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RESEARCH PAPER

A New Interpretation of the Dominance and Diversity of Horseshoe Island (Antarctic Peninsula) Epibenthic Communities

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Abstract

This study investigates the epibenthic communities of Lystad Bay on Horseshoe Island (Western Antarctica) using underwater video imaging techniques during the eight Turkish Antarctic Expedition in 2024. The primary objective of the study was to assess species diversity across different depths, substrate structures and potential ice scouring. Six sampling stations were selected, varying in depth (3–34 m) and substrate type (rocky, sandy, and muddy). Results show that a general tendency for an increase in species diversity with depth, particularly below 19 m, and is higher on sandy-muddy substrates than on rocky ones. The analysis of video footage identified 30 species from six phyla, with the highest species richness recorded at deeper stations (St 6) and the lowest at shallower rocky areas (St 1). The analysis of diversity indices (Shannon-Weiner, Margalef, and Pielou's evenness) indicates that substrate type exerts a significant influence on species richness, with sandy-mud habitats exhibiting higher diversity. Station 4 exhibited a low species richness, possibly as a result of local ice scouring impacts despite its depth and the presence of suitable benthic habitat. This study highlights the importance of oceanographic and environmental factors, such as ice scouring and terrestrial inputs, are in determining the organization of Antarctic benthic communities. Further research is required to understand the long-term effects of comprehend these elements on the biodiversity of the Antarctic ecosystem. This study is the inaugural comprehensive study in this region and will serve as a pivotal reference point for future research endeavours.

Introduction

The benthic life has presented enduring challenges and fascination for marine biologists, particularly concerning its unique biodiversity. To investigate these organisms and ecosystems, it is necessary to employ highly specialized equipment and methodologies, which are meticulously adapted for the extreme conditions that prevail in benthic habitats (Peck, 2018). Significant advances in technology have enabled exploratory efforts to reach hitherto unprecedented depths, facilitating rigorous studies of neritic flora and fauna. Such investigations have significantly expanded taxonomic knowledge, leading to the identification of numerous new species and ecosystems. Each discovery contributes to scientific understanding of the biological and ecological complexity of the neritic zone, revealing the intricate interactions within these specialized environments.

Antarctica and the Southern Ocean that encircles the Antarctic continent exhibit numerous unique characteristics. Among these are documented lowest temperatures on Earth and the largest ice mass (Peck, 2018). Others, though less recognized, have significant

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implications for the region's resident organisms and their ecological adaptations (Chown *et al*., 2015). The Antarctic ice sheet, which contains nearly 70% of the Earth's freshwater, influences global sea levels and ocean currents, impacting climate patterns worldwide. Research in Antarctica provides insights into past atmospheric conditions through ice core sampling and contributes to understanding Earth's response to environmental changes, making it vital in climate science studies (Selbesoğlu et al., 2023). Antarctica stands out as a pivotal focus for scientific research due to its extreme climate, unique ecosystems, and critical role in global climate regulation. Currently, 29 nations operate research stations—either seasonal or permanent—primarily situated in coastal regions (Stark et al., 2014; Comnap, 2024). Despite considerable research in recent years on the impacts of these stations on adjacent marine ecosystems (Costa et al., 2024), there remains a significant knowledge gap regarding their environmental impacts. Key physical factors influencing organisms in polar marine environments include salinity, temperature, different forms of ice, seafloor topography, and depth. These parameters exhibit notable variations with depth, particularly within the first 100 meters, extending down to depths of 1000 meters and beyond. These factors significantly influence the habitats that marine organisms occupy (Chown *et al*., 2015).

Benthic organisms play a pivotal role in the food chain, serving as a sustenance source for larger predators such as fish, penguins, and seals. Analyses of the stomach content of these predators frequently reveal amphipods and other shrimp-like crustaceans. Many benthic species, including starfish, sea cucumbers, annelid worms, crustaceans, and bivalves such as the Antarctic scallop *Adamussium colbecki*, inhabit the sediment surface, enabling mobility for foraging. Pycnogonids, giant marine relatives of spiders, are common in Antarctic waters; they exhibit slow movement and primarily consume small corals, sponges, and bryozoans. Amphipods, a highly diverse and abundant group within soft-sediment communities, exhibit a variety of feeding strategies, ranging from predation and algal grazing to omnivorous scavenging (URL 1, URL 2).

The West Antarctic Peninsula (WAP) is a biologically rich and ecologically significant region, hosting diverse benthic fauna and flora uniquely adapted to the extreme conditions of the Southern Ocean. Sponge (*Porifera*), sea star (*Asteroidea*), brittle star (*Ophiuroidea*), bivalves, polychaetes, crustaceans, and notothenioid fish are among the diverse taxa that comprise benthic fauna. These organisms are essential to the ecosystem's carbon sequestration, energy transfer, and nutrient cycling (Griffiths, Linse, & Barnes, 2011; Clarke, Murphy, & Convey, 2007). The breakdown of organic matter and biogeochemical processes are aided by microbial communities, which include bacteria and archaea (Smith, Rabouille, & Fennel, 2006). Macroalgae and microphytobenthos make up the majority of the benthic flora, which grows well in shallow, light-penetrating waters and is essential to primary production. Many benthic consumers rely on it as a source of food (Wulff, Pereira, & Mengerink, 2011). Environmental factors like sea ice cover, sediment type, and iceberg scour affect the distribution and composition of benthic flora and animals, resulting in a dynamic and diverse bottom ecosystem (Barnes & Clarke, 2011). Benthic ecosystems are changing as a result of the quick environmental changes along the WAP, including as increased iceberg activity, decreasing sea ice, and warmer seawater temperatures. According to Aronson, Hughes, and McCauley (2011) and Gutt, Barnett, and Griffiths (2018), these alterations might potentially upset current ecological dynamics by posing serious challenges to habitat stability, changing species distributions, and facilitating the establishment of non-native species.

Benthic habitat research employing remotely operated vehicles (ROVs), sometimes referred to as underwater drones, has emerged as a cutting-edge and incredibly successful approach to investigating marine ecosystems (Smith, 2020). Corals, sponges, fish, and invertebrates can all thrive in benthic ecosystems, which are found on the bottoms of lakes, rivers, and seas (Garrison & Ellis, 2021;). High-resolution imagery, which allows researchers to take precise pictures that support species identification, habitat health evaluations, and tracking environmental changes over time, is one of the main advantages of employing underwater drones for benthic research (Thompson & Green, 2018). Furthermore, a lot of underwater drones come with collecting equipment like grabbers and suction devices, which enables scientists to gather biological and sediment samples for examination of pollution levels, species richness, and other ecological aspects (Miller *et al*., 2021). With its ability to descend to depths well beyond human reach, these drones provide accurate navigation for accessing and studying deep-sea benthic zones while causing the least amount of harm to delicate ecosystems like coral reefs (Patel & Lee, 2022). In a variety of applications, such as biodiversity research, underwater drones are crucial in exploring benthic habitats and cataloguing species, providing vital information on the health of ecosystems (Kumar & Singh, 2023). They also play a key role in coral reef monitoring, allowing scientists to measure coral cover, monitor bleaching, and analyze reef health-all crucial information for comprehending the effects of both human activities and climate change (Santos *et al*., 2020). Drones provide high-resolution data on seafloor topography and structure, which is useful for mapping the seafloor and investigating geological features, sediment flow, and habitat distribution (Anderson *et al*., 2021). In order to analyze potential impacts on benthic ecosystems and help conservation efforts, drones are also utilized in environmental impact assessments prior to industrial operations like deep-sea mining and oil drilling (Davis & Carter, 2022). They are also useful for monitoring pollution, identifying chemical pollutants or plastic debris on the seabed to address the impact of human activities on marine ecosystems (Robinson & Wright, 2021). The use of underwater drones has several advantages, such as being non-intrusive, allowing data collection with little ecological disruption, being more affordable than manned submersibles or extensive diving operations, and being able to reach remote areas with little human presence, such as the deep sea or Arctic and Antarctic habitats (Baker, 2022).

