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RESEARCH PAPER

Pigment-based Phytoplankton Size Classes and Community Composition along the Western Antarctic Peninsula during the Turkish Antarctic Expedition of 2019

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Abstract

This study investigates the spatial variability of phytoplankton size classes (PSCs) and community composition along the western Antarctic Peninsula (WAP) during the Turkish Antarctic Expedition (TAE-III) in 2019. Using high-performance liquid chromatography (HPLC) pigment analysis, microscopy, and hydrographic data, we characterized phytoplankton communities across 11 stations during the Turkish Antarctic Expedition (TAE-III). The results showed considerable regional differences, with a high contribution of nanophytoplankton to the total phytoplankton biomass (23–78%), followed by microphytoplankton (3–53%) and picophytoplankton (1–69%). Prominent pigments, including chlorophyll-*a*, fucoxanthin, and 19-hexanoloxyfucoxanthin, indicated diatom and haptophyte dominance in specific areas. Variations in community composition were strongly influenced by sea surface temperature, salinity, and nutrient availability, driven by regional hydrographic conditions and ice melt dynamics. The findings enhance our understanding of phytoplankton adaptive strategies under changing environmental conditions and highlight their crucial role in the WAP's polar marine ecosystem. The present study provides baseline data that is essential for the monitoring of climate-driven changes in Antarctic phytoplankton communities.

Introduction

Phytoplankton communities serve as primary producers, establishing the foundation of the aquatic food web and contributing to global biogeochemical cycles, nutrient dynamics, and climate regulation (Käse & Geuer, 2018; Naselli-Flores & Padisák, 2023). Comprehending the composition and distribution of these microscopic organisms offers insight into the health and dynamics of marine ecosystems, along with the possible effects of altering environmental circumstances. Phytoplankton display significant variability in community composition, frequently classified into size categories including picophytoplankton (Cyanobacteria, Prochlorophytes, Chlorophytes, Prochlorophytes), nanophytoplankton (Prymnesiophytes, Pelagophytes and Cryptophytes), and microphytoplankton (Diatoms and Dinoflagellates) (Sieburth et al., 1978; Feyzioglu et al., 2023). Each class demonstrates unique ecological functions, physiological adaptations, and reactions to environmental changes. Consequently, alterations in community structure and abundance may profoundly affect the larger ecosystems (Henson et al., 2021). The quantity, composition, spatial distribution, and nutritional components of phytoplankton communities in the Antarctic ecosystem are shaped by a complex interaction of physical, chemical, and biological processes (Biggs et al., 2019; Hernando et al., 2018; Y. Lee et al., 2016). Principal environmental factors in the Antarctic ecosystem, including sea temperature, nutrient availability, salinity, and light conditions, exhibit significant variability between areas, seasons, and depth gradients (Convey et al., 2014). Seasonal ice melt distributes nutrients into the water column, fostering circumstances conducive to phytoplankton blooms, especially during the spring and summer months when light availability is heightened (Costa et al., 2023; Ducklow et al., 2018; Sabu et al., 2014). These blooms are crucial for Antarctic food webs since they sustain higher trophic levels, including zooplanktons, krill, fish, seabirds, and marine mammals (McBride et al., 2014; Wing et al., 2014).

The Southern Ocean, particularly East Antarctica and the Western Antarctic Peninsula (WAP), has been a focus of phytoplankton research due to its dynamic response to seasonal sea ice retreat and nutrient availability (Cao et al., 2019; Öztürk et al., 2022). The Western Antarctic Peninsula faced the fastest warming rates due to climate change. Thus, the area has become an important region for studying phytoplankton dynamics (Henley et al., 2019). This warming affects not only sea surface temperatures but also the extent, thickness, and seasonal duration of sea ice cover, which are critical determinants of phytoplankton productivity. Alterations in ice cover influence light penetration and mixing dynamics in aquatic environments, affecting the timing and intensity of phytoplankton blooms (Ferreira et al., 2024). Earlier ice melt may extend growth periods for phytoplankton, thereby altering community structure towards species suited for protracted growing seasons and fluctuating nutritional circumstances (Ferreira et al., 2024).

