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Abstract: A free-fall baited camera lander was launched for the first time on the Cosmonaut Sea shelf of East Antarctica at the depth of 694 m during the 38th Chinese National Antarctic Research Expedition (CHINARE) in 2022. We identified 31 unique taxa (23 of invertebrates and 8 of fishes) belonging to 8 phyla from 2403 pictures and 40 videos. The Antarctic jonasfish (*Notolepis coatsi*) was the most frequently observed fish taxa. Ten species of vulnerable marine ecosystem (VME) taxa were observed, accounting for 32% of all species. The maximum number (MaxN) of *Natatolana meridionalis* individuals per image frame was ten, and they were attracted to the bait. The macrobenthic community type was sessile suspension feeders with associated fauna (SSFA), which was shaped by the muddy substrata with scattered rocks. Rocks served as the best habitats for sessile fauna. The study reveals the megafauna community and their habitat by image survey in the Cosmonaut Sea for the first time. It helped us obtain Antarctic biodiversity baselines and monitoring data for future's ecosystem health assessment and better protection.

Keywords: Lander; Cosmonaut Sea; megafauna; Antarctica; image survey

1. Introduction

The Southern Ocean is unique among the world's oceans in terms of its linkage with the other major ocean basins, its rich and unusual marine ecosystem, and its interaction with the physical climate system and the biogeochemistry of the region [1]. It comprises 15% of the world's oceans and is home to thousands of endemic species [2–4]. The Southern Ocean has become a hot area for global research on climate change and ecological evolution due to its harsh natural environment, fragile ecosystem, and sensitivity to environmental variations. There is a growing need for marine biodiversity baselines and monitoring data to assess ocean ecosystem health, especially that around Antarctica where data are rare [5–8].

The Cosmonaut Sea (30°~60°E) is located to the west of Enderby Land in east Antarctica, and has been poorly explored [9]. Therefore, very few biological data have been recorded for the region [10–13], and existing ones mainly include the composition and distribution of phytoplankton, mesozooplankton, euphausiid larvae, krill, squid and Antarctic jonasfish [14–16]. But there is still no data about macrobenthos in the Cosmonaut Sea. Antarctic benthic ecosystems in the Cosmonaut Sea may be sentinels for monitoring the effects of climate change [17,18]. Macrobenthic communities in Antarctica differ in biodiversity and ecosystem functioning and are shaped by a variety of physical and biological drivers [19]. Some of these communities are unique in their occurrence and proportions of species and life forms. Some are typical for the entire Antarctic shelf but never occur with exactly the same proportions or compositions [18].

Trawls, sledges, and dredges are historically the common facilities for sampling the shelf benthic marine communities of Antarctica [12,20,21]. These traditional methods can help understanding the structure and function of the Antarctic benthic systems and are good for species identification of slow-moving macrobenthos. However, they cannot describe species behaviors and interactions, and have difficulty in capturing more mobile species [4]. Video surveys are the emerging methods to estimate the relative abundances of scavenging fishes and invertebrates [8,22,23]. Such studies can help us develop a better understanding of ecosystem patterns and processes in Antarctica, such as the Antarctic Peninsula, Prydz Bay and the Amundsen Sea, and the applicability has also been justified [4,24–27].

In this study, a free-fall baited camera lander was deployed for the first time on the Cosmonaut Sea shelf during the 38th Chinese National Antarctic Research Expedition (CHINARE) on 22 February 2022. The objective is to preliminarily survey fish and invertebrate communities, and basically understand the structure of the benthic community and the interactions among species on the Cosmonaut Sea shelf.

2. Method and Equipment

2.1. Location

The lander was deployed on the shelf (48°50.980′E, 66°22.226′S) near the slope of the Cosmonaut Sea (Figure 1). The Cosmonaut Sea is the site of an important confluence in polar circulation, but poorly investigated, meriting more research efforts [9].

