational taxonomic units (OTUs), which is a significant increase in complexity and resolution over the 2006 survey (44 OTUs) in order to incorporate those taxa recently put forward by CCAMLR as taxonomic indicators of VMEs. In 2006, the members of the phylum Bryozoa were pooled. In 2009, the phylum Bryozoa was divided into 2 functional groupings: a) filamentous or foliose forms and; b) hard or reef-building forms. Likewise, Tunicata was split into: a) solitary forms and; b) colonial forms. Ascidiacea is a Class level taxon (CCAMLR Code, SSX) of the subphylum Tunicata rather than Urochordata which is no longer recognized as a distinct phylum from Chordata (World Register of Marine Species (WoRMS); www.marinespecies.org). The On-deck Classification Guide for potentially vulnerable invertebrate taxa in the Ross Sea long-line fishery (Parker et al., 2008) includes the Order Euryalinida (Phylum: Echinodermata) which, according to the WoRMS, is no longer a valid taxon; the appropriate order is Pharynophiurida. If this designated VME indicator taxon should be further refined to the Family level - that which encompasses the three species depicted on the On-deck Classification guide (Parker et al., 2008), i.e. Gorgonocephalidae, - remains to be determined.

Weights of each OTU were recorded and individuals counted where appropriate. Any dead or unsortable organic matter was also weighed and, for the latter, characterized (e.g. 60% demosponge, 30% irregular echinoid fragments, 10% organic matter). Algae were also weighed and recorded, but the data is not presented here. Incidentally caught pelagic invertebrates such as jellyfish and salps (but excluding decapods and squid) and inorganic matter were weighed only in the cases where subsampling was necessary. When excessive biomass prevented complete analysis of a haul, weighed baskets of benthos were numbered and a subset (maximum feasible) randomly chosen for characterization.

For the purpose of meso-scale comparisons of benthic invertebrate composition between stations, weights were pooled within each phylum to calculate the proportion each contributed to the total. In past field seasons, stations within the same stratum and in close vicinity were pooled and averaged for visual simplicity. However, with the current focus on VMEs, and how CCAMLR is to define and designate them, it was deemed essential to treat each station separately so that an indication of the size of various benthic ecosystem types could be gained.

Underwater Photographic/Video Imaging System

Digital imagery was obtained during the 2009 survey from both Subareas using a custom-built high resolution photographic/video imaging system on an open-frame, towed sled. The system used a Canon EOS 450D, 12.2 MP SLR with 16GB memory for still images and a Canon Vixia HF11 HD with 32 GB memory for video images. Data was transferred from the camera via an Ethernet connection and processed using a PC running Windows Vista with Remote Camera and custom control and monitoring software.

The photographic/video imaging system was deployed a total of 21 times: 17 deployments in the South Orkney Islands and four off the northern Antarctic Peninsula. The camera completed 17 hours of total bottom time; 2865 still photographs were taken, and video was recorded on 20 of

the 21 tows. The system was deployed in the close vicinity (~100m) of bottom trawl stations taken during the course of the two surveys. Transects ranged from 20 min to 1 hr.

Designation of VMEs

The occurrence of VME indicator taxa was observed in the trawl catches for almost all stations sampled for both areas (74 of the 75 stations around the South Orkney Islands and 66 of the 67 stations off the Antarctic Peninsula). However, in the majority of stations the occurrence of VME taxa was relatively small, and as such would not likely be consistent with the spirit of CCAMLR CM 22-06. To establish a level of VME taxa occurrence in the trawl catch that could be used as criteria for encounter of a VME, we draw on the guidelines as set out in CCAMLR CM 22-07. These guidelines specify that when a minimum of 10 VME indicator units (=10 kg or 10 liters of VME taxa) on a 1200 m section of line is observed, that this area be declared a VME risk area. Using this criteria and the density of VME indicator taxa observed in the trawl, standardized to a 1200 m^2 swept area, we propose expressing each trawl station in the form of VME indicator units. This would be analogous to the minimum 1200 × 1 m fishable area potentially impacted by fishing a section of longline (see SC-CAMLR-XXVII, para 4.228). We further propose that, consistent with CM 22-07, a level of 10 VME indicator units could be used as a threshold trigger level for declaring a VME, i.e. 10 kg/1200 m^2. This threshold was used as the basis for our VME declarations for those notifications based on trawl data.

With respect to declaring a VME through direct observations using the underwater photographic/video system, we considered imagery of seabeds with anomalously dense or well developed communities of VME indicator taxa to be consistent with CCAMLR CM 22-06. These areas were proposed as VMEs and photographic evidence is provided.

Results

South Orkney Islands (Subarea 48.2)

The density of standardized VME indicator taxa in the catches (for stations where taxa were present) ranged from <.01 to 63 kg/1200 m^2. Figure 1 shows the distribution of densities by station number for the South Orkney Islands. Using the above VME trigger criteria, we propose 11 of the 75 stations to be VMEs: eight based on standardized biomass ≥10 indicator units in trawl catch, three based on underwater imagery, and one based on both. The number of VME indicator units for standardized trawl catches ranged from 10 to 63. The proposed VMEs are relatively well clustered on the shelf area west of Coronation Island, and the shelf area around Laurie Island in the eastern part of the island chain (Figure 2).

The standardized density of VME indicator taxa for the proposed VMEs, based on occurrence in trawl catch, demonstrates the significance of taxa in the phylum Porifera, particularly siliceous sponges (Demospongiae) as the primary VME indicator taxa triggering the VME declaration (Table 1). This occurrence accounted for six of the nine VMEs proposed utilizing trawl data. One station was triggered by the occurrence of a high density of colonial tunicates (Ascidiacea). These two VME taxonomic groups, in addition to anemones (Actinaria) have considerably more mass and density relative to the other VME indicator taxa, and dominate the composition of

VME taxa. The composition of VME taxa, and the dominance of these 'heavy' taxa (Hexactinellida, Demospongiae, Actinaria, Solitary Tunicates, Colonial Tunicates) with respect to triggering the presence of a VME, is illustrated in Figure 3 for the western region of the South Orkney Island Shelf (compare to Figure 4A-B). Because of the compositional dominance of 'heavy' taxonomic groups and the magnitude of VME indicator unit criterion, it was deemed instructive to break down the VME indicator taxa composition by 'heavy' and 'light' (the remainder of VME taxa) groups. The composition of VME indicator taxa by 'heavy' and 'light' groupings around the South Orkney Islands is illustrated in Figures 4A-H.

The VME indicator taxa communities on the western shelf of the South Orkney Islands show some biogeographic patterning. For those 'heavy' VME indicator taxa communities at the western most sites (Figure 4A), a high dominance of anemones is shown, which are replaced by demosponges to the east. Southwest of the western tip of Coronation Island hexactinellid sponges increase in importance to the VME indicator taxa community composition. Although not as conspicuous, the 'light' VME indicator taxa communities (Figure 4B) also transition from west to east on the western South Orkney shelf; stony corals and sea pens are prominent components to the west, while traveling east bryozoans (foliose/filamentous as well as hard/reef-building species) dominate the megafauna. Southwest of the western tip of Coronation Island where hexactinellids increase in importance amongst the 'heavy' taxa, hydroids increase in importance amongst the 'light' taxa.

Although no similar pattern between the distributions of the two groupings is as striking north of the main South Orkney Islands, there are certain associations of 'light' taxa with 'heavy' taxa that are evident in the distributions (Figures 4C-D). Sea pens are prominent components where anemones have a strong influence. Bryozoans, particularly folios/filamentous species, increase in importance at the same locations that tunicates occur. To the south of Coronation Island sponges, with glass sponges varying in importance, dominate the 'heavy' communities while among the 'light' taxa communities there is quite a lot of diversity. However, hard/reef-building bryozoan species and primnoid gorgonians are outstanding. Interesting is the strong bamboo coral component at two locations north of Laurie Island.

On the South Orkney Islands' eastern shelf, hexactinellid and demosponge species dominate the 'heavy' VME indicator taxa communities to the north (Figure 4E) while the influence of tunicates and anemones to the composition increases further south. To the north, bryozoans, particularly hard/reef-building species (Figure 4F), decrease in importance the further east from Laurie Island is the station. Sea pens show themselves to be an important component of the 'light' VME indicator taxa communities on the southern portion of this eastern shelf.

The occurrence of VME indicator taxa on the southern South Orkney Island shelf (Figures 4G-H) within the trawls was well below the proposed threshold, and thus no VME were notified in this region. A broad pattern of Porifera giving way to anemones in dominance towards the outer southern shelf is evident. However, no discernable pattern can be deciphered among the 'light' VME indicator taxa communities in this region.

Direct evidence of VMEs was acquired for 4 of the 17 underwater photographic/video imaging system deployments (stations 6, 60, 63, and 82). For Station 82, the existence of a VME was

confirmed by both the imaging system and the trawl data. These station locations are set out in Figure 2. Examples of the direct imagery evidence for each of the four VMEs proposed by this method is provided (with brief community descriptions in the captions) in Figures 5A-B through 8A-B for Stations 6, 60, 63, and 82 respectively.

Antarctic Peninsula (Subarea 48.1)

The density of standardized VME indicator taxa in the catches for stations (where taxa were present) ranged from <.01 to 89.6 kg/1200 m^2. There were a considerably larger number of VMEs detected, with higher densities, around the Antarctic Peninsula compared to the South Orkney Islands. Figure 9 shows the distribution of densities by station number for all the Antarctic Peninsula stations sampled. Using the VME trigger criteria, we propose 17 of the 67 stations as VMEs: 13 based solely on density in the trawl catch, one based on underwater imagery alone, and three based on both trawl data and underwater imagery. The number of VME indicator units for standardized trawl data ranged from 10 to 90. The proposed VMEs are relatively well clustered on the more shallow regions of the lower and central Antarctic Peninsula stations. The region offshore of the Joinville Island demonstrated very little evidence of VMEs (Figure 10).

As was illustrated for the VME indicator taxa composition around the South Orkney Islands, the standardized density for the proposed VMEs, based on occurrence in trawl catch, demonstrates the significance of taxa in the phylum Porifera. While Demospongiae continued to serve as an important indicator taxa triggering VME declarations, we also observed a substantially greater biomass of glass sponges (Hexactinellida) and Ascidiacea than was observed around the South Orkney Islands (Table 2). The taxonomic resolution was not as great around the Antarctic Peninsula during the 2006 sampling efforts, with colonial and solitary tunicates pooled. Note that there were three additional trawl stations taken around the Antarctic Peninsula during the 2009 survey (all were slope sets), and thus for these three stations a greater number of VME taxa are described. Similar to the South Orkney Islands, the Hexactinellida, Demospongiae, Ascidiacea, and Actinaria, separated as ‘heavy’ VME taxonomic groups, dominated the composition of VME indicator taxa. To examine relative composition between the ‘heavy’ and ‘light’ VME taxa, we examined the contributions separately. The composition of VME indicator taxa by ‘heavy’ and ‘light’ groupings is set out in Figures 11A-F.