Although useful for identifying benthic communities, underwater drones have a number of drawbacks. Their limited depth range is a major drawback that may prevent them from being used in deep or harsh underwater conditions. Furthermore, these drones' imagery may not have a high enough resolution to detect minute or cryptic creatures, which are prevalent in benthic habitats. It might be challenging to get good data when visibility is further obstructed by water conditions like turbidity, strong currents, or low light. Additionally, because drones are primarily used for visual data collection and are unable to physically sample sediment or assess other environmental variables that are crucial for investigating benthic populations, they have limited sampling capacity.

The majority of underwater drones have limited operational time due to their battery life, which limits the quantity of data that can be collected during a single deployment. Furthermore, high-quality drones can be costly, and their ongoing maintenance raises the total cost. Another difficulty in interpreting drone data is that identifying species from photos or videos, particularly when they have similar appearances, frequently calls for specialized knowledge. Drone propellers may disturb the very ecosystems they are intended to investigate by stirring up sediments, therefore environmental effects must also be taken into account. Additionally, drones are passive instruments that are unable to interface with the environment in the same way as divers can, which restricts their capacity to gather specimens or interact directly with the habitat.

In this study, Vosviewer software, a free mapping program, was used in the bibliometric analysis of the research, mainly to analyse and classify the relationship of the keywords (Ilmasari *et al*. 2022; Basmaci *et al*., 2023). This analysis was carried out specifically for bibliometric analysis studies, which is one of the most innovative types of research, special keywords and some assumptions in the investigations were taken into account as opposed to the typical research pattern. The Scopus database was primarily searched using the keywords "shallow water" and "biodiversity" and "Antarctica". In the search conducted with the keywords, only 19 documents were found. On the other hand, if searched with other keywords "benthic" and "biodiversity" and "Antarctica", since 2014, research on benthic biodiversity in the Antarctic continent has been carried out in different areas. This search using the "benthic" and "biodiversity" and "Antarctica" keywords identified 68 studies published between 1999 and 2024 in all fields and disciplines. The distribution of the 68 articles examined in the study by year of publication is shown in Figure 1. However, when Horseshoe was added to those keywords, no research was found. In the search conducted with the keywords Biodiversity and Horseshoe, only 3 articles were found. The fact that such a limited number of studies have been carried out and the need for more research in this area, has also formed the focus of this study.

In Antarctica, a unique ecosystem, it is noteworthy that studies on benthic habitats and biodiversity have

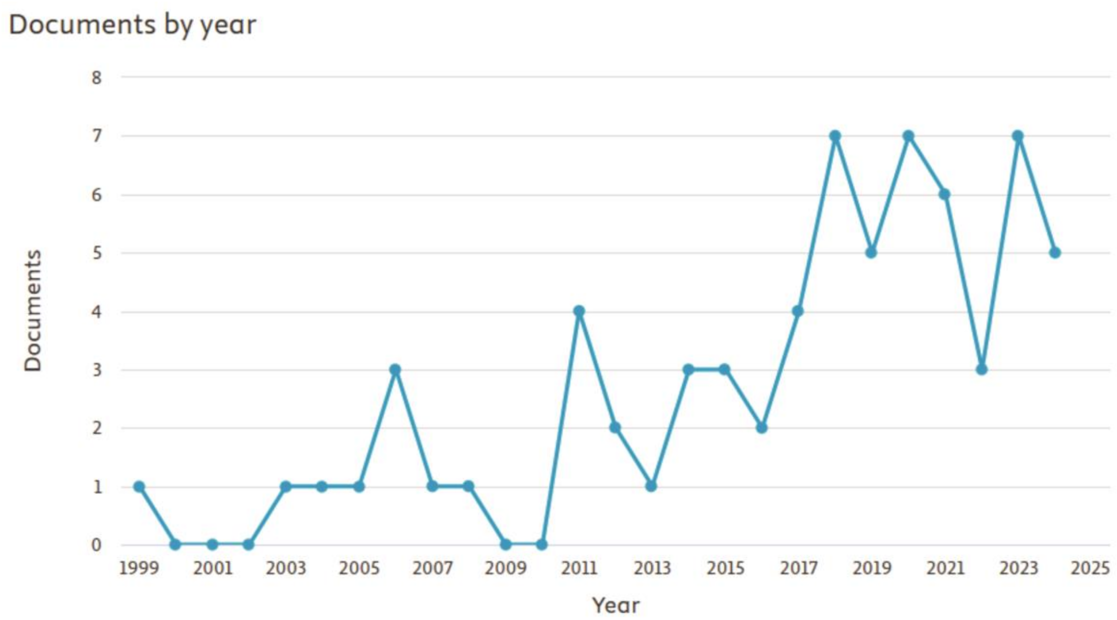


Figure 1. Distribution of total 68 articles by years of the keywords "benthic" and "biodiversity" and "Antarctica" from Scopus.

increased in recent years, particularly over the last five years (Figure 1). In this context, observation and monitoring of species within their habitats provides a valuable opportunity for the tracking of the density of identified species in the area, as weel as, their interactions with other species. The utilization of technological devices equipped with diverse functionality, in conjunction with development of novel methodologies, promises to unveil significant insight into this unique ecosystem.

This study aims to capture underwater imagery from six marine stations around Horseshoe Island (Figure 2) to analyze the species diversity of the area. A key innovation of this research is the application of surface cover mapping, which enhances the assessment of species dominance and diversity within benthic communities. The collected images were then systematically analyzed, and species inventories were compiled. Variations based on substrate type were assessed using species abundance and diversity indices, thereby elucidating the biodiversity of benthic communities. In this study, numerical species richness is assessed at six previously unstudied stations within a defined spatial framework, accounting for sampling area. This spatial consideration is essential for accurate comparison of biodiversity levels.

Materials & Methods

Study Area

The study was conducted at six selected stations according to the different seafloor depths and formations on Horseshoe Island in the Antarctic Peninsula (Figure 3). The study hypothesis was based on identifying differences in the substrate structure of the stations and the species present in the sediments. In addition, a specialized device was employed to systematically analyze the species found on the bottom. The numerical species richness of the area was evaluated using abundance and diversity indices.

High-Resolution Imaging for Benthic Habitat Mapping with QYSEA FIFISH V6 Underwater Drone

A total of six stations captured approximately 12 GB of video footage to assess the nearshore seabed benthic habitat within the study area. The videos were recorded using an underwater drone, the QYSEA FIFISH V6, specifically designed to capture high quality footage in challenging aquatic environments (QYSEA, 2021). Equipped with a 4K UHD camera capable of recording at 30 frames per second (fps) with exceptional clarity, the V6 effectively captures intricate underwater scenes (Johnson & Lee, 2020). Furthermore, its ability to record in 1080p at 120 fps enables the production of fluid slow-motion sequences (Smith *et al*., 2019).

The drone's wide 166-degree field of view (FOV), along with vertical and horizontal angles of 81° and 132°, respectively, allows for extensive underwater coverage without requiring frequent panning (QYSEA, 2021). Its performance in low-light conditions is enhanced by two powerful 4,000-lumen LED lights, ensuring high-quality footage even in murky or dimly lit waters. Adjustable brightness settings further allow users to prevent overexposure or underexposure in different underwater scenarios (Johnson & Lee, 2020).

