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Taxocene of pelagic copepods in coastal waters of the Argentine Islands, West coast of the Antarctic Peninsula, in 2021—2022

Abstract. Pelagic ecosystems are changing in response to the recent climate warming. The mesozooplankton and copepods in particular are important indicators of the state of aquatic ecosystems. Zooplankton in Antarctic waters has been monitored regularly to study biodiversity, food chains, and ecological cycles. In 2021—2022, pilot study of mesozooplankton groups was added to the marine biological research of the Ukrainian Antarctic Program. The preliminary information was obtained on the taxonomic composition and functional characteristics of the taxocene of copepods in the coastal waters of the Argentine Islands. The observed diversity is strongly influenced by the conditions and the available sampling gear. The samples were collected from motor boats using three kinds of plankton nets depending on the weather and ice conditions. From June to February, the predominant species were the common coastal species and species adapted to feeding in the cold upper layers in winter. Trawling samples collected from March to late May best illustrate the seasonal dynamics of the mesozooplankton communities' temporary and permanent components. Twelve copepods from eight families were identified to the species level. Most constituent species were omnivorous (7 species), followed by detritophages (3 species). The community's phytophages and predators were locally common. This trophic distribution likely is evidence that they were collected in the surface layer, which is not always favorable for feeding. Therefore, the percentage of omnivorous opportunists was relatively high. Some of the sampled material requires molecular-biological analysis, especially the copepods from the *Oncaea* Philippi, 1843 and *Triconia* Böttger-Schnack, 1999 genera. The older copepodites, in particular the adult specimens, were rarely collected. The state of the material was not ideal for unambiguous identification by morphological features. Comparing the results with the latest research on the west coast of the Antarctic Peninsula, we see that the species composition is highly similar (around 80%), except for the deep-water taxa.

Keywords: biodiversity, copepods, ice cover, mesozooplankton, omnivorous species

1 Introduction

Zooplankton, including copepods, play an important role in marine trophic relations by feeding on the phytoplankton and being food for the animals at the high trophic level. The main functional features of the copepods' populations, reproductive cycles, growth, reproduction, and survival rates are important factors influencing the energy transfer in the pelagic food webs (Head et al., 1999). Copepods respond sharply to climate change by changing metabolic rates and reproductive characteristics (Steinberg et al., 2015). It makes the copepods an important model in object the aquatic environment for tracking the effects of global climate change. The continuous plankton-recorder (CPR) has been used to study the zooplankton in the Antarctic Peninsula area since 1925 (Hardy, 1936), and the research continues in the form of large-scale programs (McLeod et al., 2010; Takahashi & Hosie, 2020; Palmer Station Antarctica LTER & Waite, 2022). However, most CPR research is currently being done in the Australian Southern Ocean sector (McLeod et al., 2010). Less common in the western part of the Antarctic Peninsula (WAP) are investigations focusing on smaller areas (Marrari et al., 2011a; Marrari et al., 2011b). Accordingly, the pilot study of mesozooplankton communities was started in 2021—2022 at the Ukrainian Antarctic Akademik Vernadsky station (hereinafter — Vernadsky station). The purpose of the study was to obtain some initial information on the quantitative and functional characteristics of mesozooplankton in the coastal waters of the Argentine Islands.

This work aims to discuss the primary data on the species richness of copepods in the coastal waters of the Argentine Islands (WAP).

2 Materials and methods

Samples for this work were collected during the XXVI Ukrainian Antarctic expedition. The 22 qualitative samples of mesozooplankton were collected in the period from April 2021 to March 2022 in the coastal waters of the Argentine Islands on the trawling plots (Figure) and at some other sampling sites (see Table 1).