The southwestern portion of the Trinity Peninsula shelf sampled shows a strong community dominance of Porifera (Figure 11A). Communities of very large hexactinellid sponges encountered in this region drive the impressive Porifera component here at many locations. Among the other ‘heavy’ VME indicator taxa, anemones increase in importance at the deeper stations. Among the ‘light’ VME indicator taxa communities in this same region (Figure 11B), striking is the dominance of bryozoans and stylasterid corals at the southwestern-most stations that gives away to hydroids and a variety of gorgonian and other cnidarian groups further to the east.

In the region of the shelf north of D’Urville Island, Porifera dominates from west to east (Figure 11C), with the exception of a deeper anemone-dominated station and a cluster of stations north of the gap between the tip of the Trinity Peninsula and D’Urville Island where tunicates are the

dominant component. Broadly speaking, bryozoans dominate the 'light' VME indicator taxa communities from west to east in this region also (Fig. 11D), with greater complexity to the composition of these communities seen at either longitudinal extreme.

Demosponges, hexactinellids and tunicates compete for dominance northeast of Joinville Island (Figure 11E), except at some of the deeper stations where actinarians increase in importance. Among the 'light' VME indicator taxa communities bryozoans continue their dominance evident further west (Figure 11F) although hydroids, stony corals, a variety of gorgonians and other cnidarian taxa increase in importance towards the eastern shelf limit. In the southeast, stylasterid corals become an important component of the communities.

Direct evidence of VMEs was detected for 4 of the 4 deployments of the underwater photographic/video imaging system (stations 12, 33, 40, and 101). For Stations 12, 33, and 40, the presence of VME indicator taxa communities was confirmed by both video and occurrence in the trawl. These stations are set out in Figure 10. Imagery of the direct evidence for each of the four VMEs proposed is provided (with brief community descriptions in the captions) in Figures 12A-B through 15A-B for Stations 12, 33, 40, and 101 respectively.

Discussion and Conclusion

Our notifications of VMEs for the South Orkney Islands and Antarctic Peninsula was based on occurrence of VME indicator taxa clearly relies on both the actual occurrence of VME indicator communities in the area sampled and the selectivity of the sampling gear. Although the gear we used was not a high resolution benthic invertebrate sampling device, it was adequate in capturing a considerable number of VME indicator taxa. However, in certain cases there was insufficient evidence of indicator taxa occurrence in the trawl to trigger the 10 kg/1200 m^2 threshold rule that we have proposed, though the video transect provided ample VME evidence. This is illustrated by Stations 6, 60, and 63 for the South Orkney Islands, and 101 for the Antarctic Peninsula. In the majority of the 24 VMEs based on presence in trawl catches alone, the three 'heavy' indicator taxonomic groups (porifera, actinaria, ascidiacea) dominate the biomass, and trigger the proposed VME threshold. Removing these three indicator taxa from the analysis results in only one VME being triggered, Station 92 off the Antarctic Peninsula. With respect to the four VMEs detected by video alone, scleractinians, stylastrids, bryozoa, and primnoid gorgonians, all 'light' indicator taxa and unlikely to trigger VME presence by way of occurrence in trawls, provided the evidence of the VME. In all of these cases, the direct imagery demonstrated very high densities of these taxa.

Given the substantial difference in mass between the 'heavy' and 'light' indicator taxa, we propose that a lower threshold of the 'light' indicator taxa be considered, as these are much less likely to occur in sufficient mass in trawls or other sampling gears to trigger the presence of a VME at the current 10 indicator unit threshold. The level of threshold that would be acceptable for these taxonomic groups requires further consideration, and should be explored in terms of the likelihood of the actual presence of the VME, the resistance and resilience to disturbance by the indicator taxa communities, the sampling efficacy of the gear, and the acceptable level of risk to the VME.

Along similar lines, it would be worthwhile considering whether the presence of high densities of more rare taxonomic groups or unique community assemblages specific to the Southern Ocean warrant additional attention, and perhaps an increased level of precaution. For example, a substantial number of the VME indicator taxa, *Umbellula* sp. (Cnidaria: Pennatulacea), were collected from Station 13 (mean depth: 350 m) north of Powell Island, in the eastern South Orkney Islands (66% of the non-sponge VME taxa were anemones and *Umbellula* sp.). This station was not proposed as a VME here, as there was an insufficient mass of pooled VME indicator taxa to trigger the proposed threshold, and a video transect was not conducted here. However, this relatively large aggregation of *Umbellula* sp. would be particularly vulnerable to commercial bottom fishing activities. The large disc shaped heads (largest measured 12 cm in diameter) are attached to very long and very thin stalks (longest measured > 3.5 m long), and they are easily dislodged. It would be worthwhile to consider whether this station should also be identified as a VME.

There were also unique and potentially endemic taxonomic groups that we encountered around the South Orkney Islands not currently listed in either ANNEX 22-06/B or the CCAMLR Benthic Invertebrate Classification Guide (Parker et al., 2008) that should be considered for inclusion as VME indicator taxa. For example, we encountered vast communities of Pterobranchia, a little known phylum of worm-like colonial organisms, at the two northeastern most stations sampled on the South Orkney Island shelf (Stations 22 and 23, mean depths: 359 m and 336 m, respectively). Given the uniqueness of these communities, this taxa should be considered for inclusion as a VME indicator taxa, and these two stations should potentially be considered VMEs.

With respect to the 28 VMEs that have been notified, there is a relatively clear pattern in terms of their spatial distribution on the shelf area of both the South Orkney Islands and Antarctic Peninsula regions. In the case of the former, the VMEs are clustered on the eastern and western shelf regions (Figure 2), with the remaining shelf regions demonstrating low densities of VME indicator taxa communities. In terms of defining a VME risk area, it would be more precautionary and more easily manageable to consider the seabed areas within the VME station clusters as also potentially harboring additional VMEs, and declare these two regions as two large risk areas. With respect to the Antarctic Peninsula region, it may be more precautionary to combine the cluster of VMEs that form a long band running along the much of the shelf area of the Trinity Peninsula (Figure 10) and treat that band as one continuous VME risk area.

In conclusion, we have provided a rationale for the 28 VMEs notified to CCAMLR in Subareas 48.1 and 48.2 under Conservation Measure 22-06, based on a very simple technique using occurrence of VME indicator taxa in fishery-independent research bottom trawl catches, as well as direct underwater imagery. The VME indicator taxa density threshold of 10kg/1200 m^2 that we have proposed, and have used as the criteria for notification of VME encounters, is only one possibly metric that could employed to determine whether a seabed area should be considered for inclusion into the CCAMLR VME registry. There are undoubtedly numerous other potential methods that could, and should be considered. Given that minimizing risk to VMEs from bottom fishing activities in the CCAMLR Convention area is an emerging scientific and management issue, and Conservation Measures designed to address these issues are still in their relative

infancy, we consider this approach as one potential step in a process that will require considerably more research and deliberation.

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Table 1. Density of VME Indicator taxa for proposed VMEs based on presence in trawl samples for the South Orkney Islands (Subarea 48.2), standardized to kg/1200 m^2.

VME-IT (kg/1200m)	**South Orkney Islands Stations with VMEs**							
	3	**4**	**16**	**19**	**58**	**64**	**82**	**97**
Hexactinellida	1.126	0.009	7.315	1.400	1.765	0.052	0.091	0.002
Demospongiae	37.101	12.076	19.475	12.033	8.304	13.357	48.682	0.026
Actinaria	0.033	0.005	-	0.029	<0.001	0.109	0.016	0.022
Solitary Tunicates	0.050	0.006	0.278	0.005	0.005	0.005	0.810	0.080
Colonial Tunicates	0.441	0.221	0.266	0.004	0.022	0.007	13.350	10.933
Hydroida	0.007	0.004	-	0.004	0.058	0.009	0.040	0.009
Stylasterida	-	-	-	-	<0.001	<0.001	-	0.001
Alcyonacea	-	-	-	-	<0.001	-	-	-
Scleractinia	-	0.001	-	-	-	-	-	-
Pennatulacea	0.034	-	0.007	-	0.001	-	-	0.001
Isididae	<0.001	-	-	<0.001	-	-	-	0.006
Primnoidae	0.026	<0.001	0.004	0.005	0.005	0.008	0.003	0.009
Paragorgiidae	-	-	-	0.000	-	-	-	-
Chrysogorgiidae	-	<0.001	-	-	-	-	-	-
F/F Bryozoa	0.454	0.006	<0.001	0.003	-	0.002	0.005	0.024
H/R-F Bryozoa	0.183	0.005	0.261	0.002	0.027	0.052	0.016	0.010
Pharynophiurida	-	-	0.002	-	<0.001	-	-	-
VME-IT Total (kg/1200)	**39.5**	**12.3**	**27.6**	**13.5**	**10.2**	**13.6**	**63.0**	**11.1**

Table 2. Density of VME indicator taxa* for proposed VMEs based on presence in trawl samples for the Antarctic Peninsula (Subarea 48.1), standardized to kg/1200 m^2.

VME-IT (kg/1200m)	**Antarctic Peninsula Stations with VMEs**															
	7	**1**	**5**	**4**	**14**	**12**	**15**	**19**	**33**	**40**	**74**	**27**	**75**	**42**	**55**	**92**
Hexactinellida	24.346	2.800	6.832	2.623	13.982	50.567	7.413	18.978	14.631	0.245	0.233	0.545	1.768	2.926	0.113	23.517
Demospongiae	42.852	9.929	12.490	57.368	7.069	9.429	1.898	12.690	41.545	75.274	10.186	0.553	0.242	3.587	7.669	2.802
Actinaria	-	0.083	0.031	0.000	0.026	-	0.114	0.045	0.088	0.002	0.036	0.022	0.018	0.228	0.001	0.001
Ascidiacea	18.408	34.650	0.126	0.036	7.999	0.547	0.694	7.054	10.681	13.211	0.009	8.208	13.437	4.452	2.930	4.662
Hydroida	0.003	0.004	0.002	0.007	0.003	0.049	-	0.040	0.463	-	0.004	0.041	0.006	0.013	-	0.590
Stylasterida	-	0.011	0.062	0.044	-	-	-	0.003	0.007	0.024	<0.001	-	0.001	<0.001	0.003	0.026
Scleractinia	-	-	-	0.004	-	-	-	0.060	0.005	-	-	0.000	-	-	-	-
Cnidaria Other	-	0.033	0.017	-	0.036	0.036	0.003	0.035	0.025	0.067	0.003	0.010	0.008	0.010	0.004	0.096
Bryozoa	0.459	1.038	0.210	0.028	0.012	-	-	0.161	8.056	0.813	<0.001	0.570	0.524	0.026	0.012	28.457
VME Total	**86.1**	**48.5**	**19.8**	**60.1**	**29.1**	**60.6**	**10.1**	**39.1**	**75.5**	**89.6**	**10.5**	**9.9**	**16.0**	**11.2**	**10.7**	**60.2**

* basket stars not included.