Phytoplankton pigments not only drive photosynthesis but also serve as biomarkers, helping to monitor phytoplankton distribution, distinguish different phytoplankton groups and assess the community composition and size classes in various marine ecosystems (Chai et al., 2016; Kramer et al., 2020; M. Lee et al., 2022). The pigment distribution in marine environments can be useful for monitoring ecosystem health, and predicting challenges such as algal blooms. Chlorophyll-*a* is the primary pigment that presents in the phytoplankton. With the help of this pigment, energy from light is captured and converted into chemical energy through the process of photosynthesis. Accessory pigments, such as fucoxanthin, 19-hexanoloxyfucoxanthin, alloxanthin, zeaxanthin, and chlorophyll-*b*, play specialized roles in photosynthesis and provide insights into the taxonomic diversity of phytoplankton (Canuti et al., 2022). Previous studies have characterized phytoplankton distribution, abundance, and community composition using pigment-based analyses and CHEMTAX methods, highlighting the dominance of diatoms and haptophytes in this region. These studies have also revealed the impact of environmental drivers, such as sea ice dynamics, light conditions, and nutrient availability, on phytoplankton productivity and succession (Heidemann et al., 2024). In the Antarctic context, pigments can reveal the dominance of specific phytoplankton groups adapted to the extreme and variable conditions. For instance, fucoxanthin, primarily associated with diatoms, is indicative of microphytoplankton dominance, while 19-hexanoloxyfucoxanthin and alloxanthin mark nanophytoplankton, where often, flagellates and cryptophytes constitute the bulk of this fraction. Similarly, the presence of pigments like zeaxanthin and chlorophyll-*b* points to picophytoplankton groups, which include cyanobacteria and small green algae (Gao et al., 2018; Mishra et al., 2020; Robinson et al., 2021). This pigment-based classification, often derived through high-performance liquid chromatography (HPLC), is a powerful approach for understanding phytoplankton dynamics across regions and seasons (Lee et al., 2020, 2024). The BROKE survey, conducted from January to March 1996, have utilized CHEMTAX analysis of HPLC pigment signatures to evaluate phytoplankton community structure and its relation to hydrographic features. This comprehensive survey revealed regional variations in chlorophyll-*a* concentrations and highlighted the influence of ice melt and pycnocline dynamics on algal blooms. Diatoms, haptophytes, and cryptophytes emerged as key contributors to phytoplankton composition, with significant spatial variability driven by thermal stratification and nutrient availability (Wright et al., 2000). Building on these findings, the BROKE-West survey further refined our understanding of phytoplankton structure by incorporating longitudinal analyses across the seasonal ice zone of the Southern Ocean. This study revealed the succession of primary blooms under ice, dominated by diatoms and *Phaeocystis antarctica*, followed by secondary blooms near ice edges. It also highlighted the influence of micronutrient availability, particularly iron, on phytoplankton productivity and community composition (Wright et al., 2010).

Comprehending the determinants of variations in primary productivity in the WAP is crucial for assessing its current role in the global carbon cycle and for predicting future alterations resulting from increased glacial meltwater and rising temperatures. Field sampling in this region is frequently impeded by pervasive sea ice and severe weather conditions for a significant portion of the year. Recent advancements in pigment-based analytical methodologies, especially HPLC, have facilitated enhanced evaluations of phytoplankton size classes and community composition. These methods facilitate the identification of critical pigments associated with diverse phytoplankton groups, hence improving the comprehension of phytoplankton dynamics. This study used pigment-based HPLC analysis to assess phytoplankton size classes and community composition along the WAP during the Turkish Antarctic Expedition (TAE-III) in 2019. This study aims to elucidate the temporal and spatial changes in phytoplankton communities along the western Antarctic Peninsula by examining the contributions of various phytoplankton size classes and their corresponding pigments, thus supplying critical data for the ongoing monitoring and understanding of polar marine ecosystems.

Material and Method

Study Area and Sampling

Spatial variations in pigment-based phytoplankton size classes (picophytoplankton, <0.2–2 µm; nanophytoplankton, 2–10 µm; microphytoplankton, >10 µm) and phytoplankton community composition were investigated at 11 stations along the western Antarctic Peninsula during the austral summer from 4 to 28 February 2019 (Figure 1; Table 1). The samplings were carried out as part of the third Turkish Antarctic expedition (TAE-III), supported by the Republic of Türkiye, Ministry of Industry and Technology (MoIT). Seawater samples for pigment analysis and phytoplankton enumeration were collected from a depth of 5 m using 5 L Niskin bottle onboard R/V BETANZOS. During the sampling period, a CTD (SBE 19Plus V2 SeaCAT Profiler) was used to measure sea surface water temperature and salinity.

HPLC Pigment Analysis

The phytoplankton pigments used to characterize the phytoplankton size classes (PSCs) were analysed using high-performance liquid chromatography (HPLC), following the methods described by Barlow et al. (1997) and Llewellyn et al. (2005). For this analysis, 1 L of