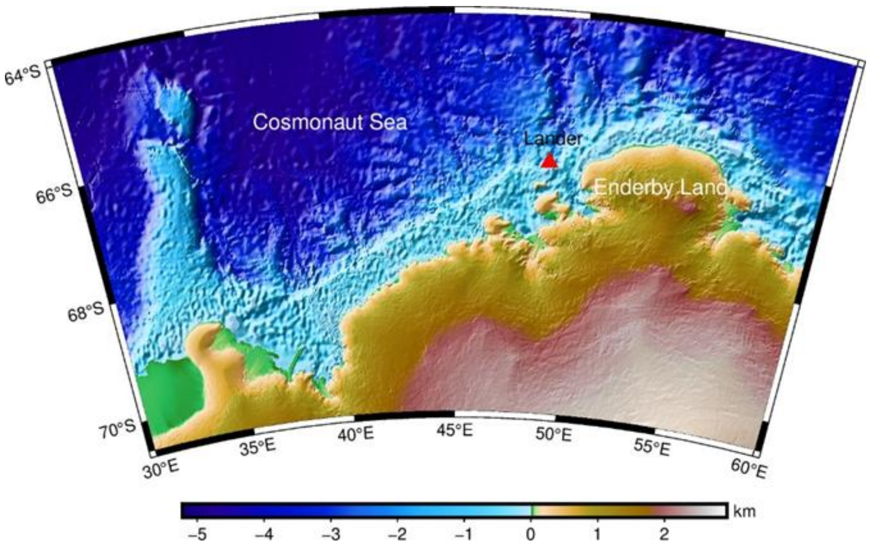

Figure 1. Sampling station of the lander.

2.2. Equipment

The lander system framework is made of titanium, consisting of batteries, an acoustic releaser, cameras, and traps (Figure 2). The batteries are rechargeable lithium battery combined with capacity greater than 96 Ah. The releaser is manufactured by iXblue. The load and communication distance of the iXblue releaser are not less than 2500 kg and 10 km, respectively. iXblue is powered by a No.1 alkaline battery or lithium battery. The Sea-Bird Scientific SBE 37 is equipped with high-accuracy temperature, conductivity and pressure sensors with an RS-232 interface, internal batteries, data storage and pump. The sampling interval was set to 120 seconds and the maximum observation depth was 7000 m. Two cameras were configured: one (CO01-016E, 3648×2736) was used to take photos,

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and the other (CO02-016HE, HD1080P) was used to record videos. The lander used a high efficiency LED lamp (CO04-50LI-6000AA), and the light was angled downward at a constant 45°from the horizontal plane. Two traps were used in the study: a large fish and invertebrate trap (82 cm × 47 cm × 47 cm), and invertebrate trap (φ10 cm × 50 cm).

Figure 2. Structure of the free-fall baited camera lander.

2.3. Deployment Process

The lander was deployed and recovered during the 38th CHINARE on the R/V Xuelong2 icebreaker, to a depth of 694 m. The equipment was deployed at 20:09 and landed on the sea floor at 20:26 on 22 February 2022 (UTC).

The lander deployment process had four stages: setup, deployment, recovery and data exporting. Prior to deployment, the cameras were activated through underwater systems by a computer. The camera was preprogrammed to take 1 picture every 30 sec, and the video camera was preprogrammed to take 10 min of video every 30 min. The survey time was set according to the battery charging time. Then, baits (chicken legs and *Silver sillago*) were loaded into the traps. The last step was connecting the acoustic releaser to the cement block. Deployment was completed, and the lander was dropped into the sea. The dropping rate was approximately 1 m/s. Location and bottom depths were based on triangulation of the acoustic releases after the deployment [28]. The lander was recovered in the daytime when the sea was calm. The ship travelled to the deployment area for lander recovery. To recover the lander, the deck unit was used to search for the signal from the acoustic releaser, and the distance between the equipment and the ship was measured. Then, the deck unit released the signal to recover the lander. The rising rate was approximately 1 m/s. The crew searched for the lander, which was attached to orange balls from the bridge. Finally, the equipment was found and brought up onto the deck.

The lander was washed using fresh water after being placed on the deck. Then, the samples were collected from the trap cage. Following retrieval, an external hard disk was used to store the images and videos from the cameras, and the data from SBE 37 for further analysis.

2.4. Metrics and Biodiversity Analyses

Annotations were made from the video footages to identify species to the highest taxonomic resolution [8]. A relative abundance metric-the maximum number (MaxN) was used in the video survey. Counts of MaxN for individuals of each species in a video frame were performed rather than the total tally per deployment to avoid double-counting [29]. Other variables were also recorded, such as the time for a taxon's first arrival of, and the time when the maximum number of a taxon was observed upon the landing of the device on the seafloor [8,23,30].

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3. Results

A total of 2403 photos and 40 videos were recorded underwater by the lander during approximately 20 hours.