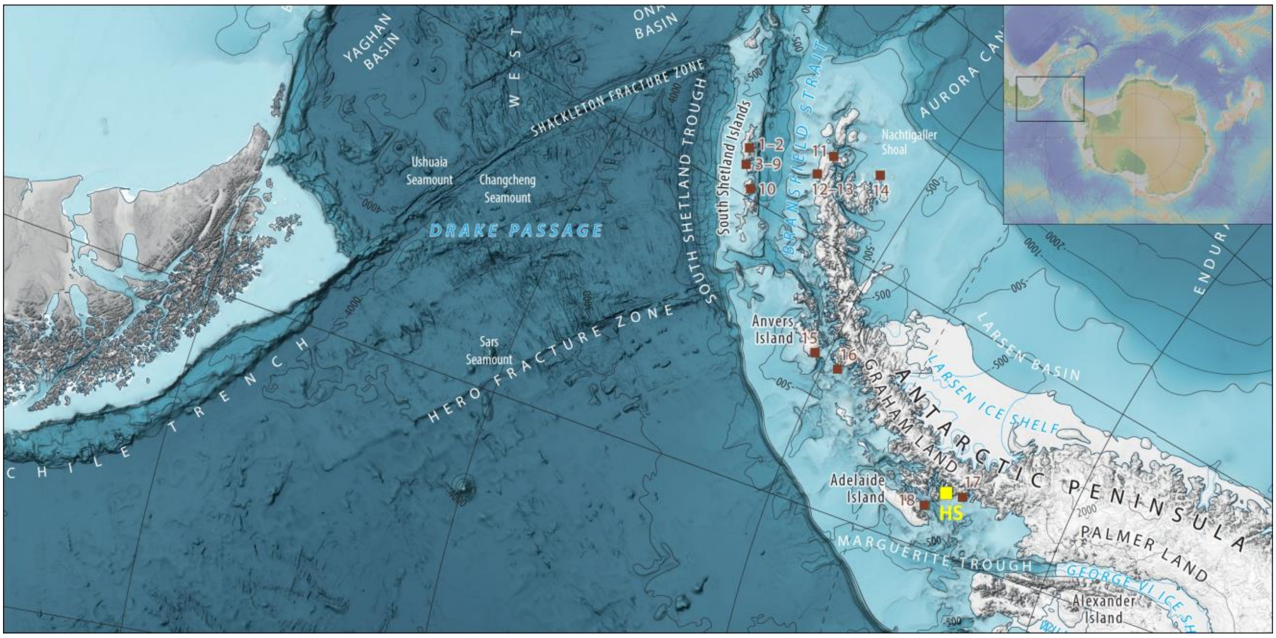


Figure 2. The location map of Horseshoe Island (yellow square, HS, Horseshoe Island), Western Antarctica (Australian Antarctic Division, 2019), black squares represent the polar research centers or camps of various countries. Inset map is from Geomapapp (Ryan *et al*., 2009).

The FIFISH V6 also supports multiple recording formats, including MP4 and MOV, providing significant flexibility for post-production editing (QYSEA, 2021). Advanced color correction algorithms enhance the vibrancy and accuracy of underwater imagery, compensating for the limited natural light in aquatic environments (Smith *et al*., 2019). Overall, the QYSEA FIFISH V6 is a versatile and professional-grade tool for underwater videography, delivering high-quality results for scientific and exploratory purposes.

The V6's 6 degrees of freedom (DOF) movement is one of its best characteristics; it enables smooth rotation, tilting, and maneuvering in any direction, including up, down, sideways, and oblique angles (QYSEA, 2021). For the purpose of recording dynamic, fluid film in any kind of underwater environment, this adaptable movement is essential. The QYSEA V6 drone's 3D digital noise reduction technology enables live streaming and real-time video transmission, guaranteeing steady, high-quality video feeds over its

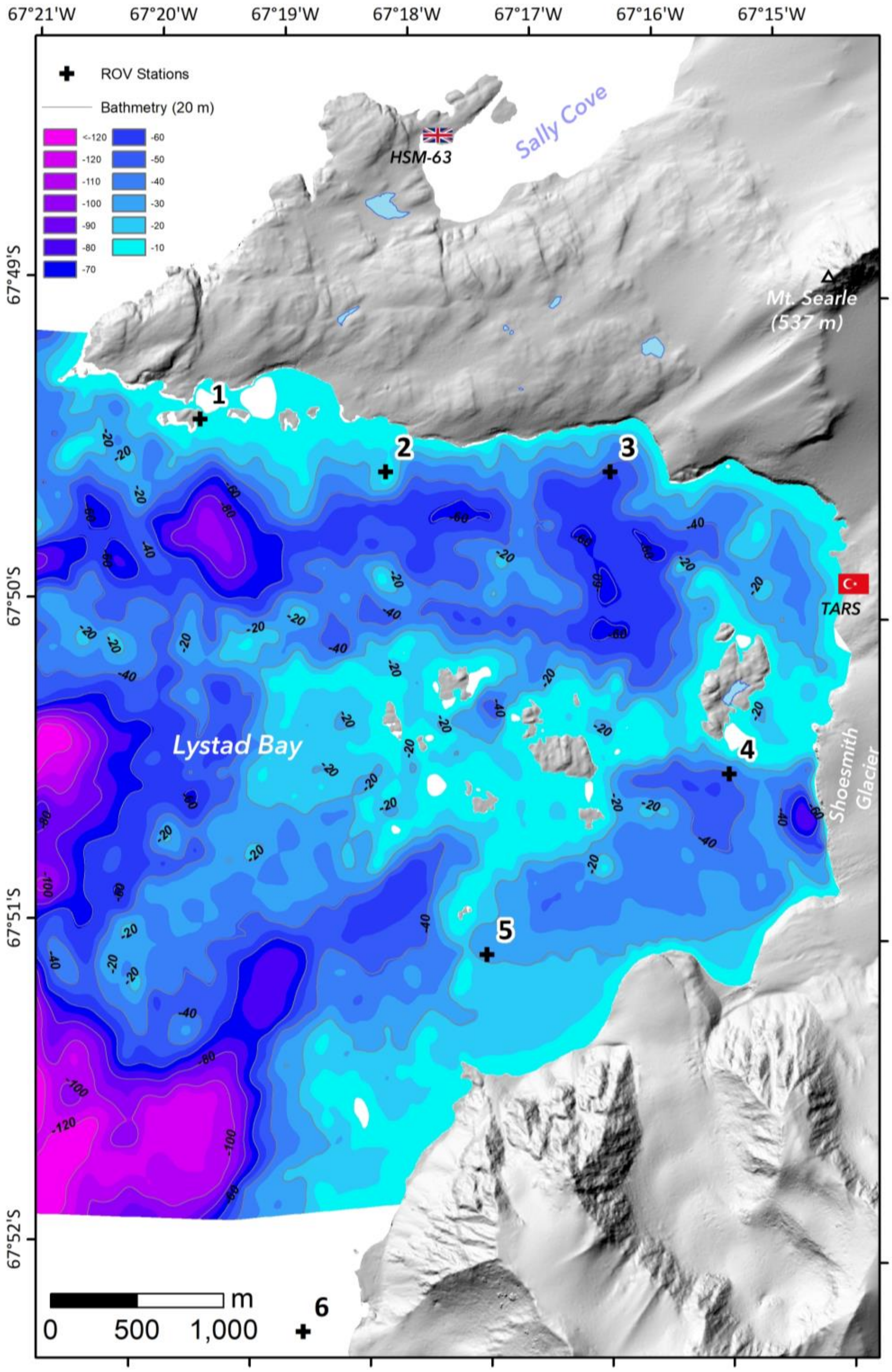


Figure 3. The topography and bathymetry map (Bathymetry data modified from Tükenmez *et al*., 2022 and Chart INT 9167, topography data from Howat *et al*. 2022) of the study area shows the video locations The depth of station 6 which is out the bathymetry data is 22 m.

tethered connection-even in intricate underwater settings. The V6 is ideal for prolonged underwater adventures because it can run for up to 4 hours on a single charge and has a 100-meter depth rating (QYSEA, 2021). With its exceptional video recording capabilities standing out as one of its main assets, these features make the QYSEA FIFISH V6 a flexible instrument for underwater research, film making, industrial inspections, and recreational exploration.

The Stages of the Video Recording Process

To understand the dimensions of video capture, resolution refers to the dimensions of a video frame, typically represented in pixels, such as 1920 by 1080. Higher resolutions provide more detail, allowing for clearer images, but require more processing power (Smith & Davis, 2020). The field of view (FOV) of a video is the observable area captured within the frame (Jones *et al*., 2019). A wider FOV can capture more of the scene but may cause some image distortion, particularly at the edges (Miller & Thompson, 2021).

The horizontal (FOV_h) and vertical components (FOV_v) of the FOV can be used to calculate the visible width and length of a scene:

$$\text{Visible width} = 2 \times D \times \tan(FOV_h/2)$$

$$\text{Visible length} = 2 \times D \times \tan(FOV_v/2)$$

where D is the distance from the camera to the reference point of the scene (Green & Patel, 2022).

