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RESEARCH PAPER

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Microplankton Composition and Spatial Distribution Along the West Antarctic Peninsula During the Late Summer of 2017

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Abstract

Microplankton is composed of organisms between 20 and 200 µm in size (greatest axial linear dimension) and is a mixture of phytoplankton and zooplankton. It is an important component of the marine pelagic ecosystem not only as primary producers but also as consumers in the microbial loop. In the present paper, the results of microplankton species abundance and their community structure during the first Turkish Antarctic Expedition (TAE-1) at late Antarctic summer were given at four coastal stations along the west Antarctic Peninsula (wAP). According to these results, a total of 37 microplankton species were observed. Diatoms were the dominant group, followed by ciliates. The highest total microplankton cell concentrations were 18370 cells l^{-1} and 24350 cells l^{-1} at P4 and P2 sampling stations, respectively. Although the most common phytoplankton and ciliate species were *Odontella weissflogii* and *Cymatocylis affinis*, respectively, diversity indexes showed that no dominance of a species could be mentioned at any station. Additionally, we observed that the southern part of the wAP is significantly different from its northernmost part in microplankton abundance/composition

Introduction

Antarctica is the Earth's most southern continent. It covers Earth's South Pole. The area of Antarctica is 13.97×10^6 km^2, making it the fifth largest of the seven continents (Stonehouse, 2002). Percent cover of coastal types around Antarctica are 95% of ice shelf (ice front 44%, ice wall 38%, ice stream/outlet glacier 13%) and 5% of rock. It contains 91 percent (30.1×10^6 km^3 of ice) of the estimated volume of all the ice on Earth (Swithinbank, 1993). Of all the world's continents, Antarctica is the coldest, the highest, and the least known.

The average monthly temperatures at sea level along the coast of Antarctica range from −26.9°C to −3.1°C during Antarctic winter and summer respectively (Faure & Mensing, 2010). Because of the mean air temperatures have increased approximately 2–3 °C along the Antarctic Peninsula in the course of the last half century, the region is known as the most rapidly warming places on Earth over the past 50 years (Moline *et al.*, 2004; Turner *et al.*, 2005). However, the model application showed that summer sea-surface temperatures (SSTs) at south of 60° S will be between 0.50 and 1.25°C warmer in 2100 than present (Flores *et al.*, 2012). This increase, which causes the glacial melting, strongly influences overall phytoplankton productivity (Prézelin *et al.*, 2000). The Antarctic coast is generally known as productive areas, but some areas are observed to be HNLC. Although the environmental conditions in the HNLC area are suitable for phytoplankton, phytoplankton biomass cannot increase

at the desired level (Schloss *et al*., 2002). Various physical environmental factors such as vertical turbulence mixing, which modulates the light intensity and light penetration depth, can affect the phytoplankton growth and explain why low amount of biomass is observed (Schloss *et al.*, 2002). Many researchers have determined that Antarctic phytoplankton growth is limited by light but not by nutrients (Hayes *et al.*, 1984; Sommer, 1988). Beside these factors, micronutrients like iron also affects the distribution, biomass and productivity of the phytoplankton community (Ryan-Keogh *et al.*, 2018).

Antarctic food web is usually described as short and Antarctic krill (*Euphausia superba*) is the key species in Antarctica. Many top-level consumers directly or indirectly use Antarctic krill as a food source (Laws, 1985). So, krill fulfils complex roles in ecosystem feedback loops through grazing and nutrient recycling (Atkinson *et al.*, 2004). Diatoms-dominated spring phytoplankton populations are main food sources for krill (Moline *et al*., 2004). Phytoplankton can stay alive during the Antarctic winter about 6 months under limited light or almost no light condition (Wulff *et al.*, 2008). Although they froze in the sea ice or buried in sediment, many of them survive and some of them are able to germinate years after (Davis, 1972; Zgurovskaya, 1977; Hollibaugh *et al.*, 1981; Ligowski *et al.*, 1992). Therefore, Antarctic diatoms rightfully constitute those microorganisms called extremophiles (Sterrenburg *et al.*, 2007).