3.1. Substrate Type

The images were used to determine substrate characteristics. The transect was dominated by muddy substrate containing some rocks. The rocks were scattered on the sea floor, and served as substrata for different species, such as sponges, bryozoans and corals. These species, in turn, served as living substrata for ophiuroids, asteroids, holothurians and others (Figure 3).

Figure 3. Substrate type of the Cosmonaut sea shelf.

3.2. Observation of the Hydrological Environment

The SBE 37 started to record data on salinity, temperature and pressure at the bottom at 21:00. The pressure was relatively stable with the average of 701.081 dbar and increased slowly during the whole observation period. The highest pressure was 701.545 dbar at 16:06, and the lowest one was 700.542 at 23:42. The average value of salinity and temperature was 34.6096 psu and 0.1091 °C, respectively. The highest salinity was 34.6446 psu at 5:42, and the highest value of temperature was 0.1584 °C at 8:20. Salinity and temperature varied strongly (Figure 4) with a sharp fall at 13:00. The salinity reached its lowest value (34.5511 psu) at 13:42. The temperature reached its lowest value (-0.0478 °C) at 13:32. The lower temperature and salinity lasted approximately one hour, and they quickly increased at 2:20 p.m. Data here may imply that there was a low-temperature and low-salinity water mass passing over the bottom.

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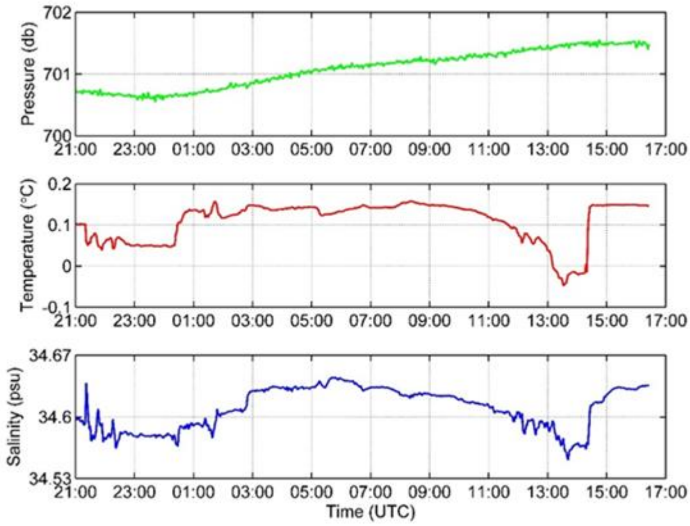

Figure 4. Data collected by the SBE 37 recorder.

3.3. Recorded Taxa

Thirty-one species were identified, representing 8 phyla, 20 orders and 30 families (Table 1). Invertebrates accounted for 23 species, and fishes accounted for 8 species. Bryozoa dominated in the images (Figure 5).

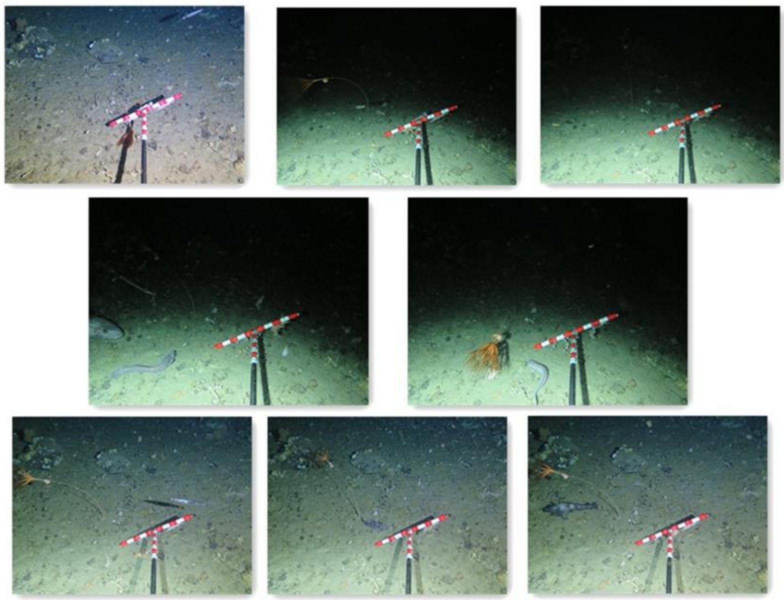

Figure 5. Fish images from the shelf of Cosmonaut Sea.