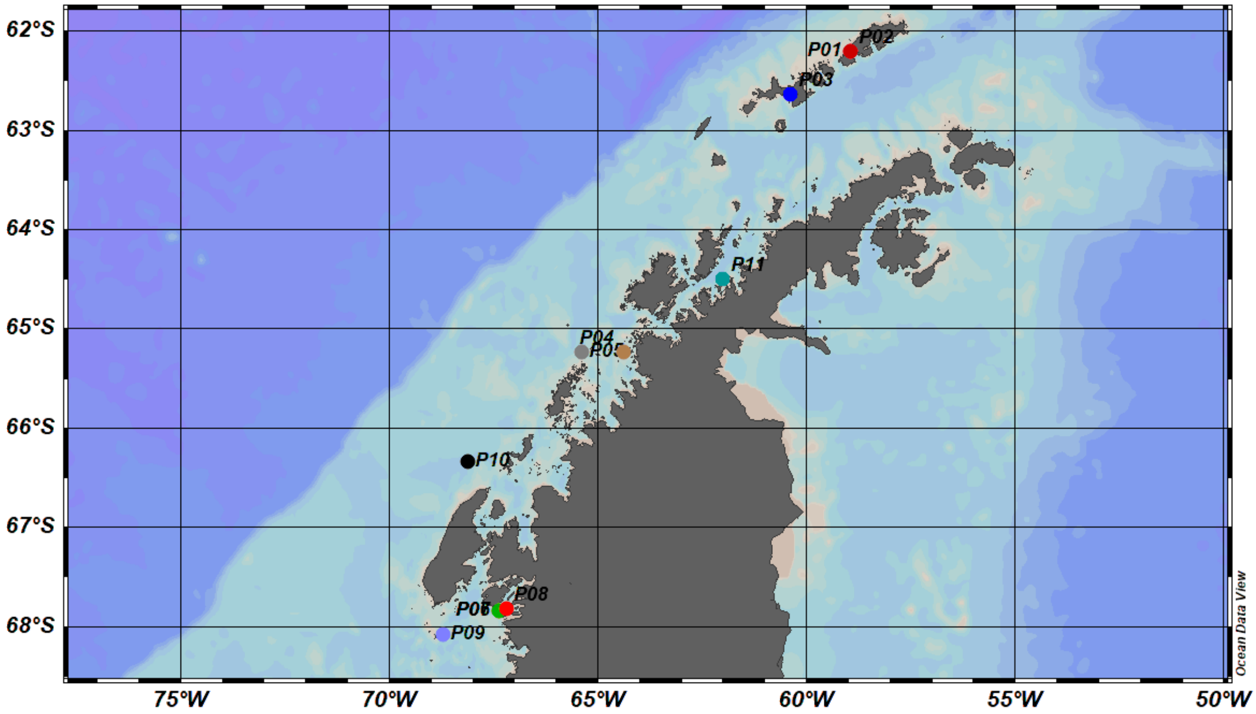

Figure 1. Study area and sampling points along the coast of the western Antarctic Peninsula.

Table 1. Locations of sampling points along the West Antarctic Peninsula (WAP)

Station	Locality	Sampling date	Latitude	Longitude
P01	King George Island	4-Feb. 2019	62° 12' 22,91" S	58° 56' 39,85" W
P02	King George Island	4-Feb. 2019	62° 12' 22,91" S	58° 56' 39,85" W
P03	Livingston Island	7-Feb. 2019	62° 38' 06,64" S	60° 23' 11,93" W
P04	Argentina Island	8-Feb. 2019	65° 13' 46,12" S	64° 23' 11,93" W
P05	Argentina Island	8-Feb. 2019	65° 13' 46,12" S	64° 23' 11,93" W
P06	Horse Shoe Island	12-Feb. 2019	67° 50' 27,5" S	67° 21' 43,99" W
P07	Horse Shoe Island	12-Feb. 2019	67° 50' 27,5" S	67° 21' 43,99" W
P08	Horse Shoe Island	18-Feb. 2019	67° 49' 09,62" S	67° 11' 35,55" W
P09	Marguerite Bay	24-Feb. 2019	68° 04' 40,76" S	68° 42' 43,64" W
P10	Adelaide Island	25-Feb. 2019	66° 20' 04,04" S	68° 07' 29,88" W
P11	Nansen Island	28-Feb. 2019	64° 30' 07,02" S	62° 00' 12,54" W

seawater samples were filtered through GF/F filters (47 mm in diameter), and the filters were stored at -20℃. Subsequently, pigments were extracted in 5 mL of 90% acetone (HPLC grade) via ultrasonication (Sonics Vibra-Cell) for 60 seconds. The cellular debris were removed with centrifugation at 3500 rpm for 10 minutes.

Separations of pigment were performed using a C8 column (Intertsil C8-3 4.6 x 150 mm, 3 µm particle size, 120 Å pore size and %6.5 carbon load) connected to a Shimadzu LC-20 AT/Prominence HPLC system. This system was equipped with a solvent pump (1 ml/min flow rate), auto sampler, UV absorbance, fluorescence and a Diode Array Detector (DAD) at two different wavelengths (450 and 665 nm), operated through LC solution software. The mobile phase included Eluent A, consisted of 100% methanol and 1 M ammonium acetate (80:20 v/v), and Eluent B, composed of 100% methanol. Pigment identification was conducted based on retention times and spectral matching using PDA (Jeffrey and Vesk, 1997). The response factors derived from calibration with a set of pigment standards (DHI Water and Environment, Denmark) were used to calculate pigment concentration.

Phytoplankton Size Classes Derived from HPLC Analysis

In order to estimate the contribution of different phytoplankton size classes, diagnostic pigments (DP), the sum of seven selected biomarker pigments, were used (Vidussi et al., 2001). The contribution of the three pigment-based size classes (pico-, nano-, and microphytoplankton) were estimated based on Uitz et al. (2006). The picophytoplankton predominantly consist of cyanobacteria and prochlorophytes (Zea) along with green flagellates (Chl-*b*). The nanophytoplankton are characterised by golden-brown flagellates (Hex-fuc, But-fuc) and cryptophytes (Allo). Finally, the microphytoplankton are primarily represented by diatoms (Fuc) and dinoflagellates (Per). The relative fraction of phytoplankton size classes [picophytoplankton (<2 µm); nanophytoplankton (2-10 µm) and microphytoplankton (>10 µm)] were estimated using the methodologies outlined by Uitz et al. (2006) and Aiken et al. (2009).

$$DP_W=1.41\,[Fuc]+1.41\,[Per]+1.27\,[Hex\text{-}fuc]+0.35\,[But\text{-}fuc]+0.60\,[Allo]+1.01\,[TChl\mathit{b}]+0.86[Zea]$$