On the other hand, increases in seawater temperature can cause changes in phytoplankton community structure (Flores *et al*., 2012). Although Antarctic waters are rich in inorganic nutrients, it is considered as oligotrophic in terms of primary production for most of the year. Recent evidence showed, however, that an important part of primary production is carried out by pico- and nanoplankton rather than large diatoms. Pico- and nanophytoplankton generally comprise more than 30% and 50% of chlorophyll *a* biomass, respectively (Azam *et al.*, 1991; Hewes, 2009; Vanzan *et al.*, 2015; Wright *et al*., 2009). This is important, because the krill which are regionally important key species, feeds on large phytoplankton, especially diatoms but not efficiently on pico- and nanoplanktonic groups. As indicated in many studies, changing in community composition from large diatoms to small size groups like flagellated cryptophytes may cause decreasing in the abundance of Antarctic krill (Moline *et al*., 2004; Mendes *et al*., 2018). Given the importance of diatoms, most studies have therefore focused on microplanktonic groups.

Antarctica is of great scientific interest not only for the valuable mineral resources and large deposits of oil and natural gas existing in its continental shelf but also because of its natural biological sources such as fishes and krill. Commercial harvesting of marine living resources in the Southern Ocean surrounding Antarctica began by hunting of seals during the late 1700s and the commercial harvesting of krill during the 1970s (Herber, 2007). Antarctica, which is the world's most important natural laboratory, is a fragile and an increasingly vulnerable ecosystem of the world. Special international regulation is needed in Antarctica due to its biological, commercial and geopolitical importance. In this context, the Antarctic treaty that was firstly established in 1959 by 12 nations, was also signed by Turkey in 1995. The Treaty has 50 member nations so far (Ozturk *et al.*, 2014). Individual scientific studies have not been conducted by Turkish scientists and Turkey has not been performed any scientific activities in Antarctica until 2016. The first joint expedition on this continent was organized with the Ukrainian Antarctic Research Center during the 2016 Antarctic summer and supported by The Scientific and Technological Research Council of Turkey (TUBITAK) (Ozturk *et al*., 2017). Moreover, Turkey's first national Antarctic expedition (TAE-1) was held between February and March 2017 and was supported by the Ministry of Science and Industry. TAE-1 provided sampling opportunity of research along Antarctic Continental Shelf at various scientific areas.

Although previous studies have given historical information on the planktonic structure of Antarctic waters (Azam *et al*., 1991; Alder & Boltovskoy, 1991; Schloss *et al*., 2002; Lange *et al.*, 2007; Hewes, 2009; Garzio & Steinberg, 2013), repetition of plankton studies is an obligation for a better understanding of environment. Thus, the main purpose of the present study is to give quantitative information on composition, community structure and biogeographic distribution of microplankton along the Antarctic Peninsula during the late summer of 2017 cruises of TAE-1.

Material and Method

Microplankton assemblages were sampled from March 5th to 19th 2017 onboard of M/Y Australis. During the expedition, samples were taken from 4 sampling stations which were located along the Antarctic Peninsula and King George Island (Fig. 1). Stations P1 and P2 were located in the southernmost part of the Grandidier Channel. Station P3 was located in the coast of Cape Renard and station P4 was located at the southwest coast of the King George Island (Fig. 1 and Table 1). The distance between the northernmost station (P4) and the southernmost station (P1) is approximately 400 nautical miles. Samples were taken between the surface and 1-meter depth by using 55µm mesh size, 50-cm diameter mouth of a Hensen type plankton net for 10-minute horizontal tows. Water volumes were calculated by using a Hydro-bios digital flow meter, which was attached to the mouth of the plankton net (Fraser & Smith, 1968).