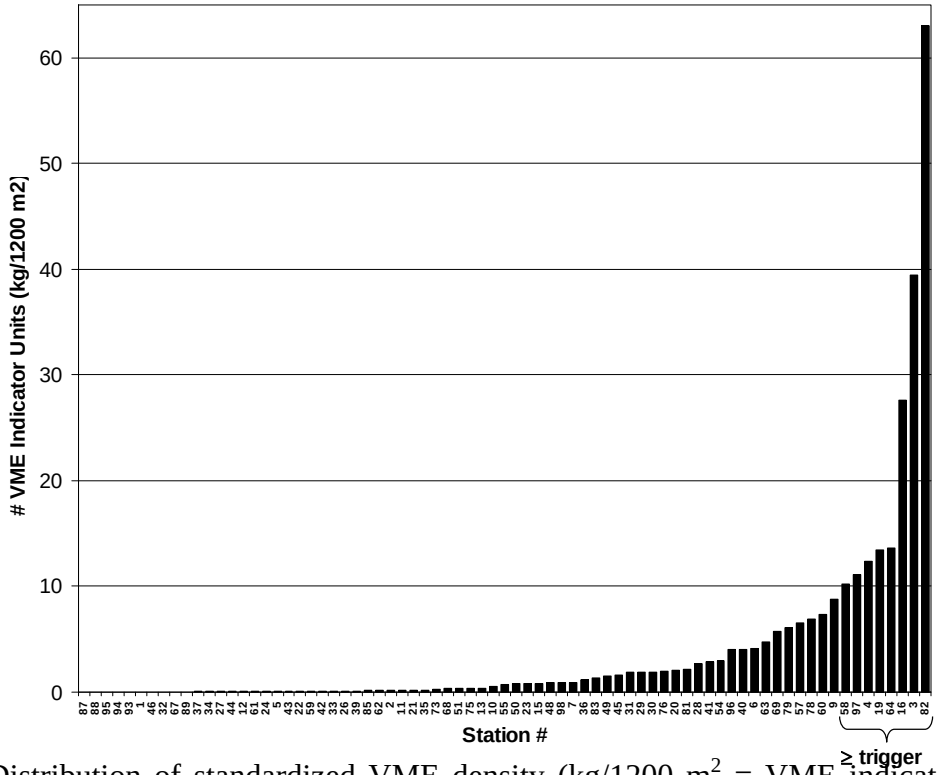

Figure 1. Distribution of standardized VME density (kg/1200 m^2 = VME indicator units) in trawl catches for the South Orkney Islands. A VME risk area is declared for ≥10 indicator units.

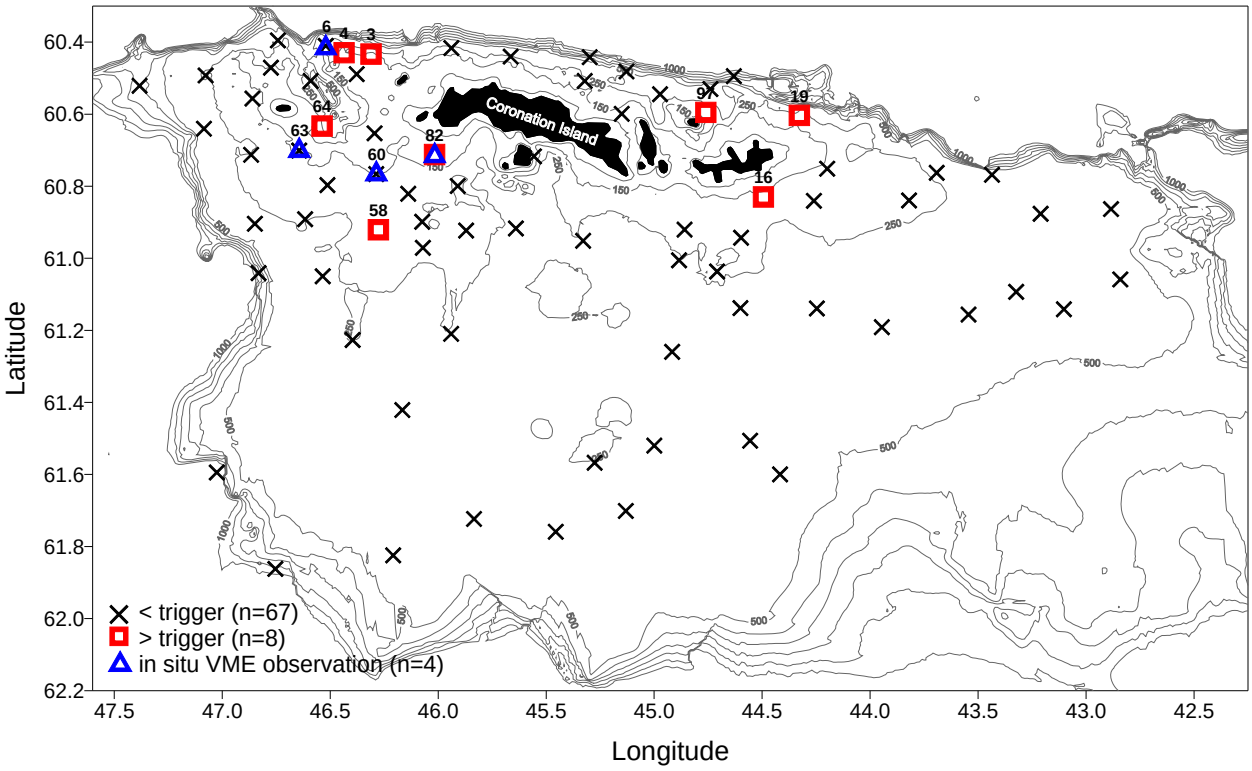

Figure 2. Trawl and video stations for the South Orkney Islands, with declared VME risk area (≥ 10 indicator units, or directly observed through underwater imagery.

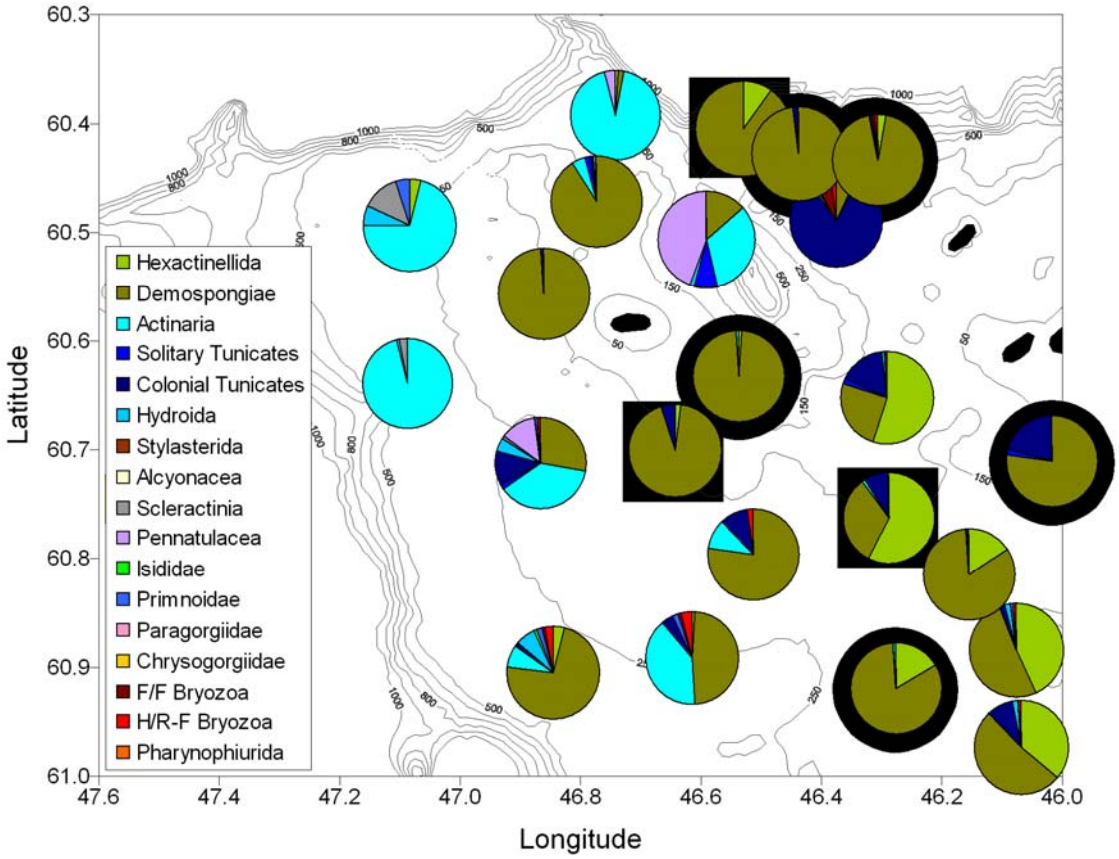

Figure 3. Composition of all VME indicator taxa for stations on the western South Orkney Islands shelf area. The thick black circles and squares indicate VMEs notified by presence in trawl catch and direct imagery, respectively.