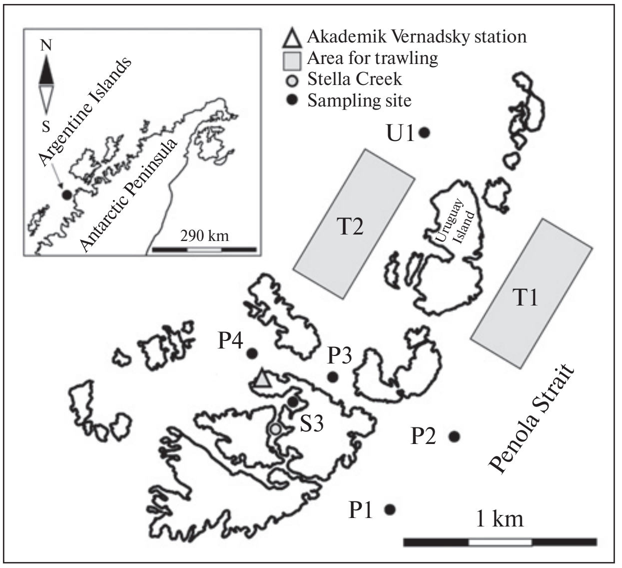

Figure. Argentine Islands study area and sampling sites location

We used standard methods (HELCOM, 2021) for carrying out our fieldwork.

Sampling at standard sites was done as vertical profiling using a small Apstein-100 net or a Juday net by lowering the tool to a specific depth and lifting it. The lifting speed was 0.8—1 $m \cdot s^{-1}$ (Volkov, 2008). In the trawling plots, the researchers used a special net in a metal body. The obtained mesozooplankton samples were condensed and stained with methylene blue. Samples were fixed in 4% formaldehyde solution pre-adjusted to pH 8—8.2 with sodium tetraborate. A stereoscopic microscope (×100) and a high-magnification microscope (×1000) were used.

Table 1. Sampling sites

Area	Site	Latitude, °S	Longitude, °W	Site depth, m	Number of samples	Net type
Penola Strait	P1	65.256	64.236	200	4	Apstein, Juday
	P2	65.249	64.220	200	2	Apstein, Juday
	T1	65.241	64.214	170	3	Trawl
Meek Channel	P3	65.246	64.245	25	5	Apstein
	P4	65.244	64.255	30	1	Apstein
Stella Creek	S1	65.247	64.255	14	3	Apstein
Uruguay Island	U1	65.229	64.235	70	3	Apstein, Juday
	T2	65.223	64.243	80	1	Trawl

Adults and older copepodites were selected for identification. The conclusion about the species' affiliation was made in accordance with the morphological diagnosis (Mazzocchi et al., 1995). Latin names of the taxa are given after the World Register of Marine Species (https://www.marinespecies.org/).

The conditions and sampling gear influenced the revealed species diversity. Three plankton nets were used depending on the weather and ice situation. In the absence of ice cover, a trawling net (mesh diameter 200 μm or 110 μm) was dragged for 300—1000 mat a depth of 30—10 m. Trawling was performed in areas T1 and T2.

Sampling of depths over 50 m was done with a Juday net (mesh diameter 200 μm). The 100—0 m water column was sieved, usually on sites P1, P2 and U1. To sample areas with depths up to 50 m given significant ice cover, the Apstein net (mesh diameter 110 μm) was used. On sites P3, P4, and S1 samples were taken from the 30—0 m water column.

Many of technical limitations caused the heterogeneity of the material. Trawling is the most efficient way to collect qualitative and quantitative samples. It eliminates some errors as the net moves at 2 m · s^{-1} and large species of actively moving copepods are caught. A larger area of trawling provides a better image of the copepod community. Also, during trawling, the net travels a long distance, and the probability of sampling more species increases; such samples are the most informative. However, the suitable ice conditions are rare.

The Juday net reaches depths of more than 50 m. However, in our conditions, it has several disadvantages. One is that it is difficult to lift it at 1 m · s^{-1} or faster with a hand winch which greatly affects the catchability, as the moving copepods avoid it. Another disadvantage is the inability to cover a large area. Samples taken with this net give information about species that are not actively moving to the surface.

Sampling with the Apstein net is carried out under the most unfavorable ice situation, when only the nearby sites are available for work in areas with intense currents and shallow depths. Such samples are the least informative.

Accordingly, the most informative samples were taken in late Antarctic summer, autumn, and early winter, when ice conditions allowed trawling.

Samples taken in winter, spring, and early summer have the largest sampling errors as they were collected by Juday and Apstein nets in bad ice conditions.

Notably, long-term studies conducted in the WAP region (Stammerjohn et al., 2008; Takahashi & Hosie, 2020) using CPR show an inverse relationship between the intensity of ice cover and the number of copepods. Therefore, it can be assumed that in the case of much ice cover in August, November, and January, samples were taken from a significantly depleted surface layer, which could also strongly impact the qualitative parameters. The QGIS 3.26 software was used to prepare the map (Figure).