After each haul, the nets were carefully rinsed. The content of the collector at the lower end of the plankton net was fixed immediately after collection by adding 70% ethyl alcohol and kept inside of a 50 ml glass bottle

Table 1. Geographic locations and respective sampling dates for four sampling stations along the west Antarctica Peninsula

Sampling Stations	Geographic locations		Sampling dates
P1	66º 33'54" S	66º 29'18" W	5th March, 2017
P2	66º 23'03" S	65º 56'29" W	5th March, 2017
P3	65º 00'52" S	64º 00'16" W	8th March, 2017
P4	62º 12'59" S	59º 04'05" W	19th March, 2017

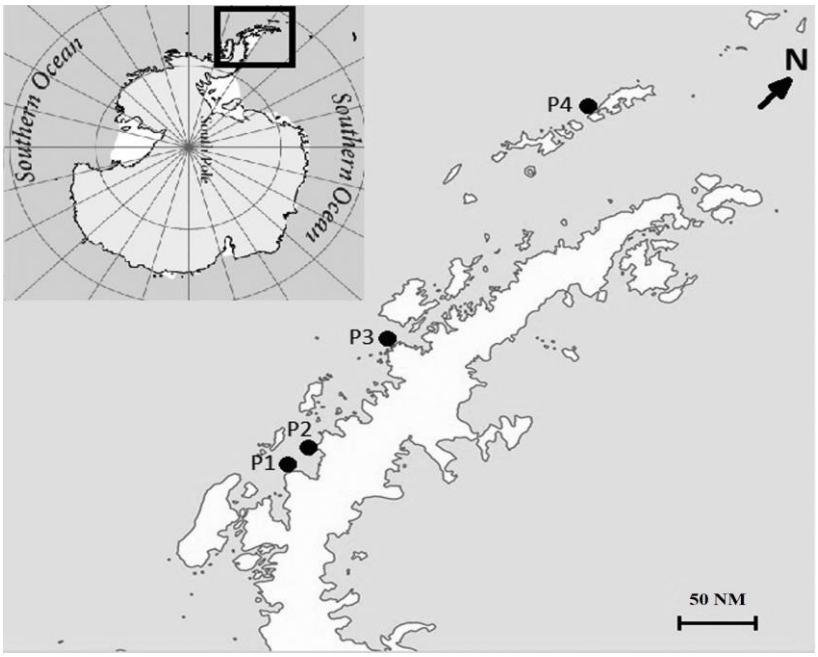

Figure 1. Sampling location.

in the dark until quantitative analysis (Alhaija *et al.*, 2015). Before counting, 1 ml of concentrated sample was taken and diluted to 40 ml. Planktonic cells in 1 ml sample were counted under a Nikon E 600 light microscopy (equipped with phase contrast, dark field and fluorescence attachment) with 40×, 100×, 200× magnification using Sedgewick Rafter Counting Chamber. 400× magnification was used for identification of plankton species. After the microscope counts, cell numbers per 1 liter were calculated using dilution factor and volume of filtered sea water by plankton net (Harris *et al.*, 2000). Pictures of planktonic organisms were taken with Microsystem Kameram 2 attachment and the Kameram Image Analysis System software was used for cell measurements. Sea Surface Temperature (SST) and chlorophyll-*a* data were obtained from NASA World View Earth Data WEB site (NASA, 2017). Bray-Curtis Similarity Index, MDS (Multidimensional Scaling) statistical analysis (Beals, 1984; Brogueira *et al.*, 2007), Margalef Species Richness Index (d), Pielou's Evenness Index (J') and Shannon Weaver Diversity Index (H') were applied for quantifying the compositional similarity between the sampling regions (Bandeira *et al.*, 2013). All statistical analyses were done by using species number and abundance. PRIMER (Plymouth Routines in Multivariate Ecological Research, Plymouth Marine Laboratory, Plymouth, UK;) ver. 6 software was used for statistical data analysis (Clarke & Gorley, 2006).