Three fish were the most frequently occurring fish taxa. *Notolepis coatsi* appeared in 37 videos with even up to 4 individuals in one frame, *in* 29 of 2403 photos with up to 3 individuals in one photo. *Trematomus lepidorhinus* was found in 16 of 40 videos, and 809 of 2403 photos. *Melanostigma gelatinosum* appeared in 117 of 2403 photos. *Dissostichus mawsoni* was recorded only once by the cameras at 3:35, 23 February 2022.

Ten species of VME (vulnerable marine ecosystem) taxa were observed, accounting for 32% of all species. VME taxa include sponges, sea mats and cold-water corals, which can provide important

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habitat for a diversity of marine organisms [31]. Sea pens, sea anemones and sea squirts were the VME taxa commonly observed (Table 1).

Table 1. Maximum number (MaxN) of individuals of each species.

Phylum	Order	Family	Genus species	MaxN	VME
Porifera	Demospongiae		Demospongiae und.	1	✓
Cnidaria	Scleralcyonacea	Umbellulidae	*Umbellula carpenteri*	1	✓
		Mopseidae	*Primnoisis* sp.	1	✓
	Actiniaria	Actinostolidae	*Stomphia* sp.	2	✓
	Scleralcyonacea		Scleralcyonacea und.	3	✓
Mollusca	Neogastropoda	Cancellariidae	*Nothoadmete* sp.	4	
		Cochlespiridae	*Aforia* sp.	1	
	Elasipodida	Psychropotidae	*Psychroteuthis glacialis*	1	
Arthropoda	Euphausiacea	Euphausiidae	*Euphausia superba*	5	
	Decapoda	Thoridae	*Lebbeus* sp.	1	
		Nematocarcinidae	*Nematocarcinus lanceopes*	1	
	Isopoda	Cirolanidae	*Natatolana meridionalis*	10	
	Amphipoda	Uristidae	*Abyssorchomene* sp.	13 (trap)	
Echinodermata	Velatida	Pterasteridae	*Pteraster* sp.	1	
	Paxillosida	Astropectinidae	*Psilaster charcoti*	1	
	Ophiurida	Ophiopyrgidae	*Ophioplinthus* sp.	5	
		Ophiacanthidae	Ophiacanthidae und.	1	

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	Crinoidea		Crinoidea und.	1	✓
Bryozoa	Cyclostomatida	Horneridae	Horner sp.	10	✓
	Cheilostomatida		*Austroflustra vulgaris*	6	✓
		Cellariidae	*Melicerita obliqua*	1	✓
Brachiopoda	Terebratulida	Terebratulinae	Terebratulinae und.	1	
Chordata	Aplousobranchia	Polyclinidae	Polyclinidae und.	2	✓
	Perciformes	Nototheniidae	*Dissostichus mawsoni*	1	
			Trematomus lepidorhinus	1	
		Zoarcidae	*Melanostigma gelatinosum*	2	
		Artedidraconidae	*Pogonophryne* sp.	1	
		Channichthyidae	*Chionobathyscus dewitti*	1	
			Perciformes und.	1	
	Myctophiformes	Myctophidae	*Gymnoscopelus* sp.	1	
	Aulopiformes	Paralepididae	*Notolepis coatsi*	4	

Nothoadmete sp. was firstly observed at 21:09, and the MaxN per image frame was four. *Natatolana meridionalis* was observed at 9:17, and the MaxN per image frame was ten. These two species were the main ones influencing the MaxN of individuals per image frame each hour.

The species caught in the traps were Isopoda (*N. meridionalis*), Amphipoda (*Abyssorchomene* sp.) and fishes (*N. coatsi*) with 9, 13 and 3 individuals, respectively.

4. Discussion

4.1. Substrate Type and Assemblages

Seabed imagery was used to determine substrate characteristics. Substrate type and water depth have frequently been associated with the distribution of benthic biota on the Antarctic shelf [32,33]. Muddy substrate with scattered rocks was found in this study. Many rocks may be dropstones from

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iceberg scouring [33]. Rocks were found to serve as substrata for sessile taxa, such as sponges, bryozoans and corals. These species, in turn, served as living substrata for ophiuroids, asteroids, holothurians and others in this survey. Rocks are important for building benthic communities, and they provide a hard attachment site and an elevated position off the bottom enhancing the food supply for sessile suspension feeders, such as sponges, bryozoans, pennatulaceun, and actiniae [32]. Deposit feeders are often associated with soft substrates where they are able to feed on fine particles [34]. Amphipods were associated with muddy substrates from the images recorded, and the phytodetritus in muddy substrates may be the food source for them.