Another important consideration in video capture is sea velocity measurement, which accounts for the difference in velocity between the air and sea. Objects in the sea appear closer by approximately 1/4 due to this velocity difference. This adjustment helps normalize the image when transitioning from airborne to underwater media (Jones & Lee, 2020).

Morphological Analysis of Species from Video Footage

The identification of genera and species was made by examining 22 screenshots, where the external morphological characteristics of the species were detailed, from the video recordings of the stations. The sources particularly utilized for species identification were evaluated with Fautin (1986), Clarke & Johnston (2003), Galea et al. (2009); Hibberd & Moore (2009), Schories *et al*. (2015), Schories & Kohlberg (2016), Mou et al. (2024), Brueggeman & Peter (2024), WoRMS Editorial Board (2024), Mou *et al*. (2024), URL-3, URL - 4, URL- 5.

To determine the species' frequency at the stations, Soyer's (1970) Frequency Index and Bellan-Santini's (1969) Dominance Index were used to determine the levels of dominance. To assess the diversity, homogeneity (in terms of individual count), and the similarity/difference between the benthic samples, Shannon-Weaver's Diversity Index (H'), Pielou's Evenness Index (J'), and Bray-Curtis' Similarity Index were employed. Using a matrix created with the similarity index, MDS analysis was performed, and the most important species driving similarity or difference between stations were identified using SIMPER analysis (Clarke and Warwick, 2001).

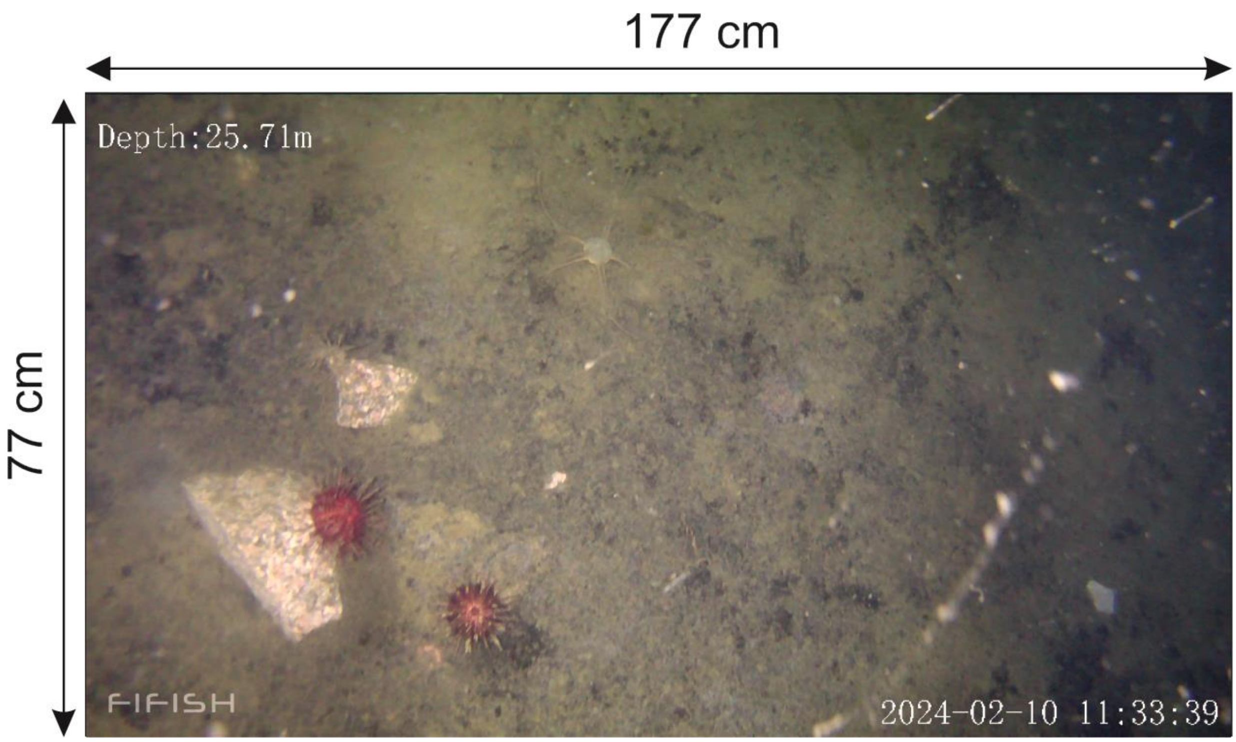


Figure 4. An example for calculated values and applied corrections for photo measurements.

Results and Discussion

The most prominent result of this study is that species diversity consistently initiates around a depth of 15 meters across all sampled stations. Substrate variability plays a crucial role in influencing species composition, with both species richness and diversity showing marked differences according to substrate type. Specifically, the distinct sedimentary characteristics, such as rocky versus sandy substrates, significantly impact the diversity of species identified.

The Species in the Epibenthic Fauna of Horseshoe Island

Antarctic research stations have the potential to exert significant impacts on marine benthic communities, with contaminant accumulation in marine sediments leading to alterations in community structure and reductions in biodiversity. Benthic community responses to anthropogenic disturbances exhibit regional variability, primarily due to differences in local community compositions. However, some responses and species are consistently observed as indicators or sensitive markers of disturbance, potentially facilitating rapid impact detection across regions. Evaluating the relative impact of research stations relies on a well-defined understanding of sampling effort and the potential for methodological bias.

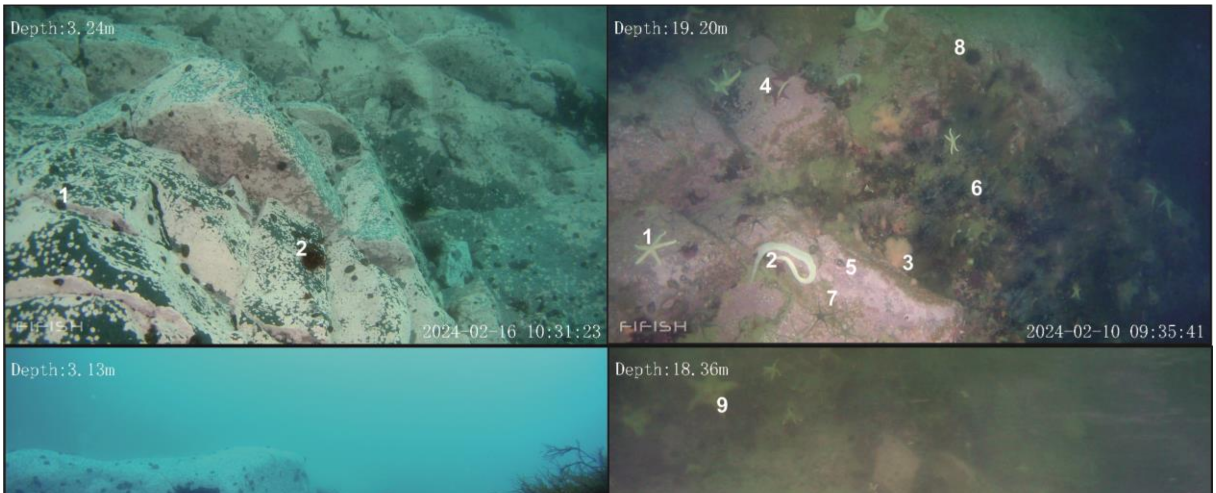
Based on these general results, the species identified at each station are presented in detail with the captured photographs. The resolution of the images and the differences between species are highlighted in Figures 5-8. Both substrate characteristics and species have been defined.

Examples of photographs from the first station are shown on the left side of Figure 5. The images from this station, located in the northwest of the bay, have an average depth of 3 meters. The substrate is covered with white rock blocks, and only two species were identified, with low density. The second station, located in the northern part of the bay, characterizes the area (Figure 5 right column). Although the seabed primarily consists of pink-colored rock blocks, sediments of sand and gravel size are present. The average water depth at this station is approximately 19 meters. Nine species have been identified in this area, and the abundance is higher in regions where relatively fine-grained sediments are found.

The third station (Figure 6), located in the northeast of the bay and with an average water depth of 22 m, is characterized by smaller, more scattered pink rock fragments on the substrate. At this station, the transition from rocky sand to muddy sand is mainly observed. Ten species have been identified in the area, and moderate coverage on the substrate has been detected. Compared to the first two stations, a higher number of species have been identified.