Results

According to satellite observations, SST ranged between 0.30–1.95 °C during the sampling period. Chlorophyll-*a* (Chl-*a*) is an important parameter for estimation of the biomass of autotrophic organisms and the satellite Chl-*a* concentrations spanned from 0.2 mg m^{-3} to 0.83 mg m^{-3} at all sampling stations during the sampling period (Figure 2). Among the sampling stations, highest Chl-*a* concentration was observed at P4 station, which was near the King George Island. In this station, Chl-*a* concentration was between ~ 0.80 and 0.83 mg m^{-3}. The lowest Chl-*a* value was observed (~ 0.2 mg m^{-3}) at both stations P1 and P2. Although the satellite observation in our sampling area shows that Chl-*a* concentration was about 0.2 mg m^{-3}, these concentrations reached to 15 mg m^{-3} at 200 m away from sampling sites at Adelaide Island's offshore areas, being 30 times higher than the Chl-*a* in the sampling stations (Figure 2)

A total of 37 microplankton species numbers belonging to diatom, dinoflagellate, cyanobacteria and ciliates were observed as 78.3%, 5.5%, 2.7%, and 13.5% respectively. Diatoms were the dominant group followed by ciliates.

Odontella weissflogii (P1) and Corethron pennatum (P3, P4) were the dominant diatom species. Among ciliates, Acanthostomella norvegica was the most

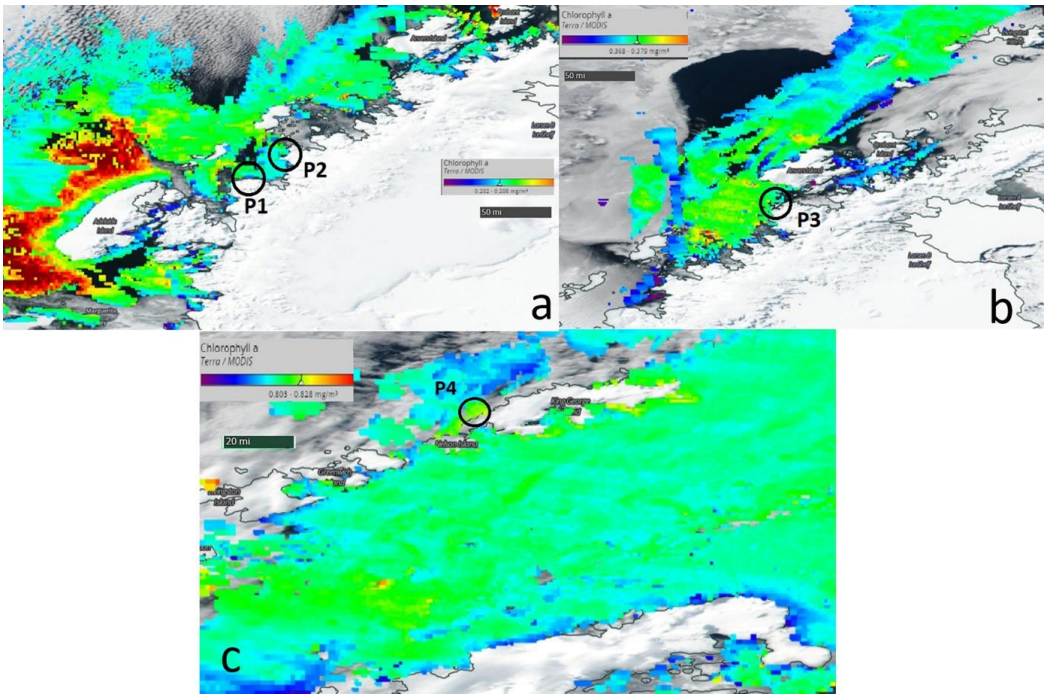

Figure 2. Satellite images of Chl-*a* concentrations around the sampling periods (for sampling stations: (a) P1-P2: March 3rd, (b) P3: March 10th and (c) P4: March 19th, 2017).