Where DP_W represents the concentration of chlorophyll-*a*, which is calculated based on the concentration of the seven diagnostic pigments (Table 2). The fractions of the three pigment-based phytoplankton size classes are calculated using the following equations:

$$f_{micro} = (1.41\,[Fuc] + 1.41\,[Per])/DP_w$$

$$f_{nano} = (1.27\,[Hex\text{-}fuc] + 0.35\,[But\text{-}fuc] + 0.60\,[Allo])/DP_w$$

$$f_{pico} = (1.01\,[TChl\mathit{b}] + 0.86\,[Zea])/DP_w$$

Phytoplankton Enumeration

Phytoplankton samples were collected using a 20 µm plankton net for microscopic examination. Samples were initially preserved in Lugol solution for further analysis of the species, following the method described by Throndsen (19789. After a two-week storage period in a dark, cool environment, the samples were concentrated to 10 ml using the sedimentation method (Utermöhl, 1958). After sedimentation, the excess seawater was carefully removed using a pipette. A 1 ml subsample of the concentrated sample (10 ml) was analysed using a Sedgewick-Rafter cell under a phase-contrast binocular microscope (Nikon E600 Fluorescence) at magnifications of 10x, 100x, and 400x for phytoplankton species identification. Phytoplankton groups including diatoms, dinoflagellates, other phytoplankton groups were identified based on the taxonomic references provided by Balech (1988), Tomas (1996), Rampi and Bernard (1978), and Algabase.

Data Analysis

The significant differences between sampling stations were assessed with One-way ANOVA. Spearman rank correlation was used to elucidate the relationships between phytoplankton size classes, pigments and environmental parameters using Sigma Plot software.

Table 2. Abbreviations for phytoplankton pigments and pigment formulae (revised from Aiken et al., 2009 and Uitz et al., 2006)

Symbol	Description
Fuc	Fucoxanthin
Per	Peridinin
Hex-fuc	19’-Hexanoyloxyfucoxanthin
But-fuc	19’-Butanoyloxyfucoxanthin
Allo	Alloxanthin
Chlb	Chlorophyll-*b*
Zea	Zeaxanthin
DP	Diagnostic pigments
f_{micro}	Fraction of Chl-*a* associated to microphytoplankton
f_{nano}	Fraction of Chl-*a* associated to nanophytoplankton
f_{pico}	Fraction of Chl-*a* associated to picophytoplankton

Results

Hydrography

The changes in sea surface temperature (SST) of the stations are illustrated in Figure 2. During the sampling period, the lowest SST was recorded at stations P08 and P09 (-1,0°C) and the highest SST was recorded at stations P01 and P02 (1,0°C). In general, the SST demonstrated an increasing pattern with latitude.

The salinity profiles of the study area revealed that surface salinity ranged between 31.9‰ and 33.8‰, with significant spatial variations (Figure 3). The lowest salinity value (31.9‰) was recorded at stations P04 and P05, while the highest value (33.8‰) was observed at station P03.

Phytoplankton Size Classes

The contribution of phytoplankton size classes (pico-, nano- and microphytoplankton) to the total phytoplankton community is illustrated in Figures 4-6. It is evident that the relative contribution of phytoplankton size classes (PSCs) exhibited a notable variation across the study area. Specifically, the contributions ranged from 1% to 69% for picophytoplankton, 23% to 78% for nanophytoplankton, and 3% to 53% for microphytoplankton. Overall, the phytoplankton community was predominantly dominated by nanophytoplankton, followed by microphytoplankton and picophytoplankton.

The contribution of picophytoplankton, representing the size range of 0.2 to 2 µm, was lowest

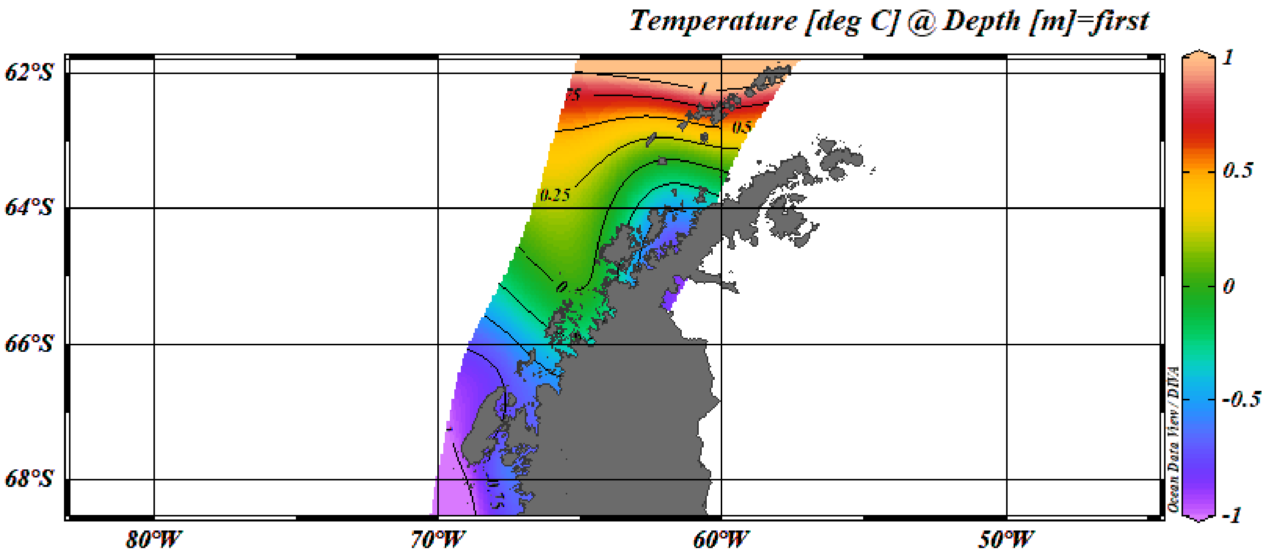

Figure 2. Temporal variation in sea surface temperature (SST) along the study area.