3 Results

There was no significant vertical stratification in the mesozooplankton communities from the quantitative samples taken from different horizons in the surface layer (0—100 m). Therefore, the results were greatly influenced by the environment. Samples taken during the winter-summer period were dominated by common background species and the species that can feed in the upper layers at this time. Meanwhile, trawling samples from late summer-early winter show us the best information about seasonal dynamics.

The processed samples yielded 12 copepod species from 8 families identified as species (Table 2). The list includes background species and species regularly found in the study area (Atkinson, 1998; Marrari et al., 2011a; Gleiber et al., 2015). The core of the copepod taxocene consists of omnivores (7) and detritophages (3). One phytophagous species and one predator were also present. This trophic composition of copepods maybe the consequence of sampling the surface layer, which is not always favorable, and the percentage of omnivorous opportunists in it may be increased.

3.1 Species description

Calanoides acutus (Giesbrecht, 1902)

Circumpolar species, one of the dominants in the Southern Ocean; in some regions, together with *Calanus propinquus* Brady, 1883, may account for more than 20% of the total mesozooplankton biomass. *Ca-*

lanoides acutus can feed on phytoplankton and detritus (Hagen et al., 1993). *Calanoides acutus* is the first to rise to the surface in the spring for feeding and reproduction in the 0—200 m layer and the first to descend, sinking below 500 m in the form of 3rd- and 4th stage copepodites (Marin & Schnack-Schiel, 1993). Males are found mainly in the deep layers in winter, where mating occurs. In the spring, fertilized females rise to the upper layers of the water for reproduction, and in the summer, a new generation exists in the productive surface layer (Schnack-Schiel & Hagen, 1994).

Calanus propinquus Brady, 1883

The circumpolar species has several adaptations for surviving the southern winter, when phytoplankton biomass is extremely low (Hagen et al., 1993). In winter, most of the population stays at 100—500 m (Marin & Schnack-Schiel, 1993). In summer, they concentrate in the surface layer, feeding and replenishing lipid reserves. In winter, some *C. propinquus* remain in the surface waters and continue to feed. Unlike *C. acutus*, they mate mainly in the surface layers, with males present throughout the summer. The life cycle in different regions of the Southern Ocean lasts from 1 to 2 years (Schnack-Schiel & Hagen, 1994).

Ctenocalanus citer Heron & Bowman, 1971

They live in Antarctica and sub-Antarctica. The species is common in the Weddell Sea. In the sub-Antarctic region, it is found at all depths, but the most numerous at 100—150 m (Mazzocchi et al., 1995). There is no diapause, so the species actively feeds and breeds all year round. Mostly phytophagous, but has a wide range of foods, changes the object of nutrition depending on the season, with high nutritional activity in autumn and winter and low in spring and summer. It feeds on small phytoplankton. Winter nutrition is due to the activity of ice-associated algae (Pasternak & Schnack-Schiel, 2007). In summer, the population is usually represented by the old generation in the 0—400 m layer. At the end of the Antarctic summer, a new generation appears (Żmijewska et al., 2000).

Paraeuchaeta antarctica (Giesbrecht, 1902)

From the family Euchaetidae Giesbrecht, 1893, this species is most commonly recorded in Antarctica, also found in the sub-Antarctic sectors of the Atlantic, Indian, and Pacific Oceans. Large (up to 10 mm) carnivorous copepods, *Paraeuchaeta antarctica* is a direct link between the herbivorous, omnivorous mesozooplankton and the higher levels of the food web

Table 2. Taxonomic composition of copepods in the study area

Family	Species	Feeding type	Occurrence in samples, %
Calanidae	*Calanoides acutus* (Giesbrecht, 1902)	omnivorous	31.3
	Calanus propinquus Brady, 1883	omnivorous	39.1
Clausocalanidae	*Ctenocalanus citer* Heron & Bowman, 1971	phytophage	60.4
Euchaetidae	*Paraeuchaeta antarctica* (Giesbrecht, 1902)	carnivorous	79.1
Scolecitrichidae	*Scolecithricella minor minor* (Brady, 1883)	omnivorous	48.2
Rhincalanidae	*Rhincalanus gigas* Brady, 1883	omnivorous	19.8
Metridinidae	*Metridia gerlachei* Giesbrecht, 1902	omnivorous	95.5
Oithonidae	*Oithona similis* Claus, 1866	omnivorous	71.3
	Oithona frigida Giesbrecht, 1902	omnivorous	73.7
Oncaeidae	*Oncaea curvata* Giesbrecht, 1902*	detritophage	45.5
	Oncaea parila Heron, 1977*	detritophage	35.6
	Triconia antarctica (Heron, 1977)*	detritophage	18.2