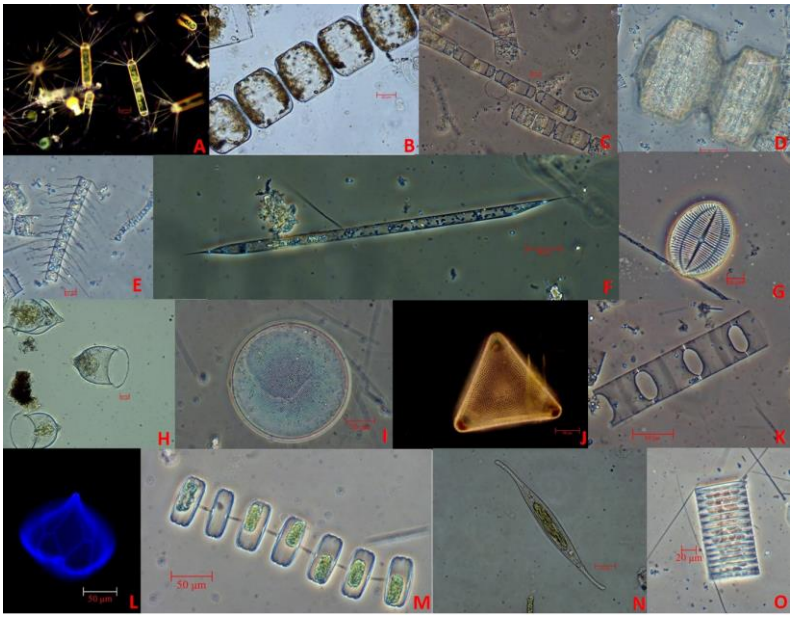

Figure 3. Microscope images of the most prominent microplankton species of west Antarctic Peninsula during March 2017 (late summer). A- *Corethron pennatum* B- *Lauderia annulata* C- *Odontella weissflogii* D- *Coscinodiscus bouvet*, E- *Chaetoceros flexuosus* F- *Rhizosolenia polydactyla*, G- *Cocconeis britannica*, H- *Cymatocylis affinis*, I-*Coscinodiscus oculus-iridis*, J- *Trigonium arcticum*, K- *Eucampia antarctica*, L- *Protoperidinium depressum*, M-*Thalassiosira rotula*, N- *Gyrosigma fasciola*, O- *Fragilariopsis kerguelensis*. Scale bar is 20µm for B, C, E, G, H, N, O and 50 µm for A, D, F, I, J, K, L, M.

prominent species at P4 station during the sampling period. On the other hand, Coscinodiscus oculus-iridis, Fragilaria islandica and *Thalassiosira* rotula were observed in all sampling stations (Table 2, Figure 3).

The highest total microplankton cell concentrations were 18370 cells l^{-1} and 24350 cells l^{-1} in P4 and P2 sampling stations, respectively. And the lowest cells number was 9440 cells l^{-1} in P3 station. Although, the diatoms reached the highest cell numbers in P2 station, the maximum for microzooplankton was observed at station P4 (Figure 4). The dominant phytoplankton species was *Odontella weissflogii,* which reached 14329 cells l^{-1} and 9200 cells l^{-1} in station P2 and P1, respectively. While *Acanthostomella norvegica* belonging to the ciliate group was observed as dominant

Table 2. A check-list of microplankton species and their level of abundance along the west Antarctic Peninsula (four sampling stations according to the Figure 1) during a late summer (March 2017)

	Sampling stations			
Diatom	P1	P2	P3	P4
Centronella reicheltii	-	-	+	+
Chaetoceros concavicornis	-	-	-	+
Chaetoceros flexuosus	+	*	-	-
Chaetoceros hendeyi	+	*	-	-
Cocconeis britanica	-	-	+	+
Cocconeis costatum	-	-	+	+
Corethron pennatum	-	-	**	**
Coscinodiscus bouvet	+	+	-	-
Coscinodiscus radiatus	-	-	+	-
Coscinodiscus oculus-iridis	+	+	+	+
Cyclotella meneghiniana	-	-	+	-
Entomoneis alata	-	-	-	+
Eucampia antarctica	+	+	-	-
Fragilaria capucina	-	-	+	+
Fragilariopsis kerguelensis	+	+	+	+
Gyrosigma fasciola	-	-	-	+
Lauderia annulata	+	+	+	-
Licmophora sp.	-	-	+	+
Navicula sp.	-	-	+	-
Odontella aurita	+	-	+	-
Odontella weissflogii	**	*	-	-
Pleurosigma directum	-	-	+	+
Proboscia inermis	-	-	-	+
Pseudo-nitzschia lineola	+	+	+	-
Rhizosolenia polydactyla	-	-	+	*
Rhizosolenia truncata	+	-	-	-
Thalassiosira rotula	+	+	*	+
Trigonium arcticum	-	-	+	+
Dinoflagellata				
Protoperidinium depressum	-	+	+	-
Protoperidinium sp.	+	-	+	-
Cyanobacteria				
Spirulina sp.	-	-	-	+
Ciliophora				
Acanthostomella norvegica	-	-	+	+
Codonellopsis morchella	-	-	+	+
Cymatocylis affinis	-	-	+	**
Laackmanniella prolongata	-	-	+	-
Protorhabdonella simplex	-	+	-	+