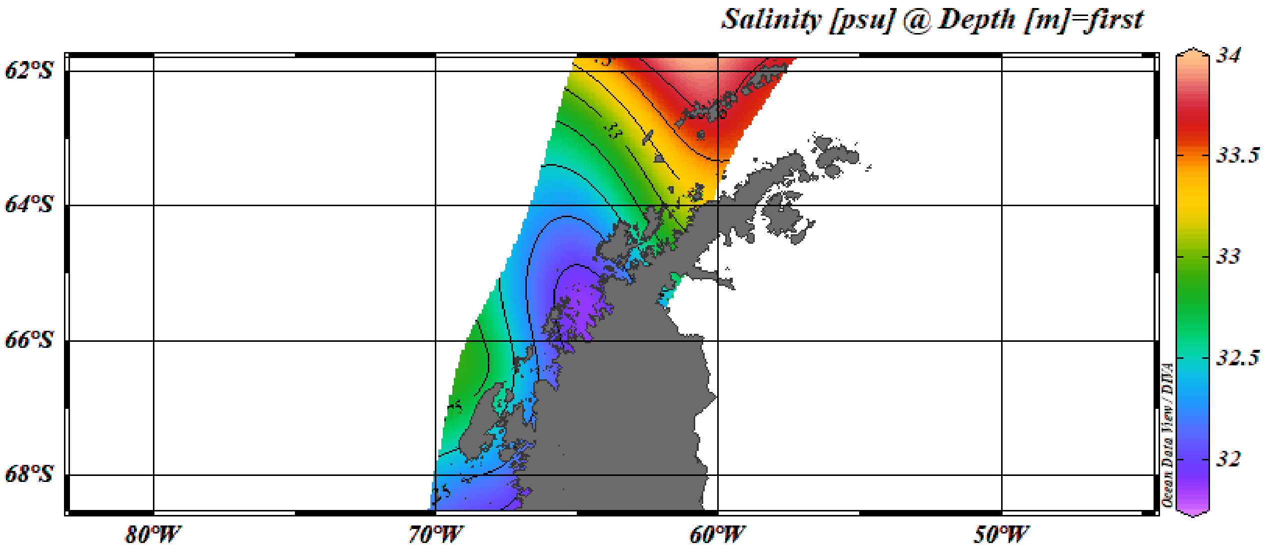

Figure 3. Temporal variation in salinity along the study area.

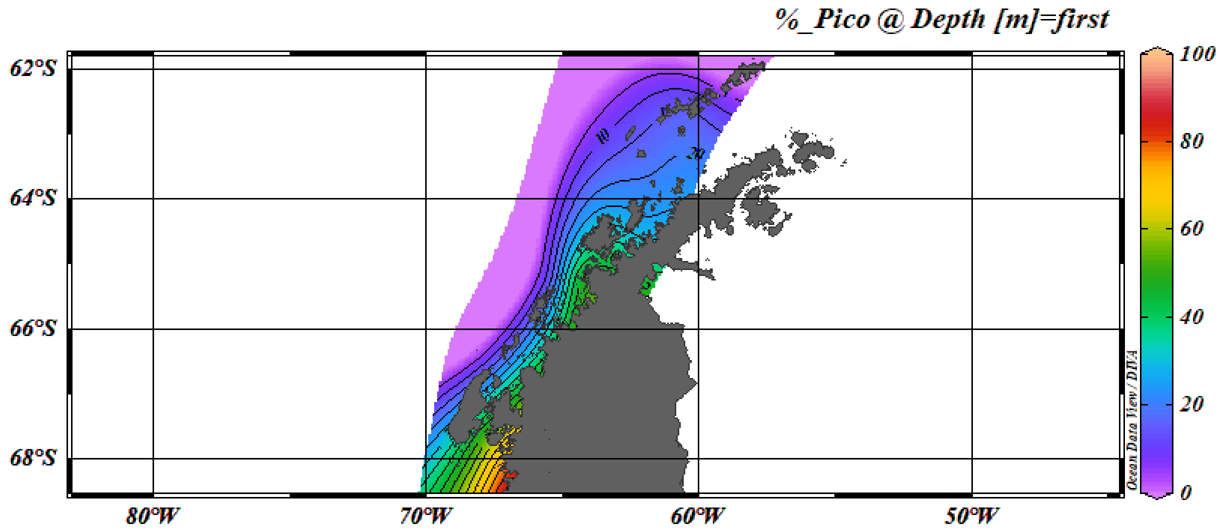

Figure 4. Temporal variation in picophytoplankton contribution (%) along the study area.