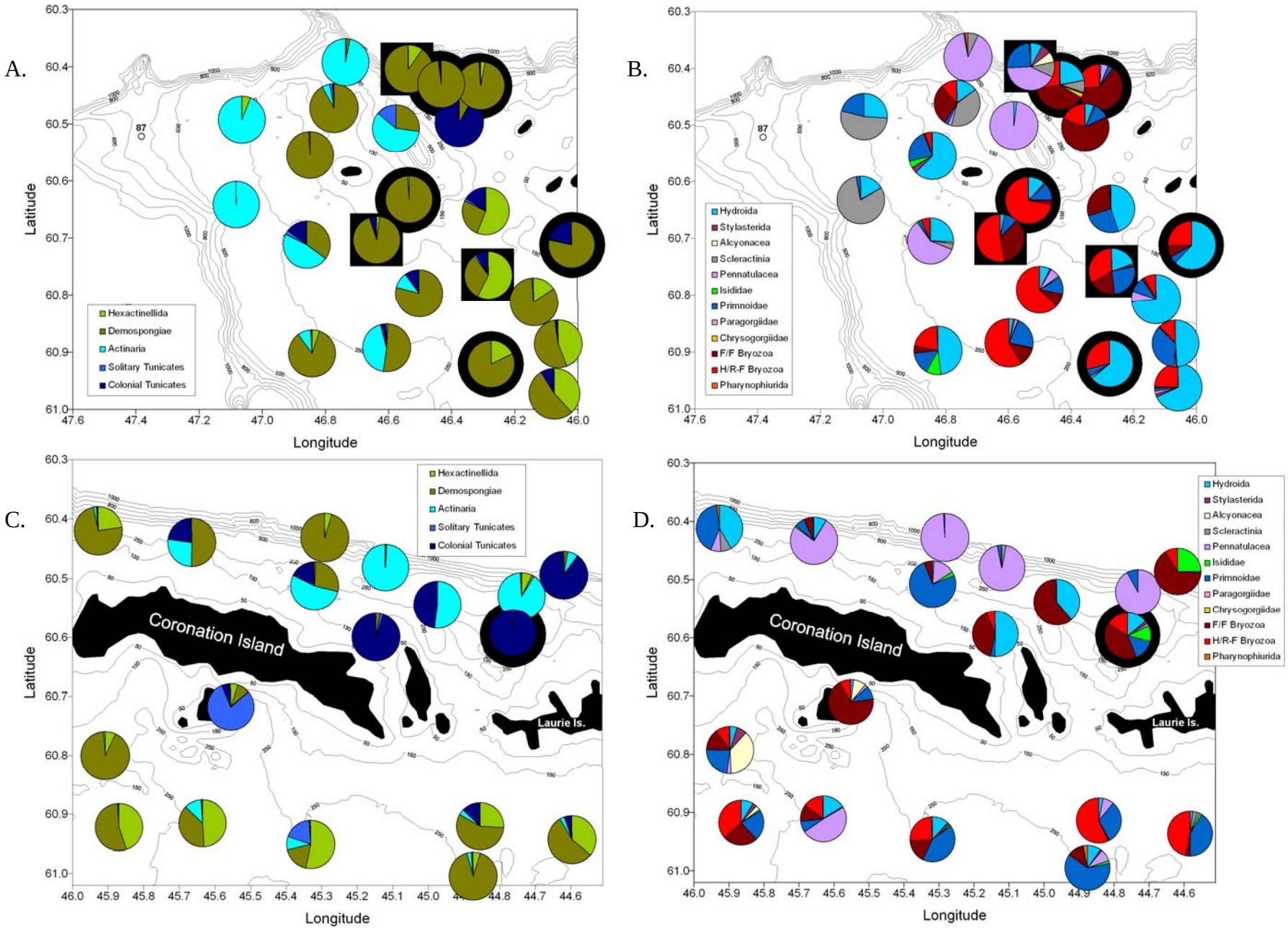

Figure 4. Composition of A) 'heavy' and B) 'light' VME indicator taxa on western South Orkney Island shelf; C) 'heavy' and D) 'light VME indicator taxa around the Coronation and Laurie Islands. The thick black circles and squares indicate VMEs notified by presence in trawl catch and direct imagery, respectively.

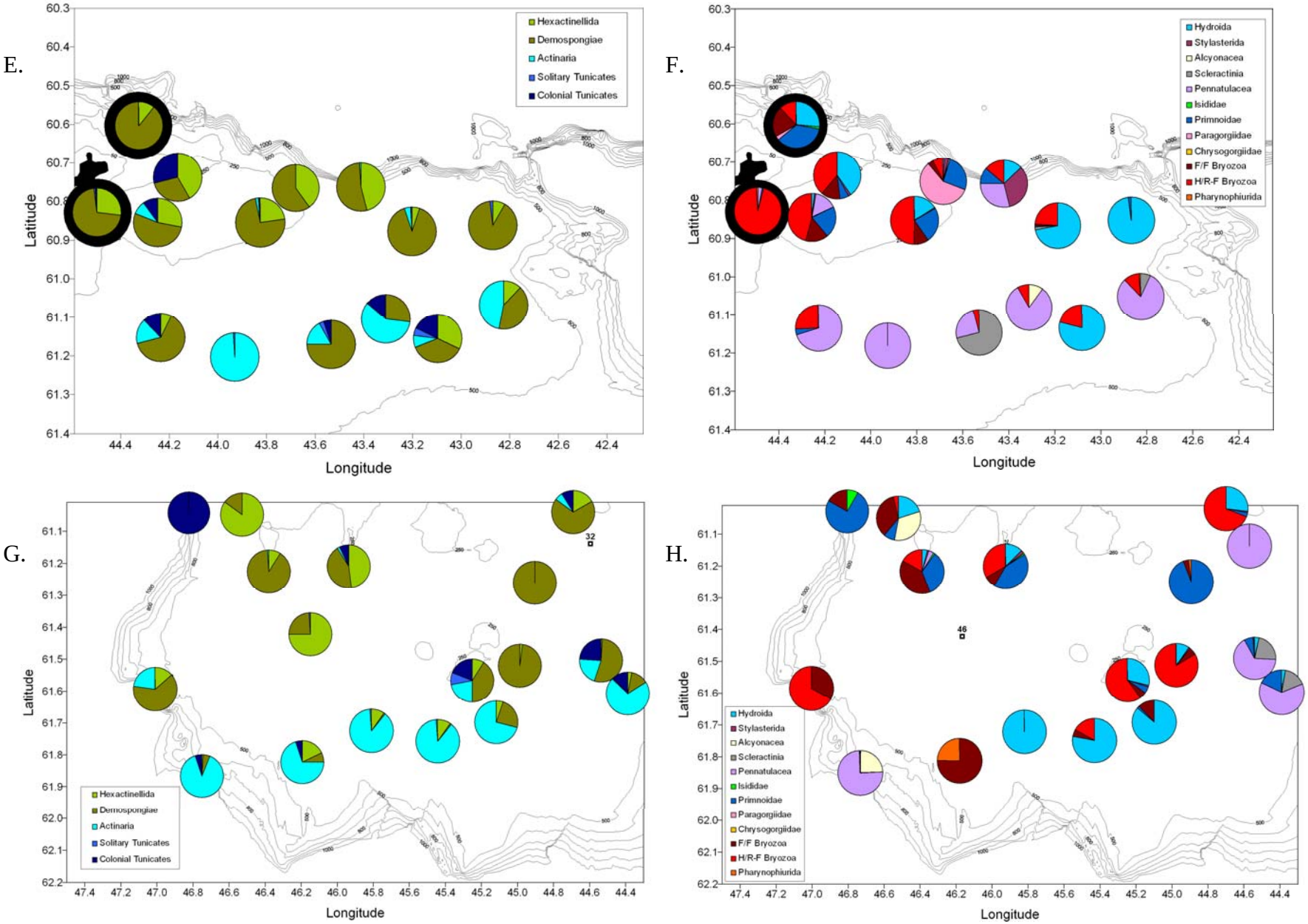

Figure 4 (continued). Composition of E) 'heavy' and F) 'light' VME indicator taxa on eastern South Orkney Island shelf; G) 'heavy' and H) 'light VME indicator taxa on the southern part of the South Orkney Islands shelf. The thick black circles and squares indicate VMEs notified by presence in trawl catch and direct imagery, respectively (no VME are proposed on the southern shelf region).

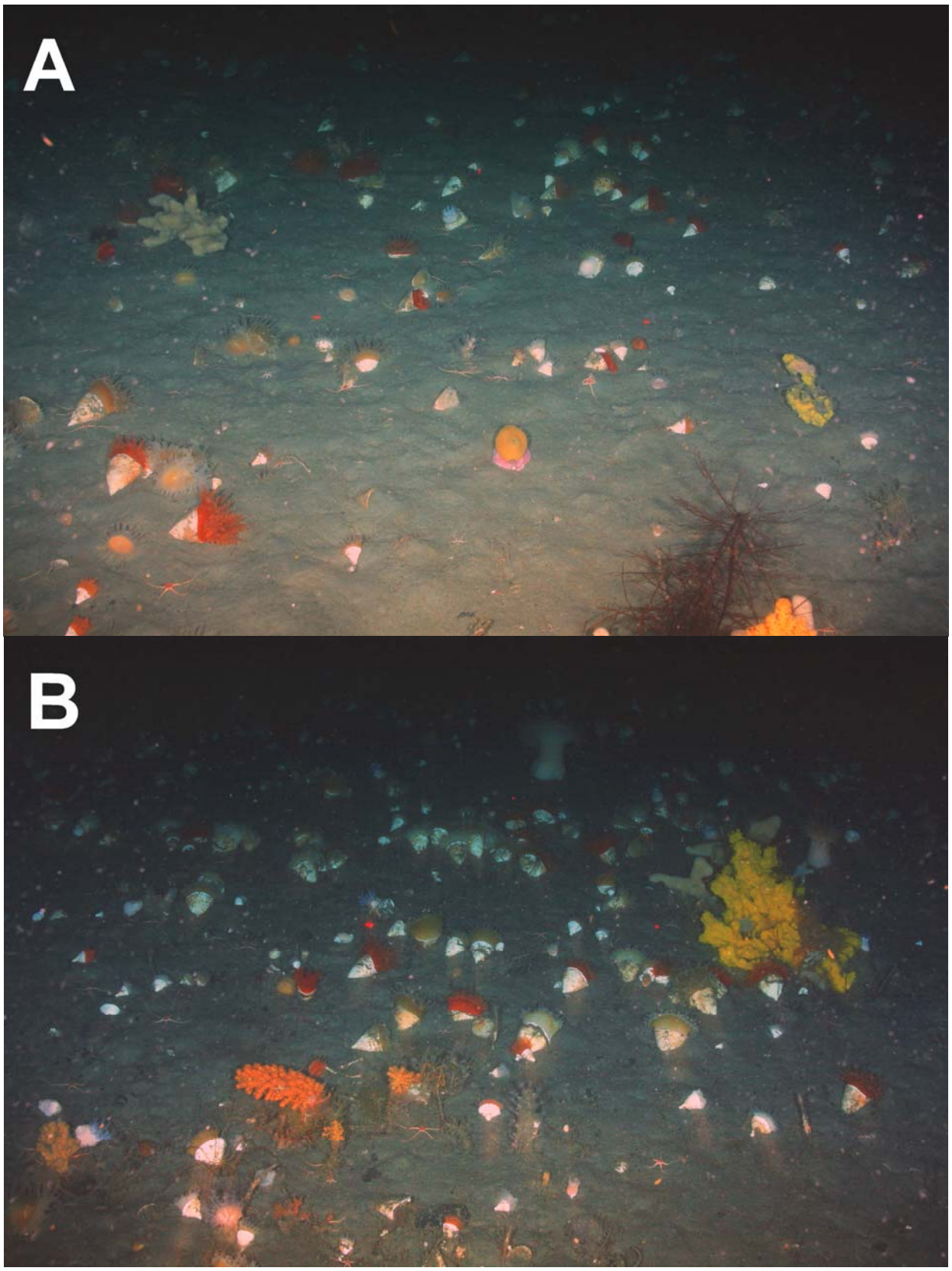

Figure 5. Station 6, north of Inaccessible Islands, South Orkney Islands (max. depth: 218 m). A) small but diverse demosponges scattered amongst a very high density of scleractinian corals, *Flabellum* spp.. B) Small- to medium-sized demosponges, large anemones, pennatulacean sea pens and primnoid gorgonians can be seen among the extremely abundant scleractinian corals.