The fourth station (Figure 7), located in the eastern part of the bay, has an average water depth of 26 meters. The substrate consists of very sparse rock fragments, with the dominant sediment being sand-sized. The substrate coverage is very rare in this area, and species diversity is also quite limited. Despite being a deeper area, it can be suggested that a terrestrial influence and/or possible ice scouring controls this region.

Antarctic benthic communities exhibit structural complexity and appear to be resilient to seasonal disturbances, such as iceberg scouring and fluctuations



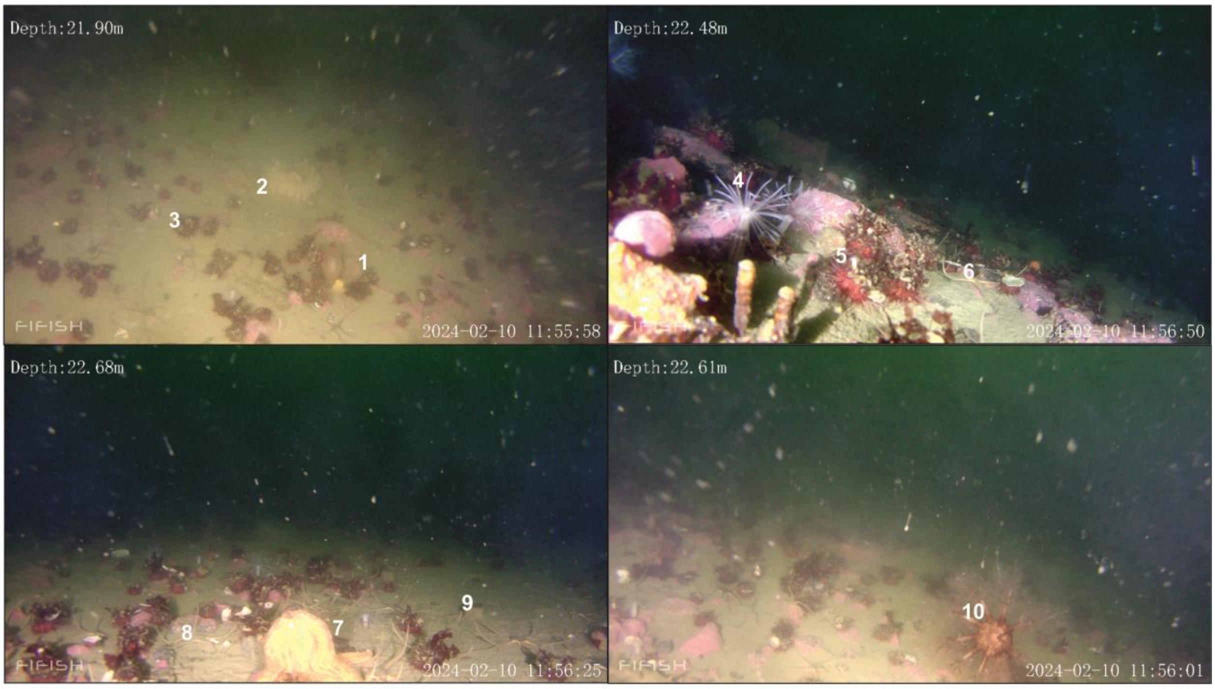
1-*Nacella concinna* 2-*Sterechinus neumayeri*

1-*Diplasterias* sp. 2- *Nemertea* sp. 3-*Gersemia* sp. 4- *Odontaster validus* 5- *Nacella concinna* 6- *Heterocucumis steineni* 7-*Ophionotus victoriae* 8-*Sterechinus neumayeri* 9-*Perknaster sp.*

Figure 5. Selected video captures from Station 1-2 (the photos at the left side are for Station 1, right side are for Station 2).

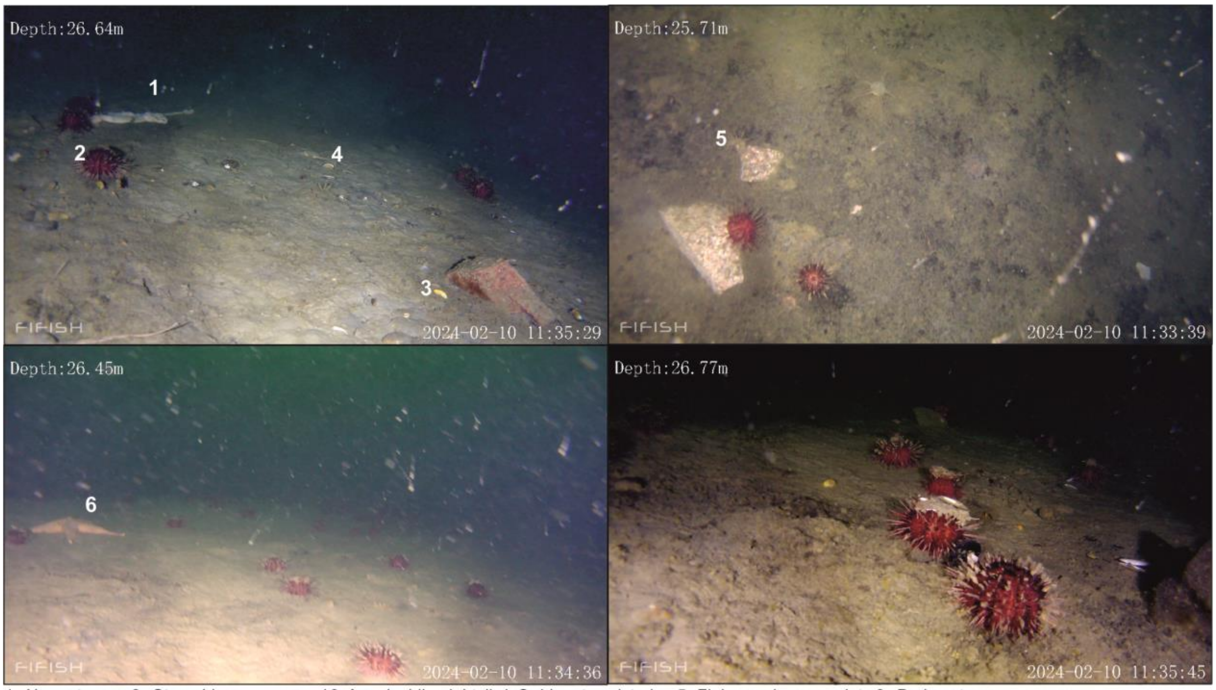
in light and temperature (Zwerschke *et al*., 2021; Sporta Caputi *et al*., 2024). In the short- to medium-term, these communities demonstrate a capacity for recolonizing disturbed habitats and rapidly exploiting newly available seasonal resources (Rossi *et al*., 2019; Caputi *et al*., 2020; Sporta Caputi *et al*., 2024).

The station 5 (Figure 8), located in the southeastern part of the bay, has an average depth of 26 meters; however, there is a significant depth variation in the imaging area compared to the other stations. While the average depth change at the other stations is around 1 meter, a 5 meter variation is observed in this area. Despite being approximately 2 km southwest of the fourth station with no significant depth difference, some areas exhibit up to 70% substrate coverage, and higher benthic structure complexity is present. Station 5, although characterized by relatively sparse coverage, exhibited high species diversity, setting it apart from the other stations.



1-*Corella antarctica* 2- *Urticinopsis antarctica* 3- *Sterechinus neumayeri* 4- *Edwardsia* sp. 5-*Hterechinus neumayeri* 6- *Ophionotus victoriae* 7-*Diplasterias brucei* 8- *Ophionotus victoriae* 9-*Agnezia biscoei* 10- *Heterocucumis steineni*

Figure 6. Selected video captures from Station 3.



1- *Nemertea sp.* 2- *Sterechinus neumayeri* 3-*Aequiyoldia eightsii* 4-*Ophionotus victoriae* 5- *Flabegraviera mundata* 6- *Perknaster sp.*

Figure 7. Selected video captures from Station 4.