Note: * — species affiliation needs clarification

(Bocher et al., 2002). It has a large vertical distribution up to depth 1500 m. In the WAP area, it is often registered as one of the dominant deep-sea species up to depth 1000 m. Most of the population is concentrated in the layer of 250—500 m, where feeding and reproduction occur (Mazzocchi et al., 1995). *Paraeuchaeta antarctica* is found throughout Antarctica and often spreads far to the north, to 35° S in the SW Atlantic, near the fjords of the Chilean coast, and 45° S in the Indian Ocean (Park, 1994).

Scolecithricella minor minor (Brady, 1883)

It is a small calanoid found in the epi- and mesohaline waters of the upper latitudes of both hemispheres. It is below the thermocline during the day and rises to the surface layer at night. It is registered down to a depth of 700 m, with the highest species density in the layer of 100—400 m (Dias et al., 2019). Copepodites carry out vertical migrations covering distances of up to 70 m, and the adults, up to 160 m. Depending on the season, they behave as omnivores or detritophages. After the spring phytoplankton bloom, they descend into deeper layers (Yamaguchi et al., 1999).

Rhincalanus gigas Brady, 1883

A typical species of the Antarctic Circumpolar Current, but not very numerous species in the Weddell Sea. Propagates mainly in autumn in warm deep waters at 1 to 4 °C but can reproduce at temperatures below 0 °C. Late autumn reproduction is registered in surface waters in the Antarctic Peninsula. The reproduction period of *R. gigas* is spread out with the main activity in spring and autumn. Various sources indicate that *R. gigas* has a more flexible life cycle of 1 or 2 years, probably influenced by the latitude (Schnack-Schiel & Hagen, 1994). Its abundance varies from 2 to 4 thousand per cubic meter in different regions. In winter, it can fall to 800 m and deeper; in the warm season, it keeps in the surface layer of 200—600 m (Ward et al., 1997).

Metridia gerlachei Giesbrecht, 1902

It is one of the most numerous calanoid species in Antarctic waters. It breeds at the Antarctic Peninsula from November to January, and two or three generations can be produced in the summer. *Metridia gerlachei* most likely neither performs ontogenetic vertical migrations nor accumulates lipids in summer (Schnack-Schiel & Hagen, 1994). The warm season it spends in the layer of 0—200 m, and in winter, it can accumulate in the surface layer in areas devoid of ice (Chiba et al., 2002). For the Bransfield Strait, resistance to nitrate compounds during algae bloom is indicated (Huntley & Escritor, 1992).

Oithona similis Claus, 1866

A cosmopolitan species abundant in coastal and oceanic regions of the tropical, temperate, and polar waters. It has not been studied for a long time due to the use of plankton sieves with a mesh diameter of 300—500 μm. Current estimates for the Southern Ocean show that the species abundance and biomass can outnumber any other copepods. Its frequent turnover, high abundance, and biomass are due to small size, wide range of food choices, and high metabolism rates. *Oithona similis* copepodites do not differ from *O. frigida* copepodites (Giesbrecht, 1902). In different seasons they can together number up to 80% of the total copepod density (Atkinson, 1998). It has a large vertical distribution and is found down to 1000 m. Its maximum numbers are recorded in the upper layer of 0—50 m (Mazzocchi et al., 1995).

Oithona frigida Giesbrecht, 1902

Oithona similis and *O. frigida* are among the numerically dominant zooplankton species in Antarctic waters, very similar in their biology and ecology. *Oithona similis* is a cosmopolitan, while *O. frigida* is particularly numerous near the polar front. Diatoms play a special role in the diet of *Oithona spp*. in the Southern Ocean (Pond & Ward, 2011). In the 300—100 m layer, there was found no vertical stratification by developmental stages in *O. frigida* (Dubischar et al., 2002).