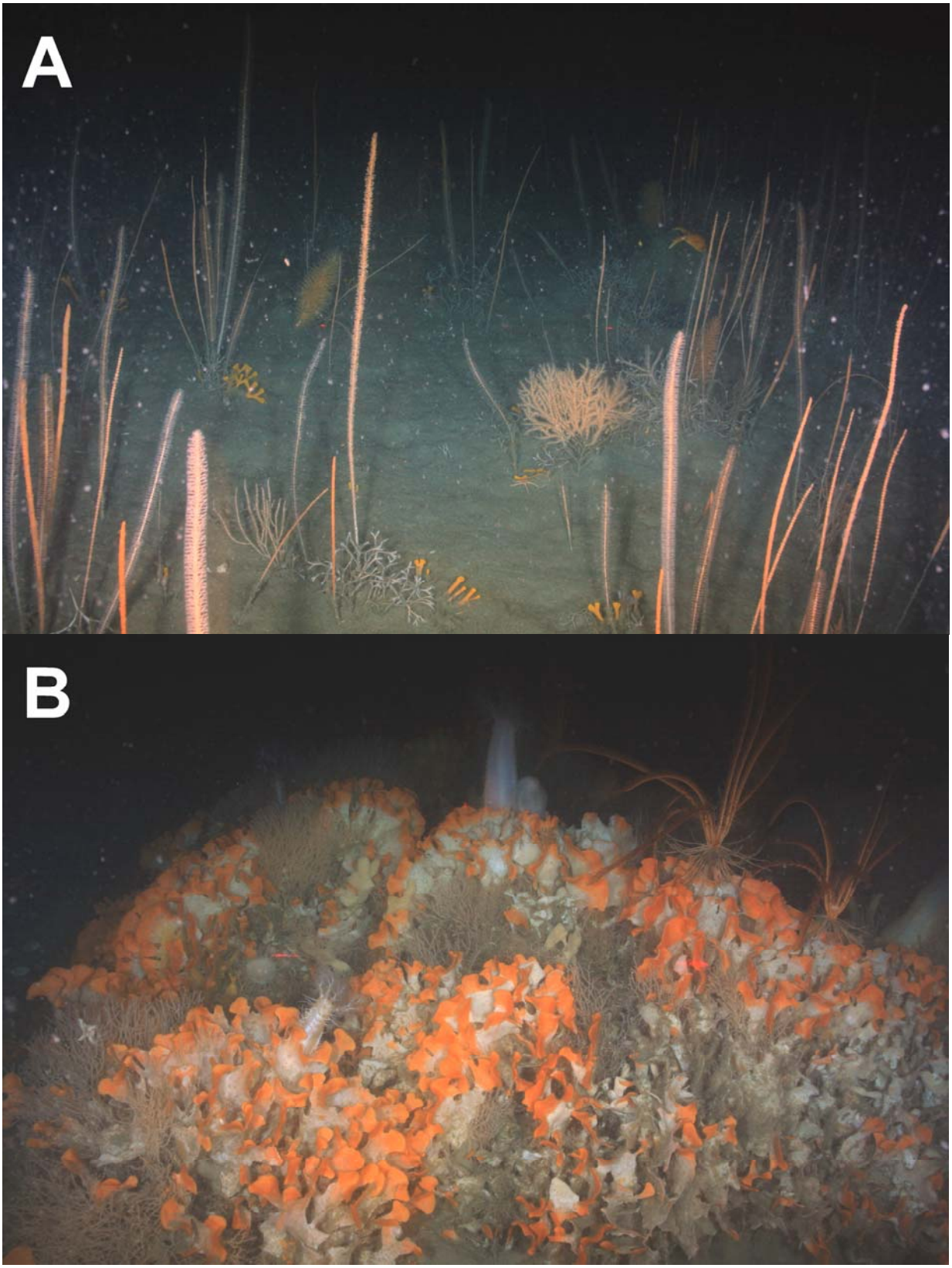

Figure 6. Station 60, southwest off the western tip of Coronation Island, South Orkney Islands (max. depth: 154 m). A) High density primnoid gorgonian assemblage and several species of hard bryozoans. B) Very large bryozoan reef structures (red laser points are 0.5 m apart) supporting an abundance of benthic invertebrate life.

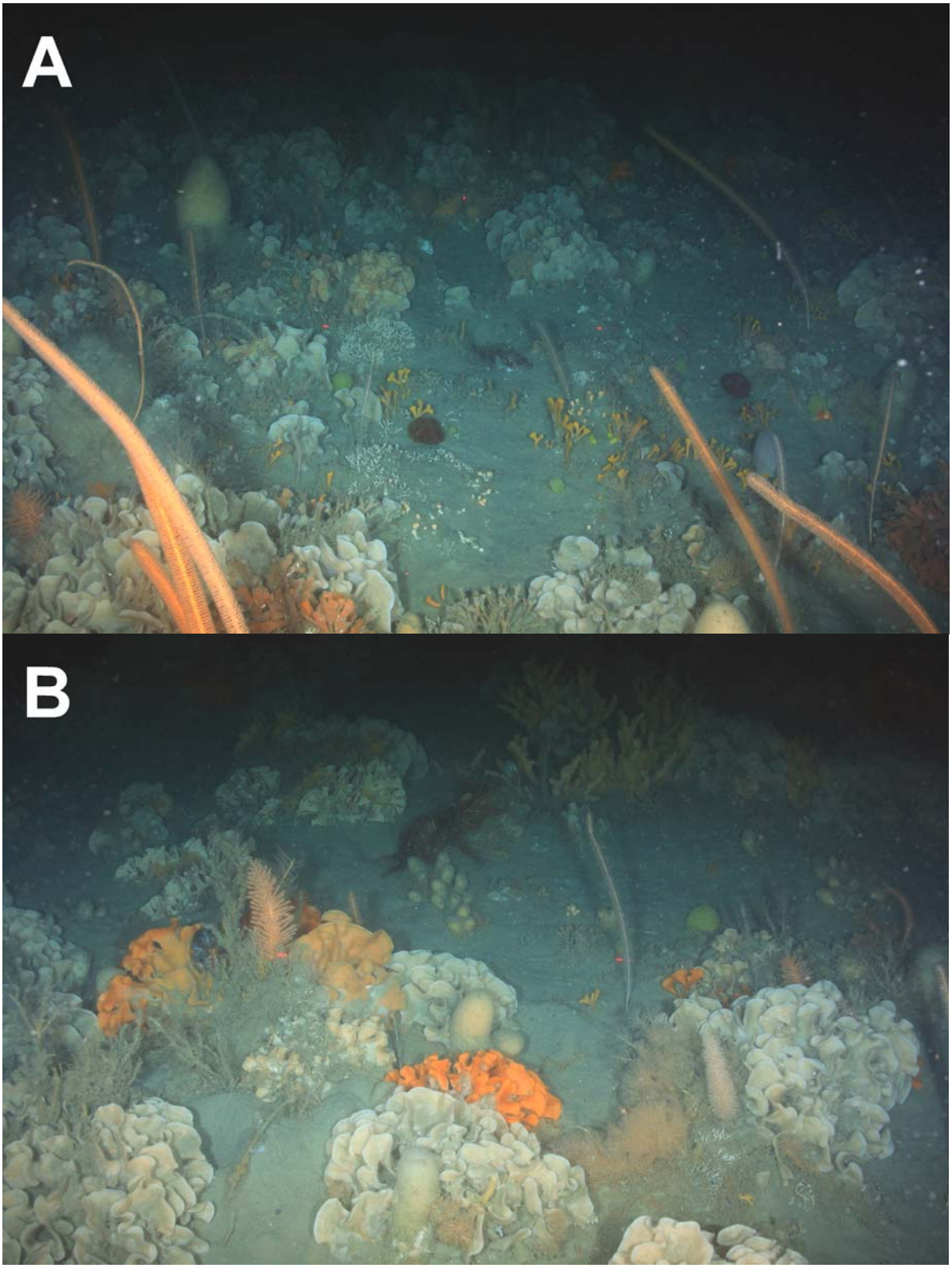

Figure 7. Station 63, south of Inaccessible Islands, South Orkney Islands (max. depth: 150 m). A) Diverse array of hard and reef-building bryozoans amongst which other VME-IT, such as compound ascidians, foliose bryozoans, sea whips and other primnoid gorgonians, can be seen. A nototheniod finfish, likely *Trematomous newnesi*, can be observed toward the center of the image. B) Erect demosponges, compound ascidians, diverse hydroids, bottle brush and other primnoid gorgonians amongst bryozoan reefs.

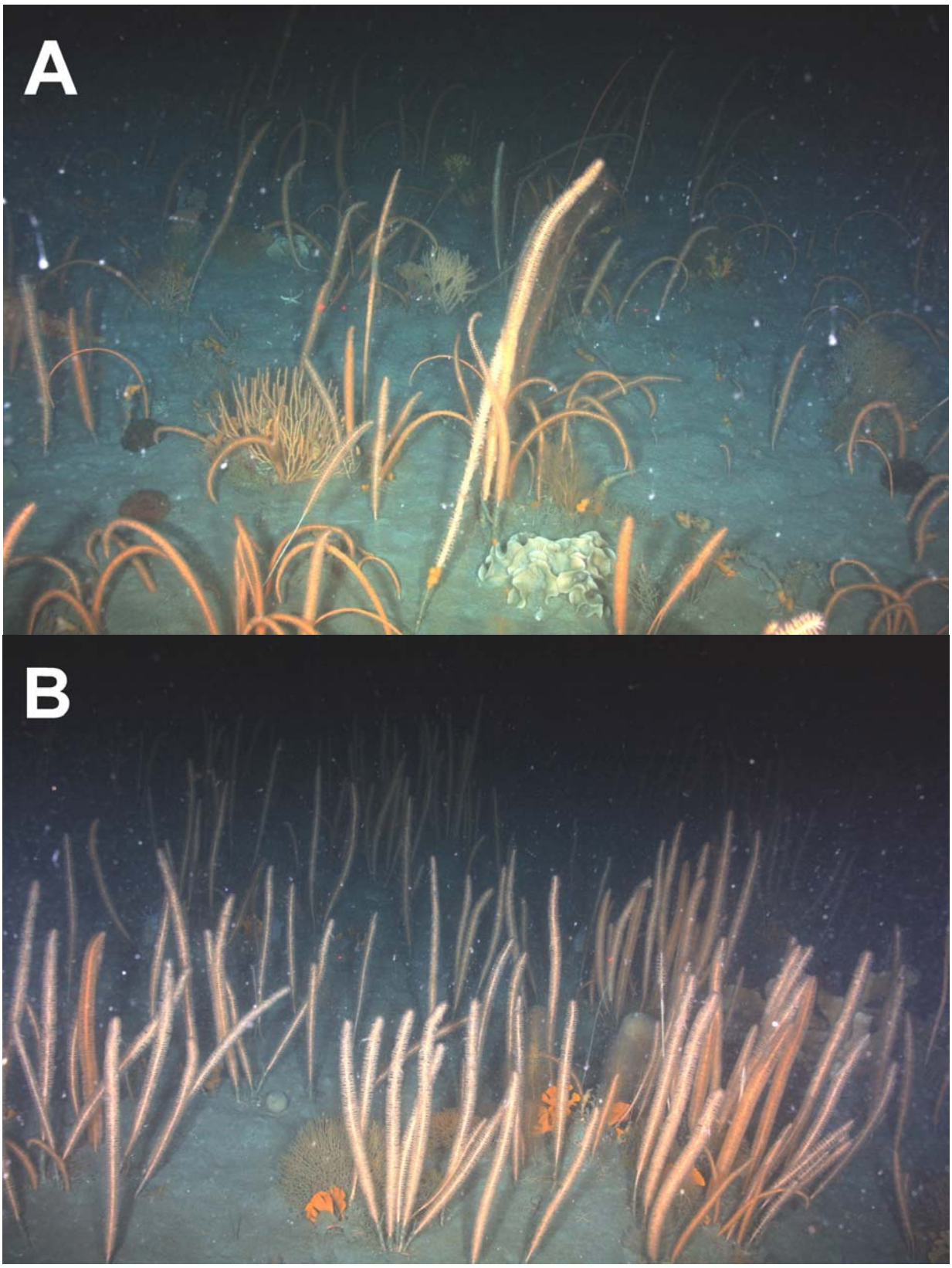

Figure 8. Station 82 South of the western tip of Coronations Island, South Orkney Islands (max. depth: 96 m). A) High density of sea whips and other primnoid gorgonians; reef-building and other forms of bryozoans. B) Hexactinellid (glass) and demosponges can be seen amongst the abundant sea whips, hydroids and bryozoans.