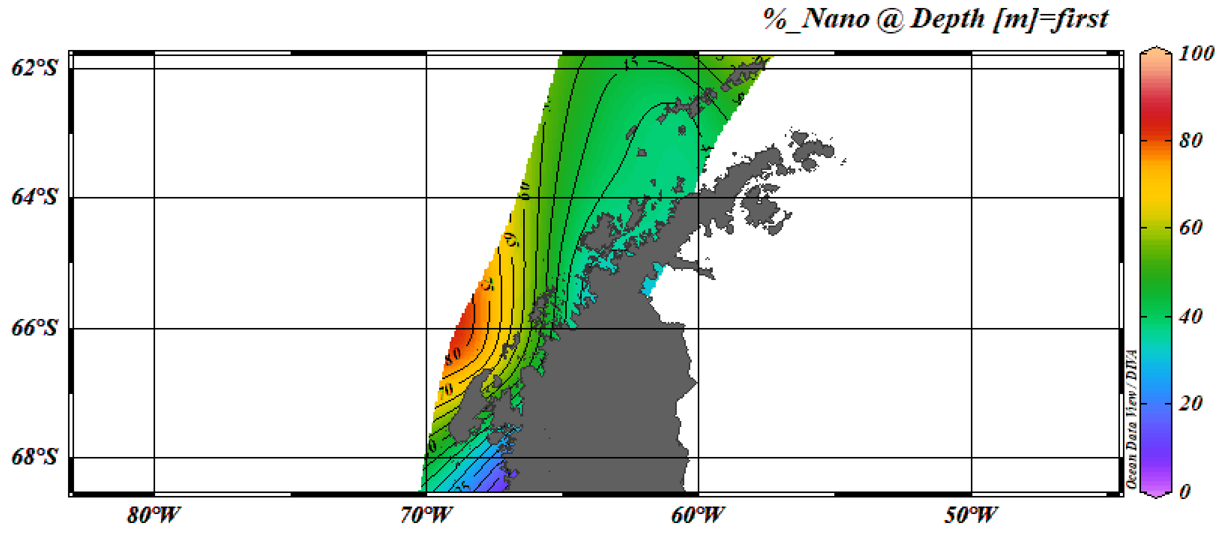

Figure 5. Temporal variation in nanophytoplankton contribution (%) along the study area.

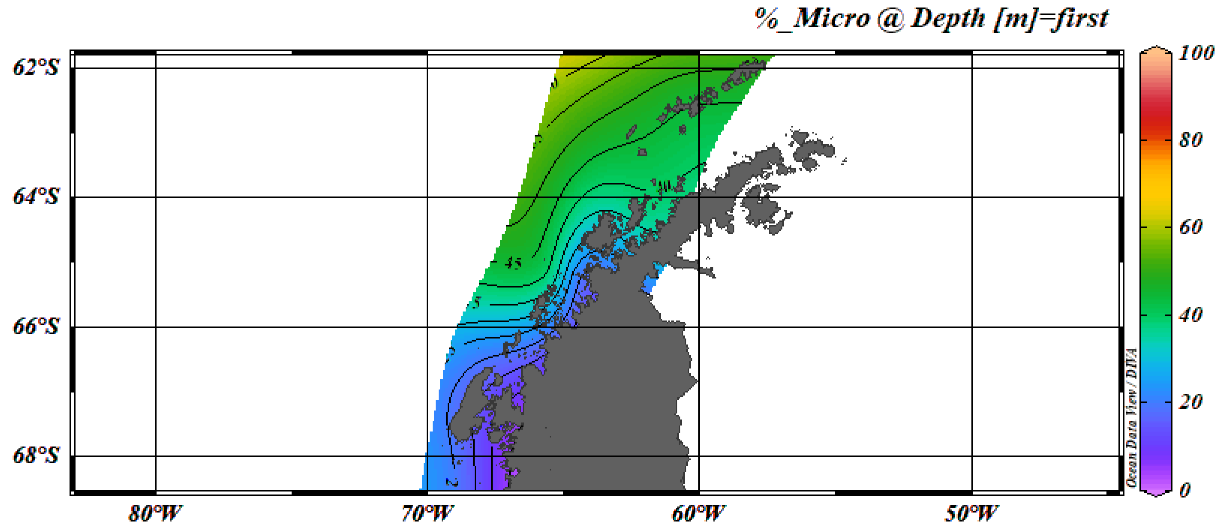

Figure 6. Temporal variation in microphytoplankton contribution (%) along the study area.

(1%) at stations P01 and P02. In contrast, the highest contribution (69.26%) was observed at station P07 (Figure 4). The contribution of nanophytoplankton across the study area displayed considerable variability, with the lowest contribution (23.09%) recorded at station P06 and the highest (78.15%) at station P10 (Figure 5). Similarly, microphytoplankton contributions varied significantly, ranging from a minimum of 2.72% at station P07 to a maximum of 53.12% at station P02 (Figure 6).

Pigment Profile

Chlorophyll-*a*, fucoxanthin, 19-hexanoloxyfucoxanthin and zeaxanthin were found as the most prominent pigments identified throughout the study area (see Table 3 and Figures 7-12). Chlorophyll-*a*, a fundamental pigment present in all phytoplanktonic groups, plays a crucial role in photosynthesis. Its concentration varied between 0.44 and 2.6 µg/L (Figure 12). Fucoxanthin, a marker pigment for diatoms, ranged from 0.03 to 1.12 µg/L during the study period (Figure 7). Additionally, 19-hexanoloxyfucoxanthin and alloxanthin, which are characteristic of nanophytoplankton groups, were also identified as significant pigments along the study area. During the study period, the concentrations of these pigments varied within a range of 0.09-1.32 µg/L and 0.01-0.61 µg/L, respectively (Figures 8-9). The zeaxanthin and chlorophyll-*b*, indicative of picophytoplankton, were also notable pigments at specific stations. The concentrations of these pigments varied considerably, ranging from 0.15 to 1.00 µg/L for zeaxanthin and 0.09 to 0.49 µg/L for chlorophyll-*b* (Figures 10-11).

Phytoplankton Composition

A total of 24 phytoplankton species were identified across the study area. Of these, 75% were Bacillariophyceae species (18 species), 13.04% were Dinophyceae species (3 species) and 12.5% consisted of other species (12.5%). The most dominant species were identified as *Corethron pennatum, Cyclotella sp., Lauderia borealis, Navicula sp., Tropidoneis antarctica, Gyrodinium lacryma, Oxyphysis oxytoxoides* and *Phaeocystis antarctica* along the study area (Table 4).