4.2. Hydrological Environment and Assemblages

Meijers et al. [9] found seasonal Antarctic Bottom Water (AABW) produced in the region (60°E), which moved down the slope and was deflected westward due to the Coriolis force. The mass water mixed with Antarctic Circumpolar Current (ACC) and Weddell Gyre waters above it as it moved westward across the regions 30°E、40°E and 50°E，eroding the strong characteristics observed in the region (60°E). Lowered acoustic Doppler current profiler (LADCP) data showed that the bottom water had large velocities near the deployment area [9]. The different postures of *U. carpenteri* showed high-strength and disordered current at the bottom. The current at the bottom brought a large number of organic debris, which provided the food source for sessile suspension feeders, such as sponges, colder-water corals and sea pens. This was important for structuring the benthic community.

4.3. Comments on Fishes and Invertebrates in Images

Notolepis coatsi was the most frequently encountered fish taxon and the second-largest fish biomass in the Cosmonaut Sea of this study like that in Prydz Bay [15,16]. It is a midsize bathypelagic fish widely distributed around the Antarctic continental shelf [16]. *N. coatsi* may feed only on krill [35] and account for 50% of the food consumed by Antarctic fur seals (*Arctocephalus gazella*) [36]. Therefore, *N. coatsi* plays an important role in the marine food web, which directly links krill and marine mammals in the Southern Ocean. *N. coatsi* is regarded as an ideal organism to evaluate the role of the Cosmonaut Sea, because of its large population size, position in the food web and specialized diet [16]. Additionally, we not only explored *N. coatsi* behavior, but also trapped the individuals using the lander.

Dissostichus mawsoni was observed by photographic survey for the first time in the Cosmonaut Sea and is a large nototheniid species endemic to the Antarctic continental shelf. The Antarctic toothfish is an important fishery resource in the Southern Ocean and plays an important role in Antarctic ecosystems [11]. Sufficient data and stock information are needed to establish fisheries, but such information is rare in the Cosmonaut Sea. The lander can help us assess the relative abundance and population size structure of the Antarctic toothfish in the Cosmonaut Sea.

In total, 10 VME taxonomic categories were observed from the lander imagery, accounting for 32% of all species. The VME taxa distributed sparsely, and most of them lived on rocks. The presence of benthic invertebrates contributes to the creation of complex three-dimensional structures and provides substrata for other organisms called sessile suspension feeders with associated fauna (SSFA) [32,33]. The main sessile suspension feeders recorded in this survey were Bryozoa. Associated fauna included Ophiuroidea, Asteroidea, Gastropoda, Isopoda and others. Isopoda and Amphipoda were the main taxa in the trap, so the bait is possibly attractive for them. *Natatolana meridionalis* firstly arrived at the bait fifty-one minutes after the lander arrived at the seafloor. The bait was consumed for approximately eight hours until it was fully exhausted. Data from the lander can help assess changes in benthic community diversity and their associated habitat structure.

4.4. Observation Advantages and Limitations of the Lander

A major advantage of the lander is that it can explore fauna behavior, including the interactions between species. It is a powerful tool for the detection of rare predatory fish species [37], which are difficultly found through physical sampling. The structure of the community should be visually determined to better understand vulnerable marine ecosystems. The lander thus allows us to clarify anthropogenic impacts, such as fishing and climate change. Also, the density of data for macrobenthos is low, especially in the Cosmonaut Sea. Although traditional trawling is advisable for the collection of all faunal types for higher resolution taxonomic investigations, the lander adds an existing monitoring program to extend biological observing capacity into the Antarctic Ocean [8]. Moreover, the lander is an unnamed vehicle that falls to the seafloor unattached to any cable, subsequently operating autonomously at the bottom, and it can carry diverse instruments for environmental parameter collections [38].

However, the lander cannot acquire images of small sessile fauna (meiofauna, infauna). Quantitative analysis like density per unit cannot be achieved, and only the relative measures of abundance (MaxN) can be applied at this moment. As the lander could help to better understand the current spatial variability on the Cosmonaut Sea shelf fauna, data here would serve as a supplement of the baseline for future comparisons [4].

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Availability of data and material: Not applicable.

Ethics approval: Although our research was about benthos in the Antarctica, all the data were from the images of the lander. Therefore, we believe an ethical review process was not required for our study.

Code availability: Not applicable.

Consent to participate: Informed consent was obtained from all individual participants included in the study.

Consent for publication: Not applicable.

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