** : Predomimant (>5000 cells l^{-1})

microzooplankton in the P4 station, reaching up to 12600 cells l^{-1} in the water column.

Margalef species richness index (d) and Shannon (H') were good indicators for understanding the species diversity and the structure of communities. High values indicate high species diversity in the sites/sampling region. Our data indicate that the P3 station has the highest species richness. However, the P2 station was identified as the region with the lowest species diversity. In general, the stations in northernmost part of west Antarctic Peninsula have low species diversity than the southernmost stations. Shannon-Weaver (H') species diversity index, which is used for the same purpose as Margalef index (d), similarly shows that stations at northern part of west Antarctica peninsula show low species diversity than the southernmost stations (Table 3). The index calculation results below 2.5 can indicate that the dominance of a species has begun. According to our index results dominance of a species can be mentioned in all station.

Pielou's evenness index (J') gives the degree of equivalence in abundance of all species at the sample. As a result of the analysis, the station P4, close to the King George Island, showed higher evenness. On the other hand, P1 showed lower J' index than other sampling stations (Table 3).

The outputs of the Bray-Curtis similarity analysis are given in figure 5A and B. Two groups were identified by cluster analysis at 70% (P1-P2) and 38% (P3-P4) similarity level. Station P1 and P2 were differed

Table 3. Number (S) and abundance in cells l^{-1} (N) of taxa, Margalef's species richness (d), Shannon-Weaver (H') and Pielou's evenness index (J') for the sampling stations across the west Antarctica Peninsula in late summer of 2017

Stations	S	N	d	J'	H'(log_e)
P1	12	10260	1,586	0,1983	0,4927
P2	11	18370	1,331	0,3334	0,7995
P3	23	9440	3,211	0,3709	1,163
P4	19	24350	2,308	0,4579	1,348

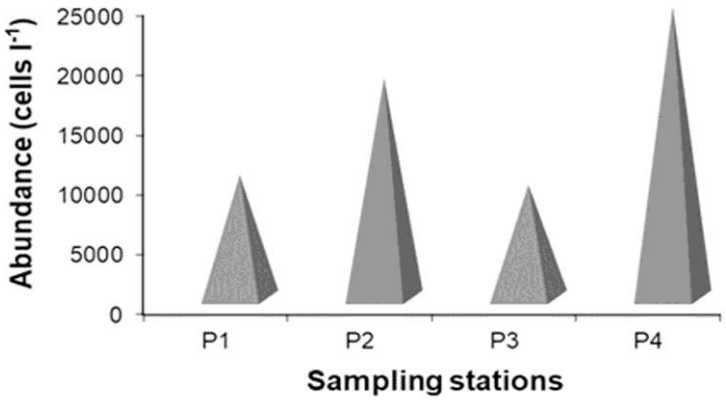

Figure 4. Total microplankton abundance (cells l^{-1}) in the sampling stations.

significantly from station P3 and P4 and the similarity between those distinct groups (P1-P2 and P3-P4) was calculated as 1% (Figure 5B). Considering 50% similarity level of such groups, this led to the formation of three different microplanktonic areas along the Antarctic Peninsula (Figure 5A).