Station 6, representing the southernmost point of the study area, is the deepest station (~ 34 m) in the sampling region (Figure 9). This area, characterized by the prevalence of mud-sized sediments, has the highest species count among all stations. The substrate coverage of benthic habitat is at a level of 40%. Notable flora coverage was observed in particular stations, with Station 6 emerging as the most biodiversity-rich site, exhibiting the highest species density per square meter.

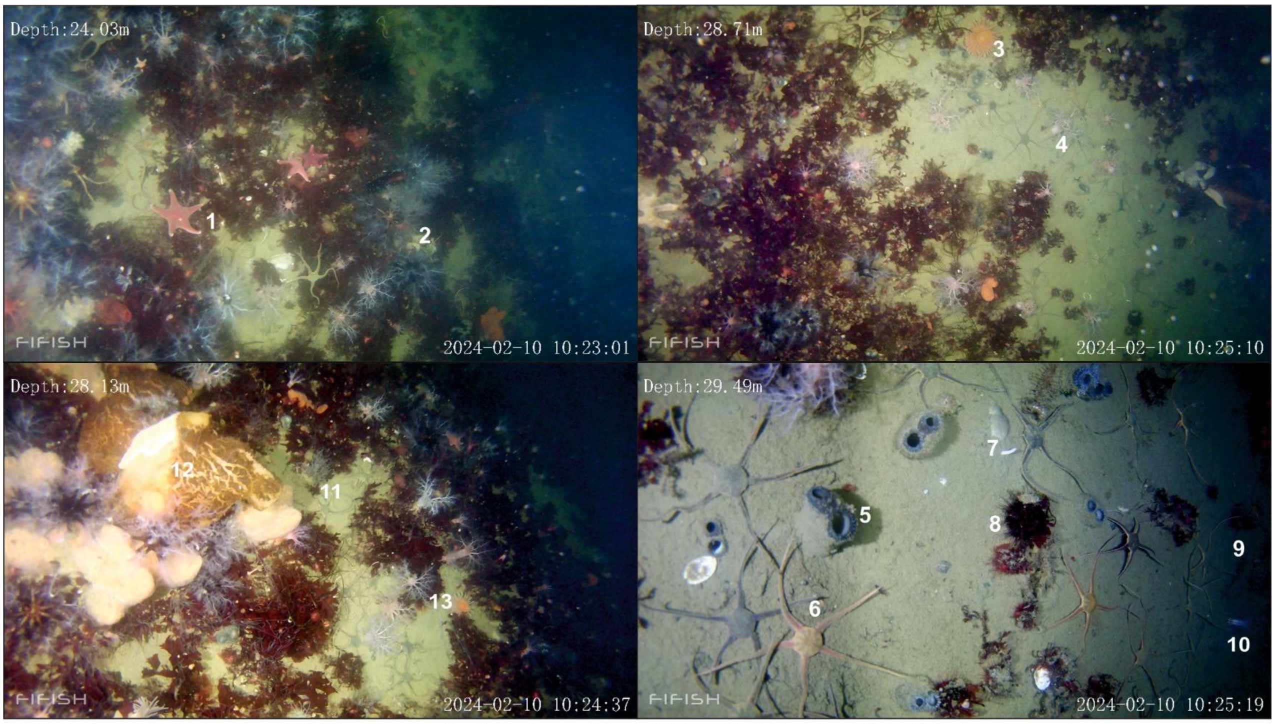
A total of 30 species from 6 phyla were identified in the epibenthic fauna of Horseshoe Island through the examination of video recordings (Table 1). To enhance the distribution and clarity of the species listed in the table, a graph has been created in Figure 10. The highest number of species was identified within the phylum Echinodermata (27%), while the fewest species were from the phyla Annelida and Nemertea (3%). The station with the highest number of species was Station 6 (20 species), while the station with the lowest number of species was Station 1 (2 species). The station with the highest abundance of individuals was Station 5 (1689 individuals per m²), and the lowest was Station 2.

Interpretation of Horseshoe Island's Epibenthic Fauna Diversity Using Diversity Indices

Shannon-Weiner diversity index (H'), Margalef richness index (d), and Pielou's evenness index (J') were calculated for all stations (Table 2). While the diversity of the species detected influences these index calculations, it was also found that the substrate differences and depths of the studied stations had a significant impact. The presence of rocky substrate and the depth limited to 5 meters at Station 1 were indicative factors contributing to its lowest values. Station 2, characterized by different habitat types and the detection of a species dominating the environment in large numbers, is considered the primary factor for the high index values recorded. Stations with higher species and individual counts are mostly found in sandy-mud habitats. At these stations, the abundance of certain species per square meter contributed to the lower diversity index values compared to Station 2. According to frequency index values, the most common species in the region were *Ophionotus victoriae*, *Sterechinus neumayeri*, *Heterocucumis steineni* (constant), *Edwardsia* sp., and *Nacella concinna* (common), with other species being rare. Based on dominance index values, the most dominant species in the region was *Ophionotus victoriae* (36.94%) (Table 1).

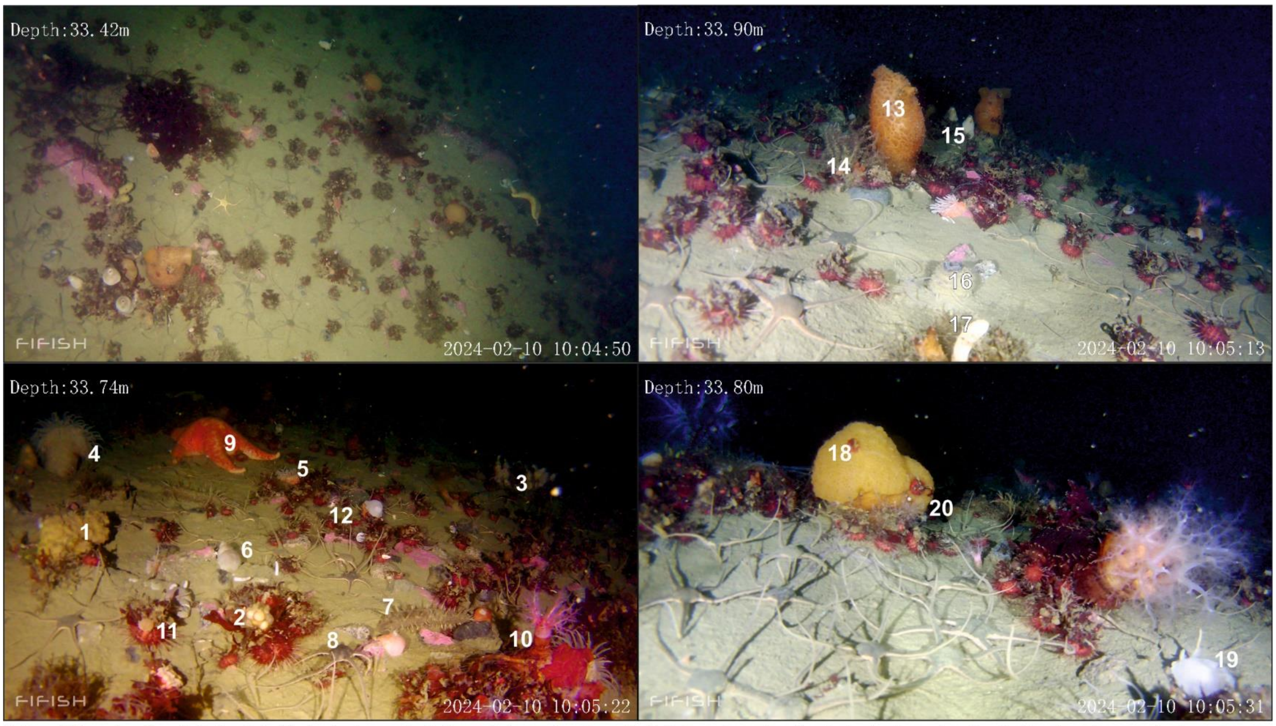
Based on the similarity analysis of abundance data, the MDS analysis also revealed three distinct groups with similar structures. Group A consists of Station 1, Group B includes Stations 2 and 4, and Group C includes Stations 3, 5, and 6 (Figure 11; Table 3). The 1st Station, represented by the fewest species, shows values that suggest it might be from a different region of the island and exhibits distinct differences, thereby supporting the geological differentiation in the formation process of Horseshoe Island. Even in the most similar stations, the value remained around 45%, which essentially characterizes the substrate differences of the area.