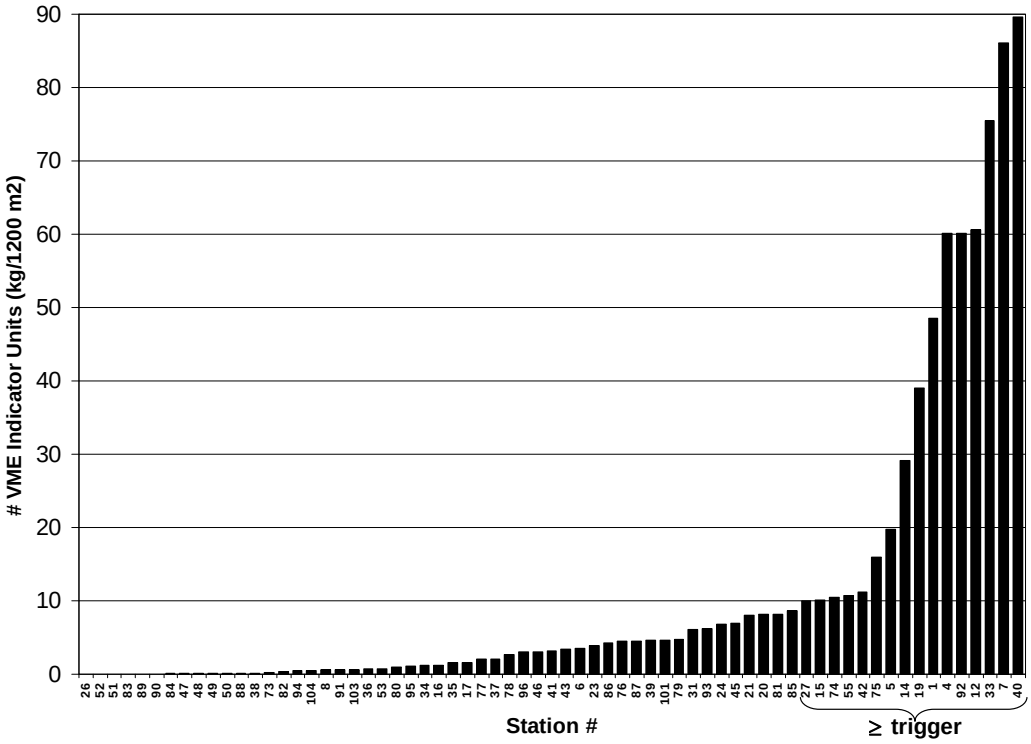

Figure 9. Distribution of standardized VME density (kg/1200 m^2 = VME indicator units) in trawl catches for the Antarctic Peninsula. A VME risk area is declared for ≥10 indicator units.

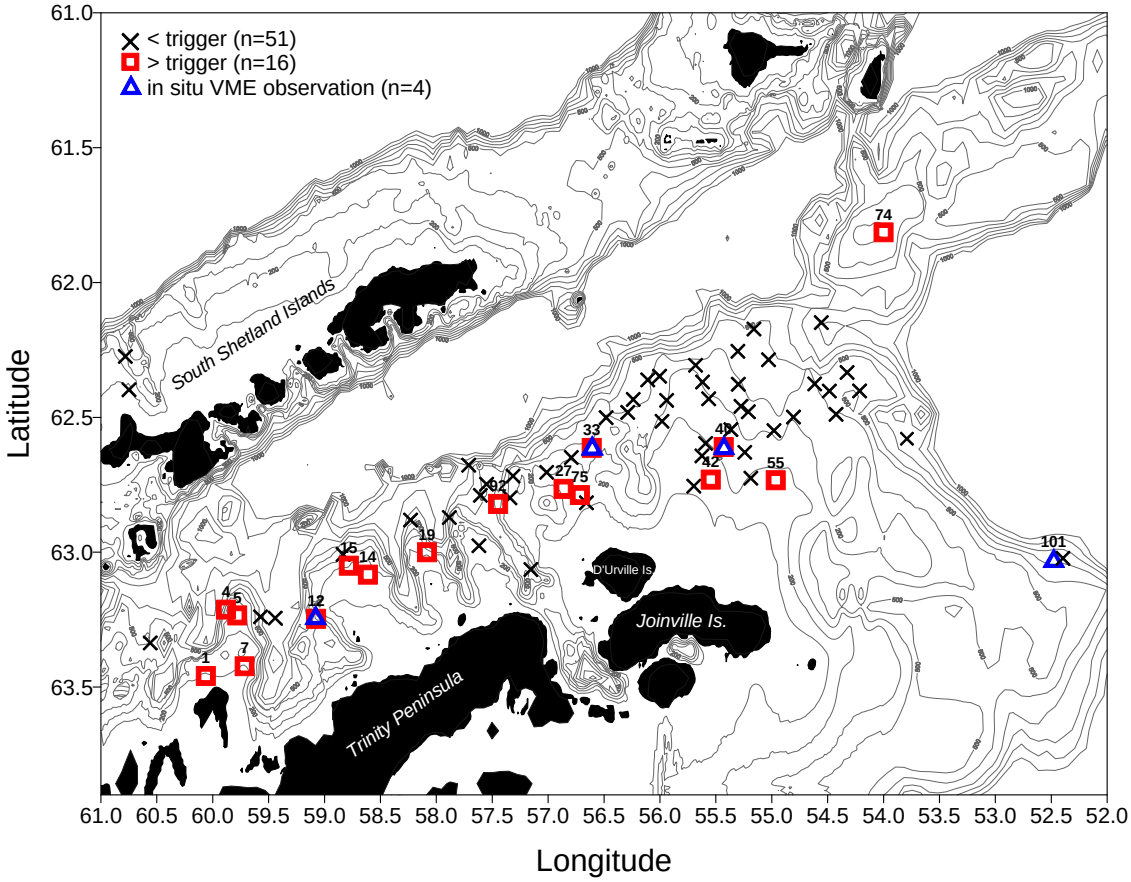

Figure 10. Trawl and video stations for the South Orkney Islands, with declared VME risk area (≥ 10 indicator units, or directly observed through underwater imagery.

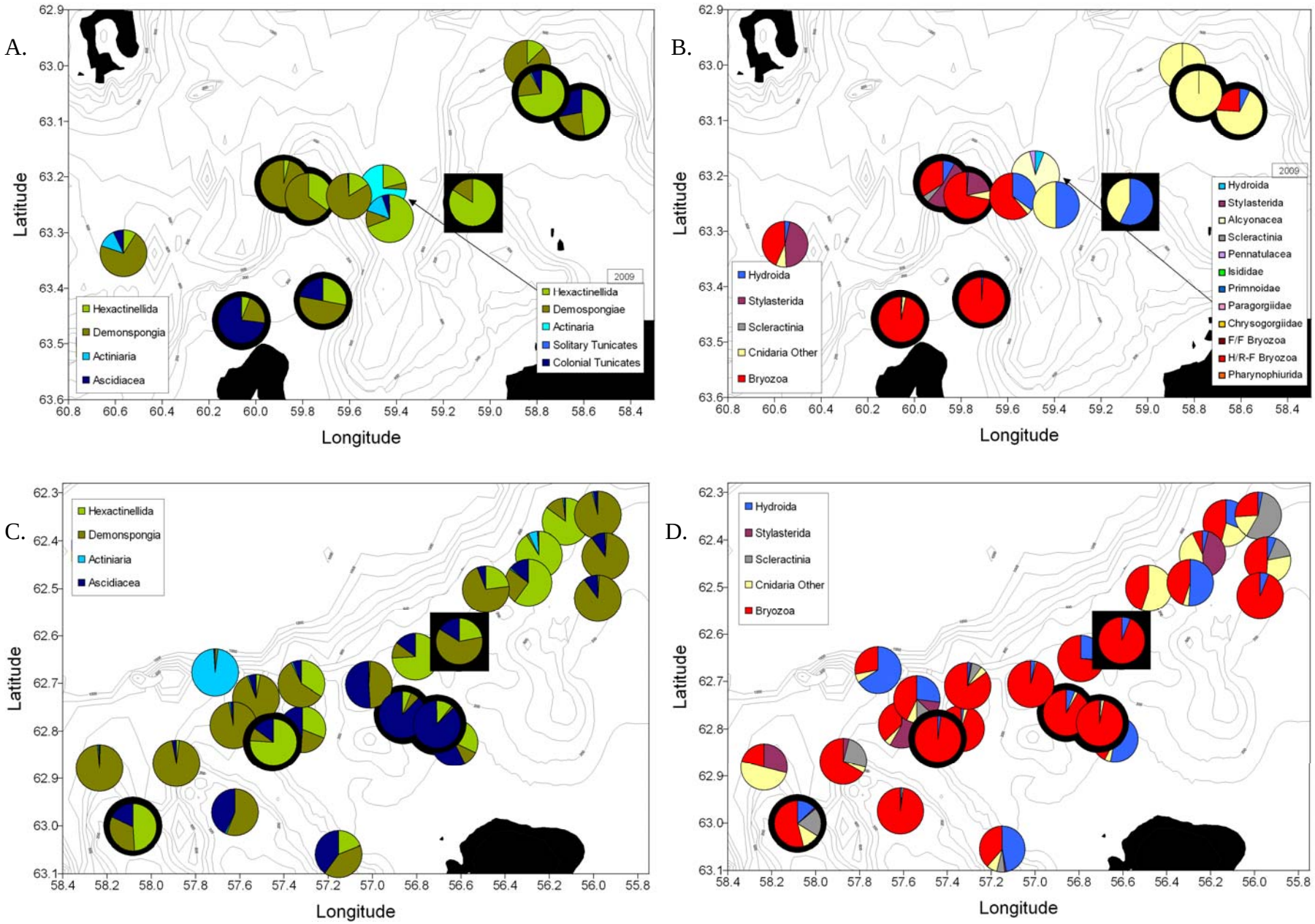

Figure 11. Composition of a) 'heavy' and b) 'light' VME indicator taxa on the southwest region of the Antarctic Peninsula stations; c) 'heavy' and d) 'light VME indicator taxa along the central Antarctic Peninsula. The thick black circles and squares indicate VMEs notified by presence in trawl catch and direct imagery, respectively.