Discussion

This study showed that the microplankton compositions might have a dynamic structure along the west Antarctic Peninsula, during the late summer. There are many studies from different countries around the west Antarctic Peninsula due to its importance in pelagic ecosystem. For instance, phytoplankton studies showed that phytoplanktonic groups have been dominated by nanoplankton (2-20 µm) and picoplankton (0.2-2 µm) (Kopczynska, 2008). Nanoflagellates such as *Cryptomonas* sp. and *Phaeocystis antarctica* can cover approximately 83% of the total phytoplankton (Kang & Lee, 1995). Kopczynska (2008) indicate that pico- and nanoplaktonic cell abundance can reach up to 4.0–5.2×10^6 cells l^{-1} in the (west) Antarctic Peninsula and has also showed that microplanktonic groups were secondary in abundance level. Although those small groups could be important also in late summer, we did not estimate the abundance of pico- and nanoplankton, since we used plankton net for sampling.

Another Antarctic study that was conducted at Neumayer Channel on five locations, in the vicinity of Vernadsky Research Base (Galindez Island) observed fifty phytoplankton species belonging to three taxonomic classes during the summer of 2016 and also, no significant difference was observed in phytoplankton species composition between the stations (Yılmaz *et al*., 2018). However, our results showed the great differences between the stations because of distinct geographic locations. These results showed that frequent sampling strategy was more important for determination of species diversity of certain areas. Diatom ratio to other planktonic groups was calculated as 78% in our studies. The relative abundance of diatoms presented here was similar to the one observed by Yılmaz *et al*. (2018).

Phytoplankton biomass is typically low in King George Island when compared to other Antarctic shelf environments. For instance, diatoms have been usually found in the west Antarctic Peninsula as typical bloom-forming species (Schloss *et al*., 2014). Lange *et al.* (2007) also showed that diversity of phytoplankton population was high and the main group was diatom during the summer 2002–2003 in Admiralty Bay at King George Island. The centric diatom *Corethron pennatum* and several species of the pennate diatom genus *Fragilariopsis* were dominant. Although, the observed microplankton species numbers were recorded as 113, maximum cells abundance were not more than 10^3 cells l^{-1} in that area (Lange *et al*., 2007).

Although the species diversity has been high in some studies mentioned above, Kang and Lee (1995) showed that the phytoplankton species was not only low but also dominated by 5 or 6 species that covered more than 95% of the total phytoplankton, as observed at wAP in our work. The species diversity was relatively