Considering all the results, the primary factors controlling the biodiversity in the bay can be identified



1-*Odontaster validus* 2-*Mycale sp.* 3-*Urticinopsis antarctica* 4- *Psolus sp.* 5-*Agnezia biscoei* 6-*Ophionotus victoriae* 7-*Neobuccinum eatoni* 8-*Sterechinus neumayeri* 9-*Flabegraviera mundata* 10-*Edwardsia sp.* 11-*Tenuisis microspiculata* 12-*Cnemidocarpa verrucosa* 13-*Isotealia antarctica*

Figure 8. Selected video captures from Station 5.



1-*Dendrilla antarctica* 2-*Antarctotetilla leptoderma* 3- *Sphaerotylus antarcticus* 4- *Urticinopsis antarctica* 5- *Isotealia antarctica* 6- *Neobuccinum eatoni* 7- *Flabegraviera mundata* 8- *Ophionotus victoriae* 9- *Perknaster sp.* 10- *Heterocucumis steineni* 11- *Sterechinus neumayeri* 12- *Adamussium colbecki* 13- *Cnemidocarpa verrucosa* 14- *Tenuisis microspiculata* 15- *Ascidiacea sp.* 16- *Agnezia biscoei* 17- *Haliclona sp* 18- *Hemimycale topsenti* 19- *Doris kerguelenensis* 20- *Edwardsia sp.*

Figure 9. Selected video captures from Station 6.

Table 1. Species list of selected video captures from stations and their average abundances (ind. m^{-2}) per station dominance (D%) and frequency values (F%)

Phylum	Class	Species	1	2	3	4	5	6	%F	%D
Nemertea		*Nemertea sp.*		0,4		0,06			4,55	0,15
Porifera	Demospogiae	*Holiclona* Grant, 1841						2	4,55	0,09
Porifera	Demospogiae	*Mycale* sp. Gray, 1867					10		4,55	0,43
Poifera	Demospongia	*Dendrilla antarctica* Topsent, 1905						2	4,55	0,09
Poifera	Demospongia	*Hemimycale topsenti* (Burton, 1929)						4	4,55	0,17
Poifera	Demospongia	*Antarctotetilla leptoderma* (Sollas, 1886)						6	4,55	0,26
Poifera	Demospongia	*Sphaerotylus antarcticus* Kirkpatrick, 1907						21	4,55	0,90
Cnidari	Anthozoa	*Urticinopsis antarctica* (Verrill, 1922)			0,33		1	2	9,09	0,13
Cnidari	Anthozoa	*Edwardsia sp.* Quatrefages, 1842			7,77		23	4	36,36	1,88
Cnidari	Anthozoa	*Isotealia antarctica* Carlgren, 1899					1	4	9,09	0,22
Cnidari	Anthozoa	*Tenuisis* microspiculata (Molander, 1929)					1	2	9,09	0,13
Cnidari	Anthozoa	*Gersemia sp.* von Marenzeller, 1878		0,4					4,55	0,02
Mollusca	Gastropoda	*Nacella concinna* (Strebel, 1908)	77	1					27,27	3,36
Mollusca	Gastropoda	*Neobuccinum eatoni* (E. A. Smith, 1875)					71	6	9,09	3,32
Mollusca	Gastropoda	*Doris kerguelenensis* (Bergh, 1884)						4	4,55	0,17
Mollusca	Bivalvia	*Aequiyoldia eightsii (Jay, 1839)*				28,63			13,64	3,14
Mollusca	Bivalvia	*Adamussium colbecki* (Smith, 1902)						2	9,09	0,09
Annelida	Polychaeta	*Flabegraviera mundata* Gravier 1906				0,06	23	11	13,64	1,47
Echinodermata	Asteriodea	*Odontaster validus* Koehler, 1906		1			8		4,55	0,39
Echinodermata	Asteroidea	*Diplasterias brucei* (Koehler,), 1907			3,33				4,55	0,04
Echinodermata	Asteroidea	*Diplasterias sp.* Perrier, 189		2,4					13,64	0,10
Echinodermata	Ophiuroidea	*Ophionotus victoriae* Bell, 1902		3	2,35	4,63	739	92	86,36	36,94
Echinodermata	Holothuroidea	*Psolus sp.* Oken, 1815					215		13,64	9,26
Echinodermata	Asteriodea	*Perknaster sp.* Sladen, 1889		1		0,06	8	6	9,09	0,69
Echinodermata	Echinidea	*Sterechinus neumayeri* (Meissner, 1900)	1	1	98	25,15	167	146	68,18	18,87
Echinodermata	Holothuroidea	*Heterocucumis steineni* (Ludwig, 1898)		1	3,33		226	8	86,36	10,22
Chordata	Ascidiacea	*Corella antarctica* Sluiter, 1905			0,61				9,09	0,01
Chordata	Ascidiacea	*Agnezia biscoei* Monniot & Monniot, 1983			6,66		144	6	22,73	6,75
Chordata	Ascidiacea	*Cnemidocarpa verrucosa* (Lesson, 1830)					2	11	9,09	0,56
Chordata	Ascidiacea	*Ascidiacea* sp.						4	4,55	0,17

as substrate structure, water depth, the depth to which winter sea ice reaches the water, possible inputs from terrestrial areas to the marine environment, and the oceanographic effects they create in the marine area. On rocky substrates, epibenthic fauna diversity is generally limited, whereas this density increases on finer-grained substrates. In the study by Vardar *et al*. (2025), the substrate parameters of the study area were determined, and it was suggested that glaciers formed in winter reach an average water depth of around 15 meters, based on the distribution of deformation and accumulation areas. However, the observations from the video images suggest that biodiversity tends to increase at depths below 19 meters. Studies have indicated that such biodiversity can recover over 10 years (Conlan & Kvitek, 2005; Zwerschke *et al*., 2021). Based on the findings of this study, it can be inferred that there is no glacial effect on the seafloor at depths below 19 meters in the bay for at least 10 years. On the other hand, at Station 4, although the depth is approximately 26 meters and the seafloor is suitable for benthic habitats, very few species were detected. However, in Station 5, located just 2 km southwest of Station 4, where the water depth and substrate characteristics are similar, the species detected are denser, as indicated by the indices. This suggests that Station 4 is likely to be affected by a different system than normal conditions. Studies in the area have reported the destructive effects of ice scouring on benthic communities (Barnes, 2017; Sahade *et al*., 2015). Zwerschke *et al*. (2021), in Figure 1a, show a photograph of how an iceberg affects a local area. Therefore, an important finding of this study is that in areas close to those directly affected by icebergs, benthic community formation and development systems continue to operate. In normal years, at Ryder Bay, Adelaide Island, on the Antarctic Peninsula, approximately 24% of the shallow seafloor is impacted by ice-scouring events, but exceptionally high rates of ice-scouring (up to 50% per year) were observed along the West Antarctic Peninsula between 2007 and 2009 (Barnes *et al*., 2014). In light of this information, it can be suggested that an ice scour effect exists within the area surrounding Station 4. However, the precise causes of the formation in this local area remain a significant research question. The authors of this study propose, as

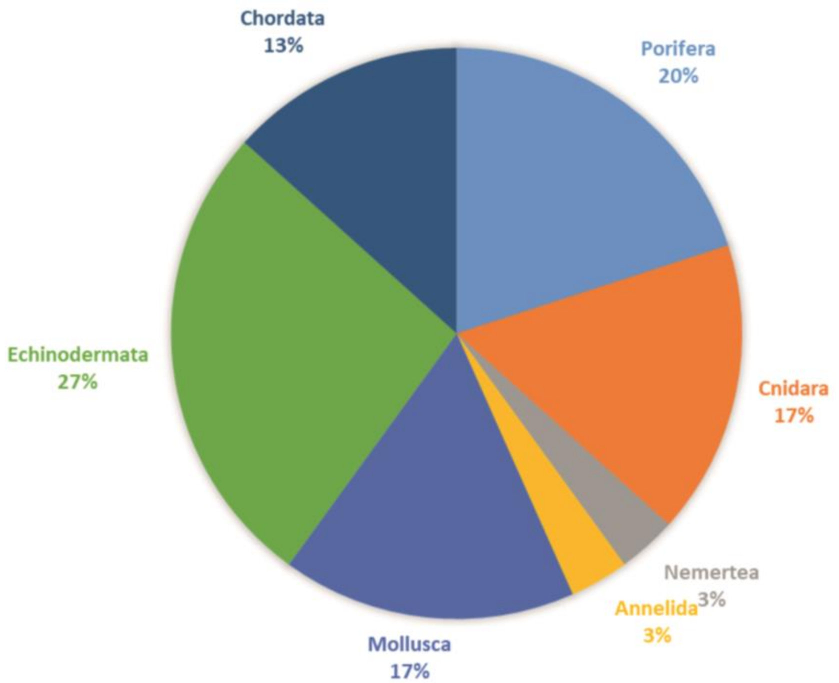


Figure 10. The distribution of the phylum in the epibenthic fauna of Horseshoe Island.