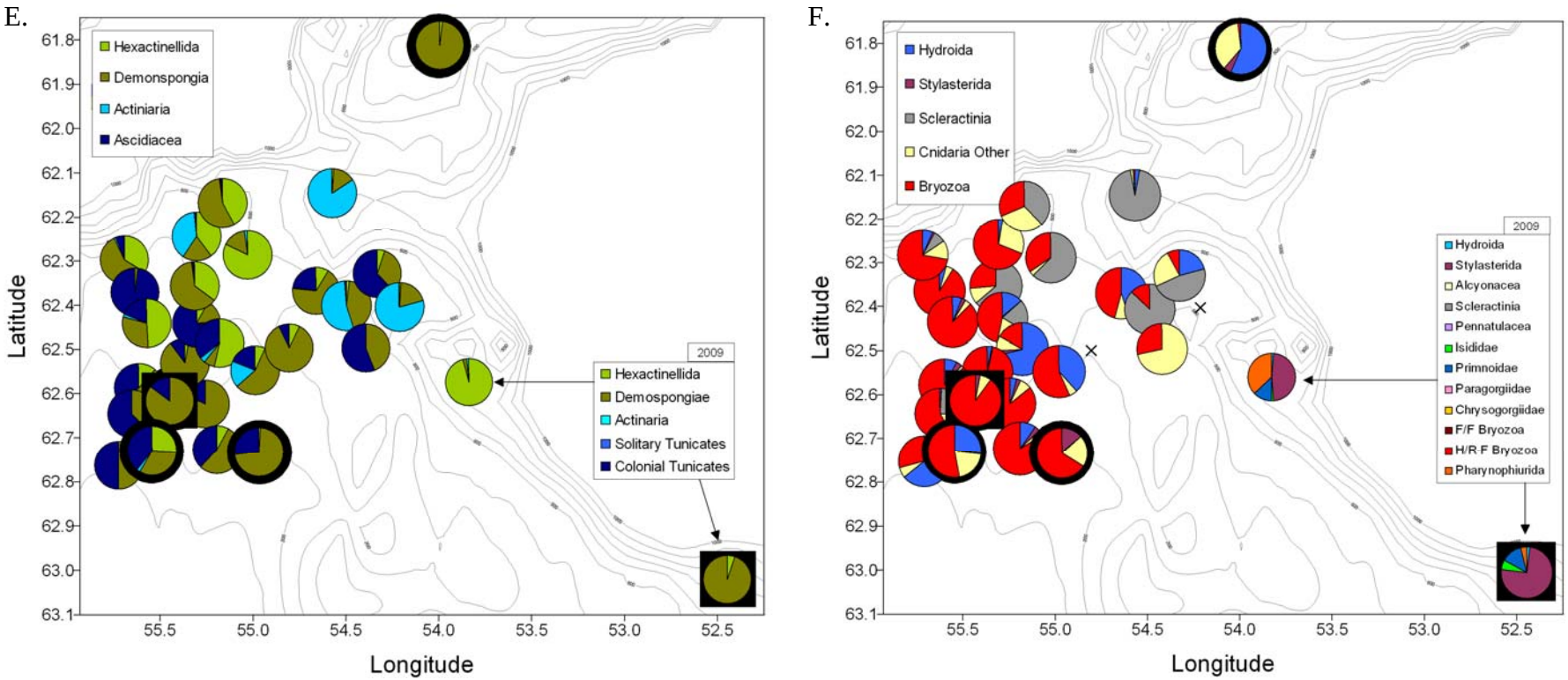

Figure 11 (continued). Composition of E) 'heavy' and F) 'light' VME indicator taxa on northwest Antarctic Peninsula. The thick black circles and squares indicate VMEs notified by presence in trawl catch and direct imagery, respectively.

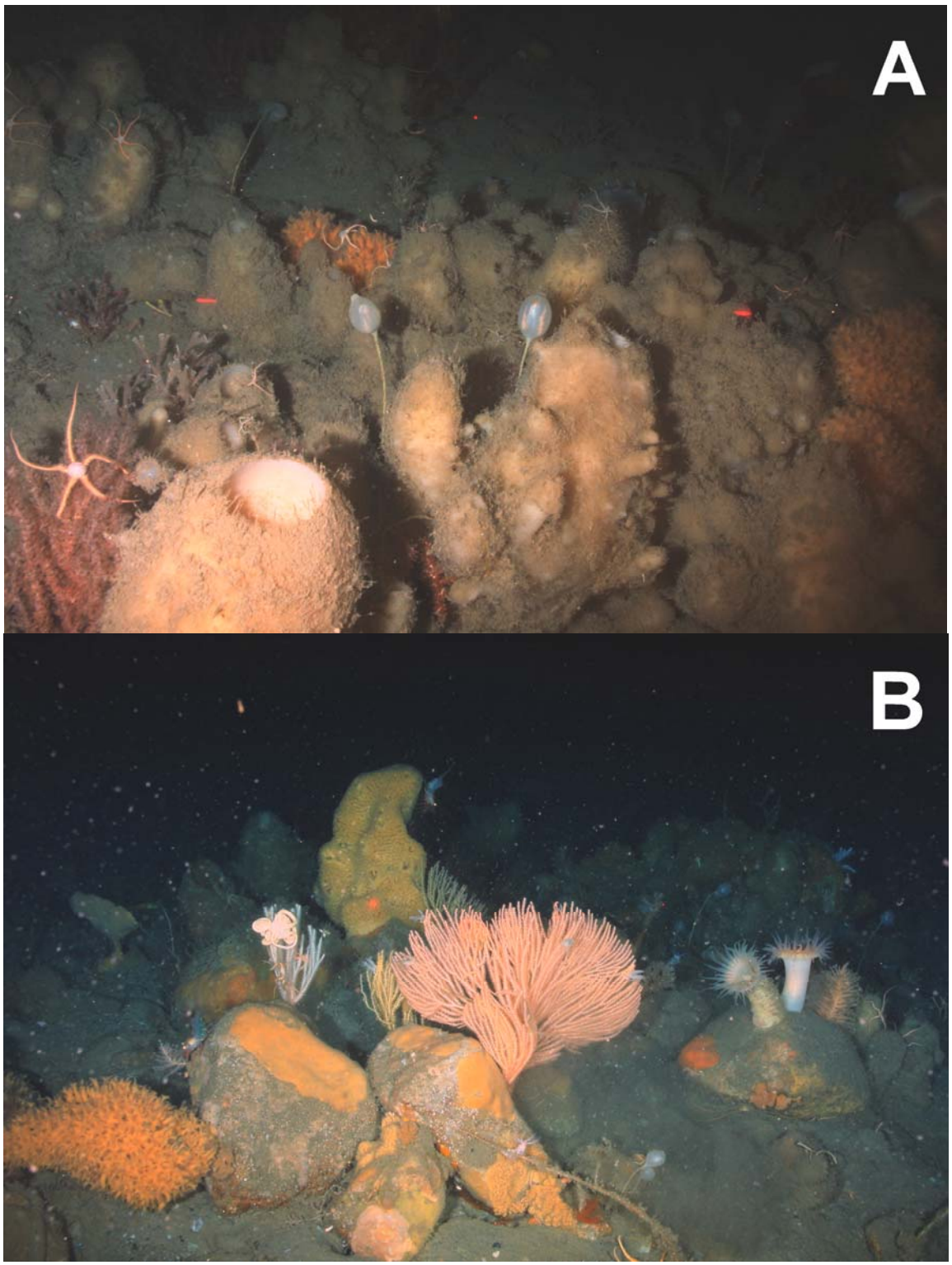

Figure 12. Station 12, north of the Trinity Peninsula (max. depth: 398 m). A) Mature assemblage (red laser points are 0.5 m apart) of abundant hexactinellid (glass) sponges amongst which are demosponges, foliose bryozoans, solitary tunicates and pterobranch colonies. A channichthyid finfish can also be seen hiding in the upper right side of the image. B) Large, erect and diverse demosponges which hexactinellid sponges in the background; diverse and mature sea fans (largest is almost 0.5 m wide) and other primnoid gorgonians; also large anemones, solitary tunicates, foliose and hard bryozoans, and basket stars.