Oncaea curvata Giesbrecht, 1902

A typical Antarctic species. It is registered in the surface layer and at depths of 100—400 m (Mazzocchi et al., 1995). Mostly detritophagous. *Oncaea curvata* performs ontogenetic vertical migrations. Migration to the upper layers is observed during development from the early to the middle copepodite stages; meanwhile, the late copepodites and adults descend deeper to reproduce (Nishibe & Ikeda, 2007).

Oncaea parila Heron, 1977

The species inhabits a wide bathymetric range of 250—2000 m. Judging by the food lumps and the composition of fecal granules, this species is mainly detritophagous. In the middle copepodite stages, it migrates to the upper layers to feed (Nishibe & Ikeda, 2007).

Triconia antarctica (Heron, 1977)

It is a circumpolar species that has ontogenetic vertical movements. Migration to the upper layers is observed from the early to the middle copepodite stages. In contrast, the late copepodites and adults descend into deeper layers to reproduce. Probably a detritophage (Nishibe & Ikeda, 2007).

4 Discussion

Comparing the obtained results with the local studies in the WAP (Marrari et al., 2011a; 2011b; Gleiber et al., 2015), we found a similar species composition, except for members of the families Oithonidae and Oncaeidae. This may be due to the fact that other authors used nets with a large mesh (333 and 250 μm), which prevents small copepods from getting into the samples. The exceptions are deep-sea species we could not extract due to technical limitations. Some issues require molecular biological analysis, namely the species taxonomy of copepods of the genera *Oncaea* Philippi, 1843 and *Triconia* Böttger-Schnack, 1999. Older copepodites and adults in the samples were rare, and the condition of individuals used for morphological diagnosis was not ideal.

The results provided the initial information about the taxonomic composition in the surface layer and showed how to improve the sampling methods. In the future, it is planned to adjust the methodology and focus on automation of the selection process.

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Таксоцен пелагічних копепод у прибережних водах Аргентинських островів, західне узбережжя Антарктичного півострова, у 2021—2022 роках

Реферат. Пелагічні екосистеми відгукуються на кліматичні зміни та поступово трансформуються під їхньою дією. Серед важливих індикаторів стану водних екосистем є мезозоопланктон та копеподи. Регулярний моніторинг зоопланктону у водах Антарктики проводиться багато років з метою вивчення біорізноманіття, трофічних ланцюгів та екологічних циклів. У 2021—2022 роках на Українській антарктичній станції «Академік Вернадський» до морських біологічних досліджень додали пілотне дослідження угруповань мезозоопланктону. Були отримані первинні відомості про таксономічний склад та функціональні характеристики таксоцену копепод у прибережних водах Аргентинських островів. На отриманий видовий склад копепод і мезозоопланктону в цілому суттєво впливали умови та доступні знаряддя відбору. Проби відбиралися з моторних човнів трьома видами планктонних сіток залежно від погодних та льодових умов. У пробах, відібраних у період з червня по лютий, домінували фонові регулярні види, а також види, які мають адаптації для харчування у холодних верхніх шарах узимку. Проби, відібрані з березня до кінця травня за допомогою тралень, найкраще показують сезонну динаміку тимчасових і постійних компонентів угруповань мезозоопланктону. За результатами обробки отриманих проб було визначено до виду 12 копепод з 8 родин. В основі таксоцену копепод домінують всеїдні види (7 видів), другі за чисельністю — детритофаги (3 види). Фітофаги і хижаки також були присутні в угрупованні, представлені типовими для регіону видами. Такий розподіл копепод за типом харчування швидше за все свідчить про те, що ми працювали в поверхневому шарі, який не є постійно сприятливим для харчування, і тому відсоток всеїдних опортуністів у ньому відповідно збільшений. За результатами обробки матеріалу виникли питання, що вимагають молекулярно-біологічного аналізу, а саме видова приналежність копепод з родів *Oncaea* Philippi, 1843 і *Triconia* Böttger-Schnack, 1999. Старші копеподити і дорослі особини в пробах траплялися рідко, стан особин, за якими складався морфологічний діагноз, не був ідеальним. Порівнюючи отримані результати з результатами нещодавніх локальних досліджень у західній частині Антарктичного півострова, ми бачимо високу схожість (близько 80%) у видовому складі копепод, за винятком глибоководних видів, вилучення яких нам недоступне через технічні обмеження.

Ключові слова: біорізноманіття, всеїдні види, копеподи, льодовий покрив, мезозоопланктон