Table 3. Pigment concentrations (µg/L) derived from HPLC (detection limit >0.005)

Station	Peridinin	19-But	Fuco	19-Hex	Allo	Zea	Chl-*b*	Chl-*a*
P01	<0,005	<0,005	0,24	0,30	0,09	<0,005	<0,005	0,70
P02	<0,005	<0,005	0,29	0,28	0,01	<0,005	<0,005	0,74
P03	<0,005	<0,005	1,06	0,97	0,15	0,15	0,43	0,95
P04	<0,005	<0,005	0,27	0,42	0,61	1,00	0,49	1,84
P05	<0,005	<0,005	1,12	1,32	0,21	0,39	<0,005	2,60
P06	<0,005	<0,005	0,13	0,16	0,19	0,80	0,18	1,95
P07	<0,005	<0,005	0,03	0,21	0,27	1,00	0,18	0,73
P08	<0,005	<0,005	0,06	0,14	0,25	0,72	0,24	0,44
P09	<0,005	<0,005	0,07	0,13	0,04	0,19	0,09	0,67
P10	<0,005	<0,005	0,04	0,09	0,12	<0,005	<0,005	1,00
P11	<0,005	<0,005	0,36	0,17	0,52	0,41	<0,005	0,55

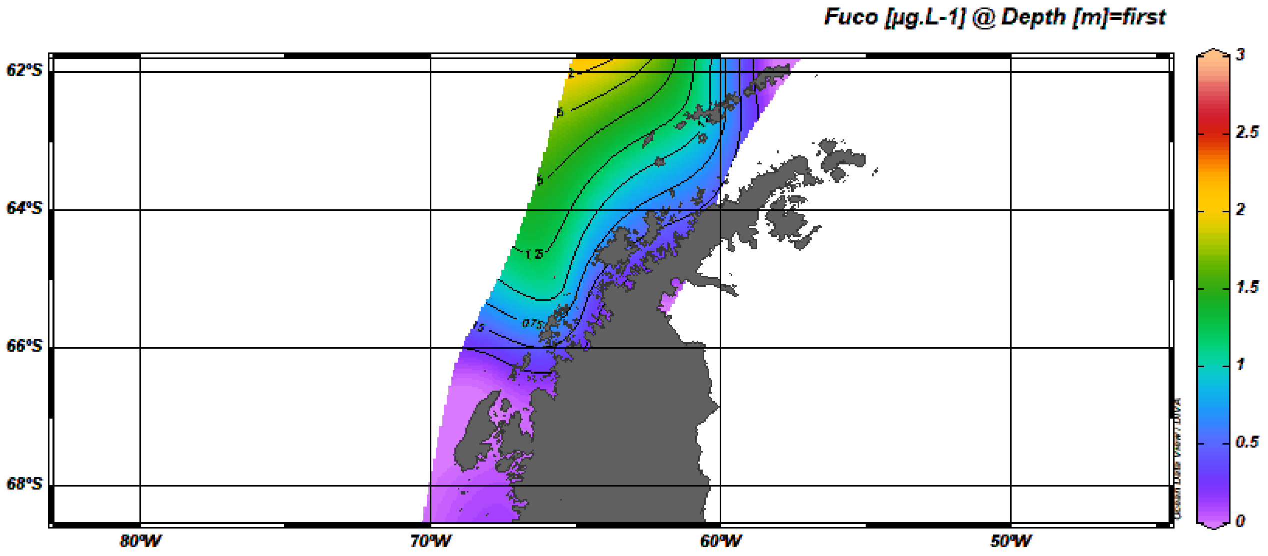

Figure 7. Temporal variation in fucoxanthin pigment concentration (µg/L) along the study area.

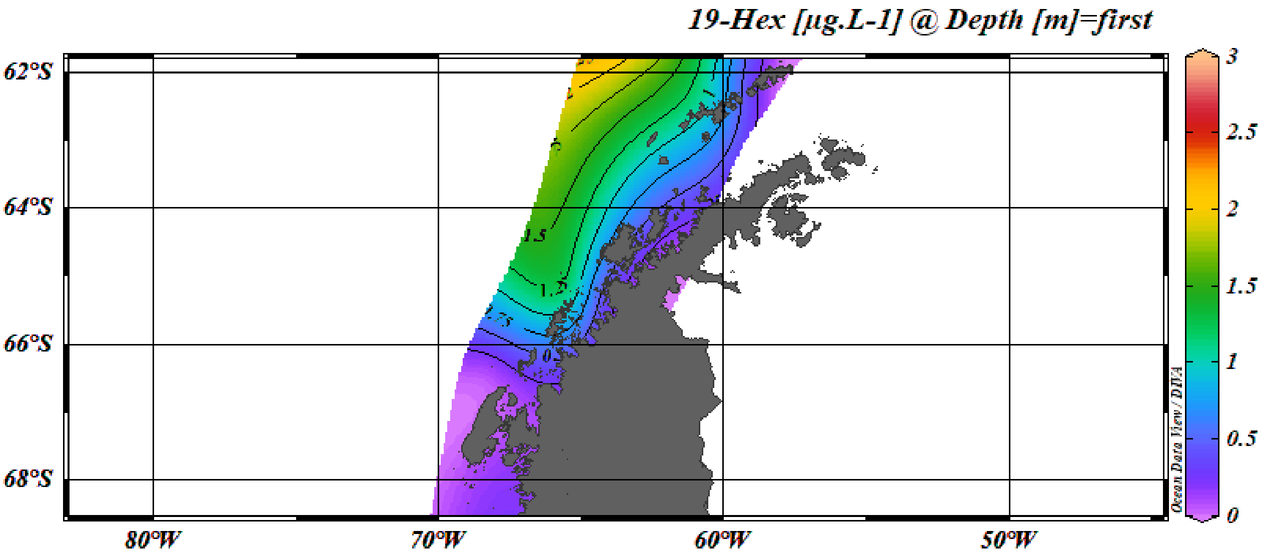

Figure 8. Temporal variation in 19-hexanoyloxifucoxanthin pigment concentration (µg/L) along the study area.