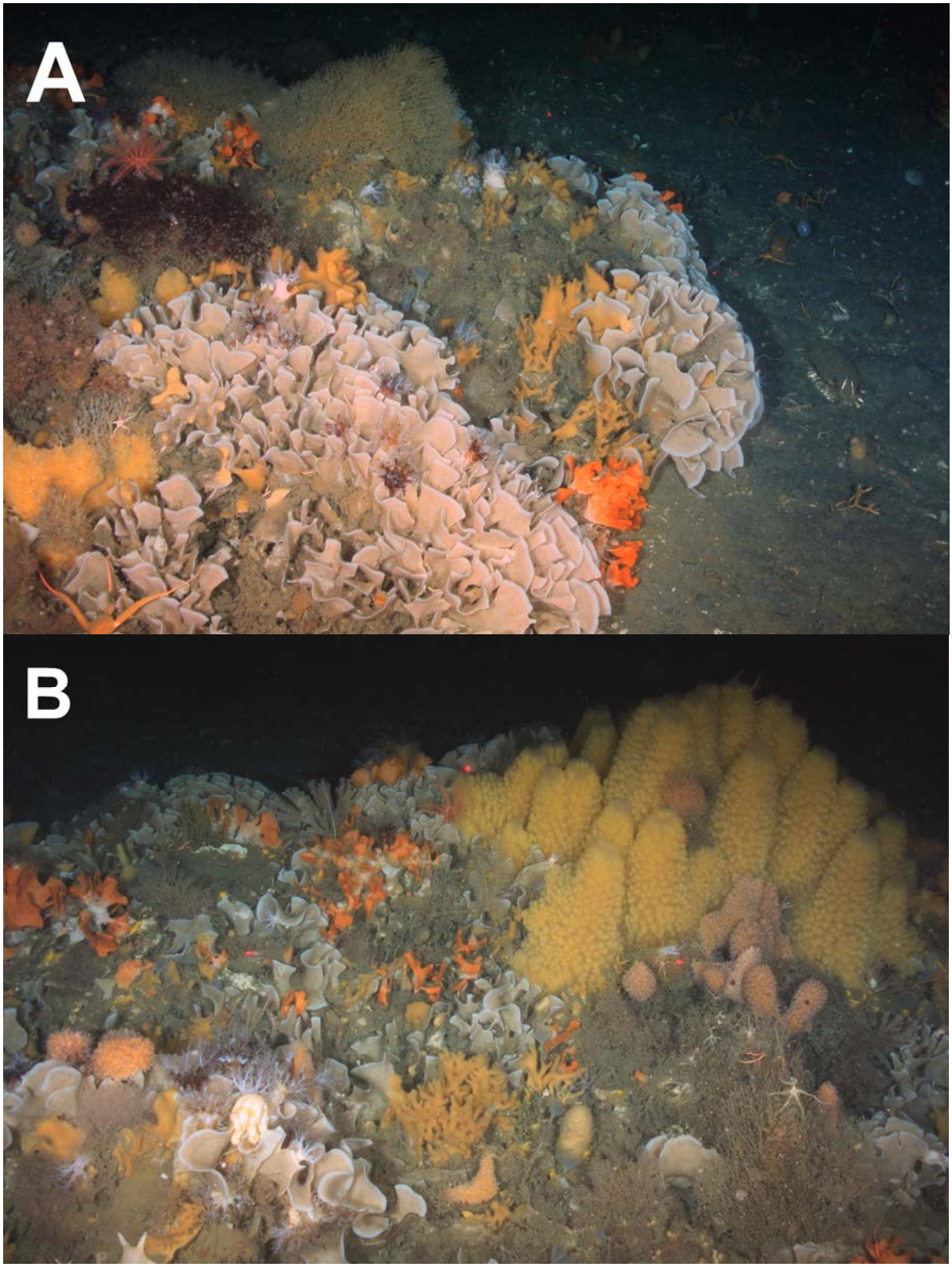

Figure 13. Station 33, north of D'Urville Island, Antarctic Peninsula, (max. depth: 229 m). A) Very large bryozoan reef structures (red laser points are 0.5 m apart) supporting an abundance of other VME-IT including, filamentous bryozoans, hydroids and demosponges. B) Mature assemblage of large demosponges and bryozoan reef supporting filamentouts bryozoans, hydroids, compound ascidians and many other invertebrate taxa.

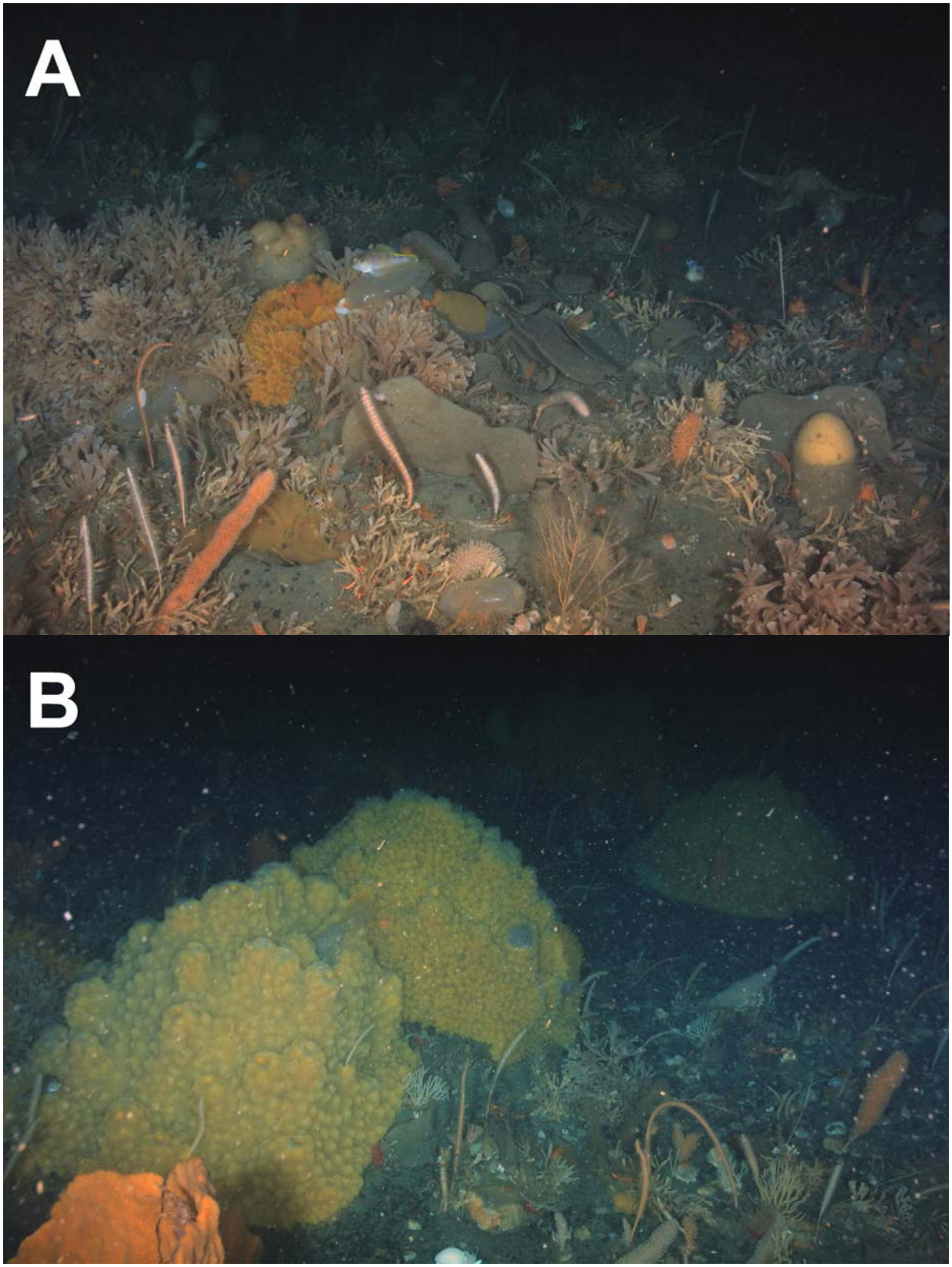

Figure 14. Station 40, north of Joinville Island, Antarctic Peninsula, (max. depth: 153 m). A) Substantial biodiversity of demosponges amongst a dense field of foliose bryozoans; other VME-IT include hydroids, solitary and compound ascidians, and a variety of primnoid gorgonians. Also note the nototheniod finfish *Lepidonotothen nudifrons* toward the center of the image. B) Numerous very large demosponges surrounded by diverse primnoid gorgonians, hydroids and bryozoans.

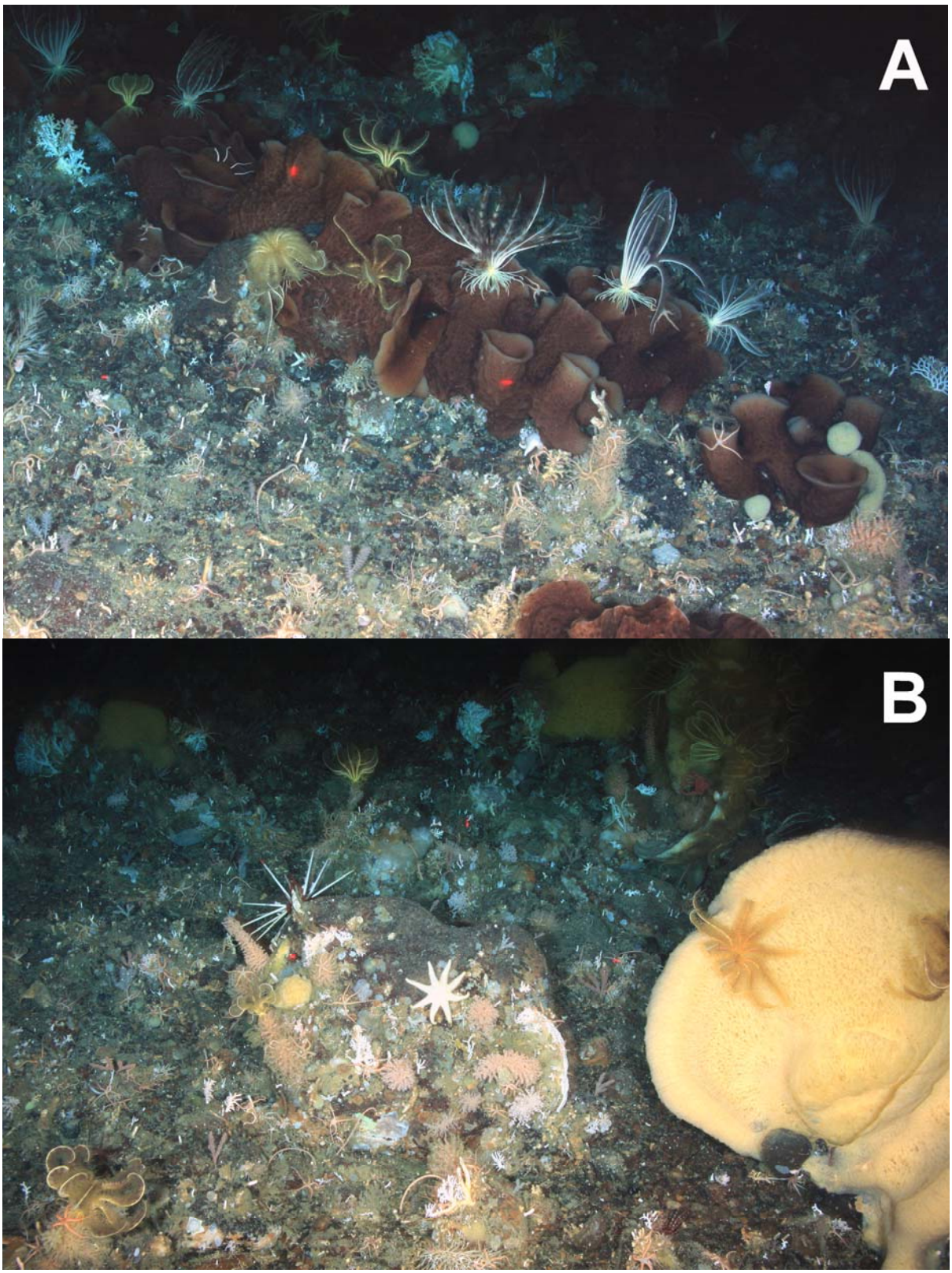

Figure 15. Station 101, east of Joinville Island (max. depth: 637 m). A) Abundant brown hexactinellid (glass) sponge species not previously observed by us; rich stylasterid coral assemblage; other VME-IT also include diverse primnoid gorgonians, hydroids, basket stars and demosponges. B) Large demosponges and abundant stylasterid corals; heterogeneous primnoid assemblage, hydroids and bryozoans.