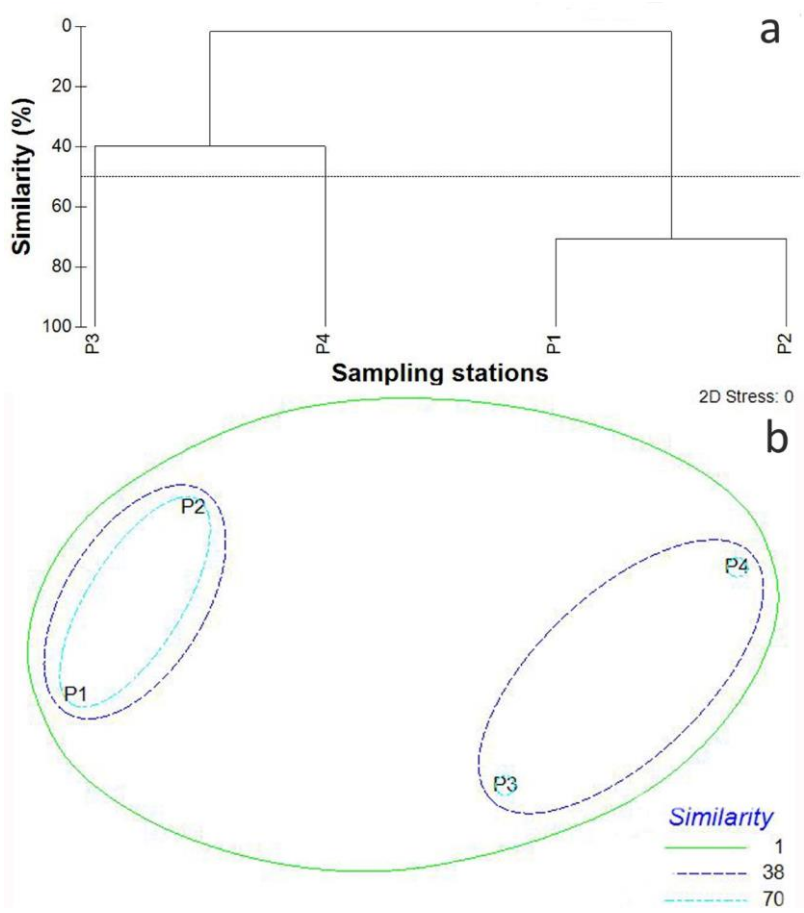

Figure 5. Groups of samples obtained from similarity matrix based on microplankton abundance data. Represented as: (a) Cluster analysis (CA) dendrogram and station groups according to 50% similarity level of microplanktonic biota. (b) MDS: Station groups are indicated in agreement with groups from the CA dendrogram according to 1% (green ellipse), 38% (dashed dark blue ellipse) and 70% (dash-dot, pale blue ellipse**).**

low in our stations, but the abundance values of species are higher when compared with Lange *et al*. (2007) and Yılmaz *et al*. (2018). In Lange *et al.* (2007) study the cells number for dominant species was 10^4 cells l^{-1}. Other studies have also indicated that *Odontella weissflogii* and *Corethron pennatum* can characterize the typical species of Antarctic summer phytoplankton community (Detoni *et al.*, 2015; Yılmaz *et al*., 2018). Almost the same species were observed at these previous studies conducted in similar summer periods. According to our observation, *Odontella weissflogii* and *Corethron pennatum* were the most abundant species across those sites of west Antarctic Peninsula (wAP) during 2017 late summer.

Microzooplankton abundance and composition have been showed some regional differences across the wAP. The exclusive high ciliate abundance in the P4 station was an example of this kind of regional variabilities. This finding could be related to pico- and nanoplankton abundance levels. Mendes *et al.* (2018) showed that the shift from large diatoms to small flagellates could stimulate the microbial loop dynamics and affect negatively the krill abundance in Antarctic food webs. For instance, even though heterotrophic dinoflagellates were the most significant grazers in oceanic zone of Amundsen Sea, ciliates co-dominated with them in the Sea Ice Zone at the same area (Yang *et al*., 2016). Also, athecate heterotrophic dinoflagellates and flagellates were the dominant groups in midsummer of 2010, while these kinds of dinoflagellates and aloricate ciliates predominated in 2011 midsummer. Whereas the tintinnids were a less important group along the Antarctic Peninsula during those same sampling periods (Garzio & Steinberg, 2013). Alder and Boltovskoy (1991) recorded the highest absolute counts for the silicoflagellates (7777 cells l^{-1}, with an average of 674 cells l^{-1}), followed by the dinoflagellates (maximum: 1312 cells l^{-1}, average: 109 cells l^{-1}) and the tintinnids (maximum: 589 cells l^{-1}, average: 52 cells l^{-1}) during the late summer 1987 along the wAP, whose (some) locations were covered by our study area. When our findings were compared with ones of previous studies, the cell numbers showed similarity and differences according to sampling sites and seasons. In studies that occupied offshore stations, the number of cells that were determined in our work, have counted high cell abundance. Alder and Boltovskoy (1991)'s results of microzooplankton in 1989 were similar to our study. Moreover, Alder and Boltovskoy (1991)'s study, which was conducted 30 years ago for the exact same period as our research, showed that the distribution of *Cymatocylis affinis* was similarly observed

in our work. However, this distribution was not mentioned in other studies. It was also observed that in March 1987 (Alder & Boltovskoy 1991) three geographical regions were defined according to the microplankton structure as in our study.

Changing climatic and ecological conditions can affect the food web dynamics starting from plankton up to the top predators through all marine Antarctic pelagic ecosystems. Consequently, time-series dataset will be very important for understanding the changes in these fragile ecosystems. When compare our study period with data obtain from the previous study our limited data that belong to the limited area in this study provide the evidence that microplanktonic community were affected by changing environmental conditions during the last two decades. For the better understanding of Antarctic marine ecosystem's future, more detailed studies, which are supported by inter-governmental foundations, are needed.

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