Table 2. The number of species(S), individuals(N), Margelef species richness (d), the diversity (H')and evenness index values (J') at each stations

Station	S	N	d	J'	H'(log2)
1	2	78	0,2295	0,0989	0,0989
2	9	11	3,311	0,91	2,885
3	8	142	1,412	0,4921	1,476
4	6	109	1,066	0,5153	1,332
5	15	1639	1,891	0,6299	2,461
6	20	343	3,255	0,6304	2,724

a valuable interpretation of the research, that a terrestrial input has affected the local salinity and temperature of the seawater, leading to a density difference that generates outflow currents. It is also highly likely that these physical variables have influenced the formation and thickness of the ice, contributing to the differences in epibenthic fauna as a natural consequence.

This study aimed to detect macroscopic epibenthic organisms that could be reached within the camera's field of view. The species/genera determined generally consist of slow-moving or sessile species. On the other hand, Arthropoda members consist of light-sensitive and fast-moving species. Since most of these species are light-sensitive cryptic species and know how to hide well, it is highly likely that they quickly left the camera's field of view.

The seasonal or multi-year data should be provided in the further studies to gain this study's importance. Even while it offers insightful short-term observations, longer time periods will be very important to fully reflect the dynamic character of benthic communities. One of the study's strong points is the application of contemporary methods, like underwater drone photography. However, the ecological interpretation of the results is limited due to the lack of observations for ambient characteristics such as oxygen levels, salinity, and water temperature.

Conclusions

In this study, the epibenthic communities of Lystad Bay (Western Horseshoe Island, Western Antarctica) were identified at six selected stations, considering different depths and sediment characteristics, using underwater video imaging techniques. The high resolution of the images allowed for the determination of habitat coverage, the presence of dominant species,

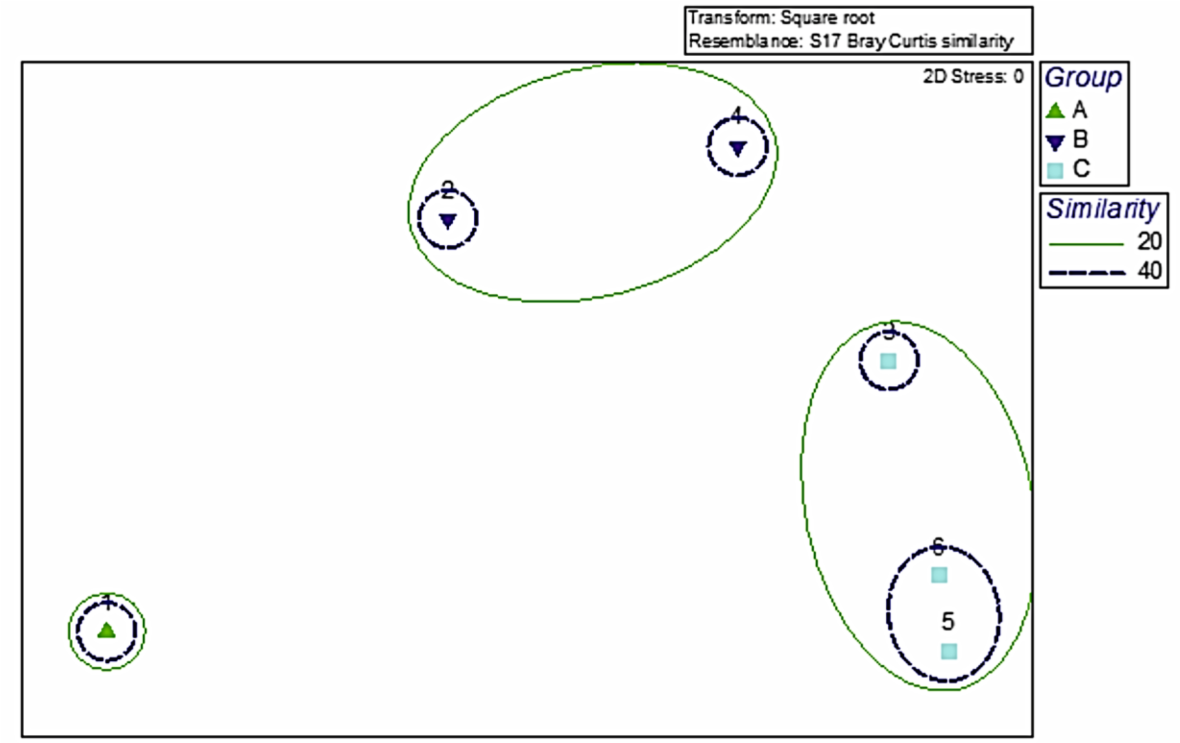


Figure 11. Results of MDS analysis, based on Bray-Curtis Similarity Index.

Table 2. Within-group similarities, between-group dissimilarities, and species contribution (%) resulting from the SIMPER analysis of station groups

	Similarity		Dissimilarity		
GROUPS	B	C	AB	AC	BC
Similarity - Dissimilarity %	30.42	42.43	86,19	96,56	80.90
Ophionotus victoriae	39.68	20.96	10.21	16.49	14,46
Perknaster sp	22.91				
Sterechinus neumayeri	22.91	40.12		17.73	15,98
Edwardsia sp.		10.10			
Nacella concinna			40.94	15.62	
Aequiyoldia eightsii			17.13		
Agnezia biscoei					8.02

and the interpretation of the seabed-species relationships using indices. After correcting for angular differences in the photos taken from the video footage, the Field of View (FOV) was calculated, enabling an analysis of the areas covered. Based on these areas, potential factors influencing this diversity and interpretations using different indices, were discussed. In general, this study demonstrates that diversity is low on rocky substrates and shallow depths, while species and individual numbers are higher in relatively deeper and more sandy-muddy habitat types. The video footage showed that diversity increased below 19 m depth, compared to other areas. In particular, the data obtained from station 4, which showed differences from the other stations, suggested the presence of an ice scour effect as a local factor. A detailed investigation of the hydrographic and oceanographic conditions that may have caused this effect has emerged as an essential scientific question for future research following this study.

Two further studies are recommended for future research. Firstly, there is a need to further explore the ecological significance of the findings, with particular attention to the variables influencing biodiversity at different substrate types and depths. Secondly, additional research is necessary to ascertain the impact of ice scouring on Station 4.

Ethical Statement

We hereby declare that the research reported in this manuscript titled "A New Interpretation of the Dominance and Diversity of Horseshoe Island (Antarctic Peninsula) Epibenthic Communities" was conducted in compliance with the highest ethical standards.

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Author Contribution

The first author collected video footage in the field, did the video processing and contributed to the writing. The second author identified the species from the video footage, performed all statistical calculations, contributed to the manuscript. 3rd author took part in field work, contributed to the figures, contributed to the manuscript. 4th author contributed to manuscript editing, research design, analysis interpretation, manuscript writing. 5th author contributed to fieldwork, writing and editing of the manuscript.

Conflict of Interest

The authors hereby declare that they have no conflicts of interest to disclose in relation to this work.

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