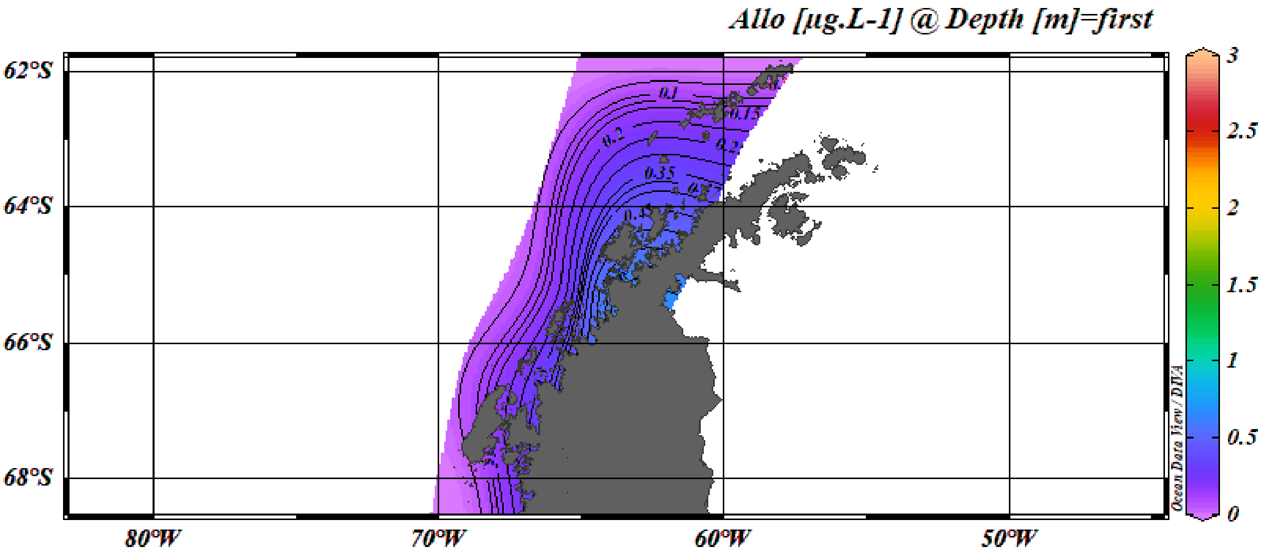

Figure 9. Temporal variation in Alloxanthin pigment concentration (µg/L) along the study area.

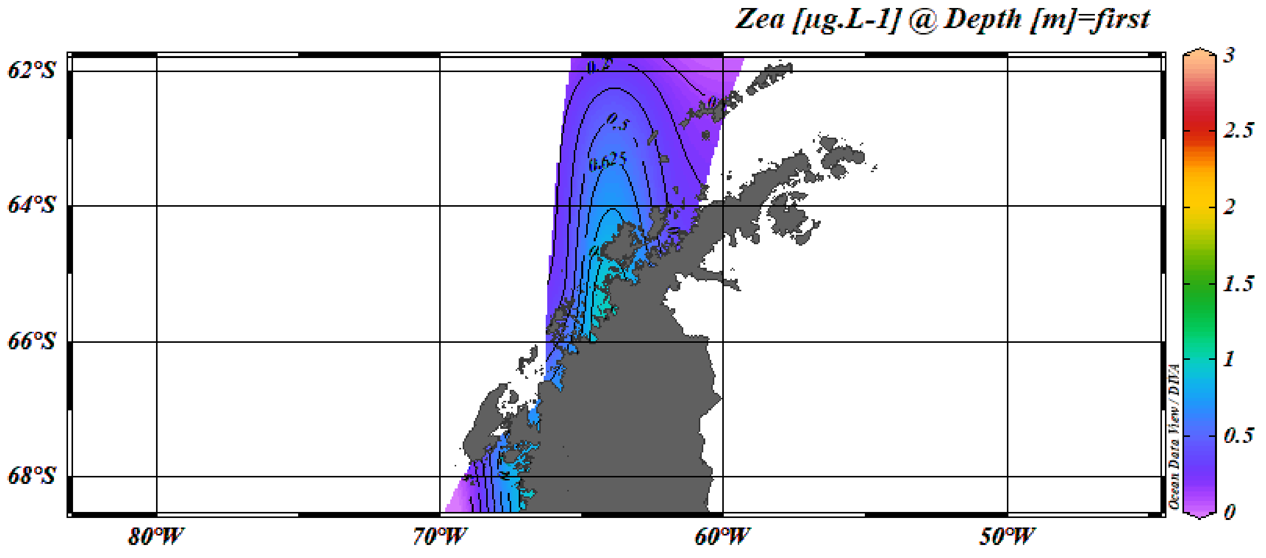

Figure 10. Temporal variation in Zeaxanthin pigment concentration (µg/L) along the study area.

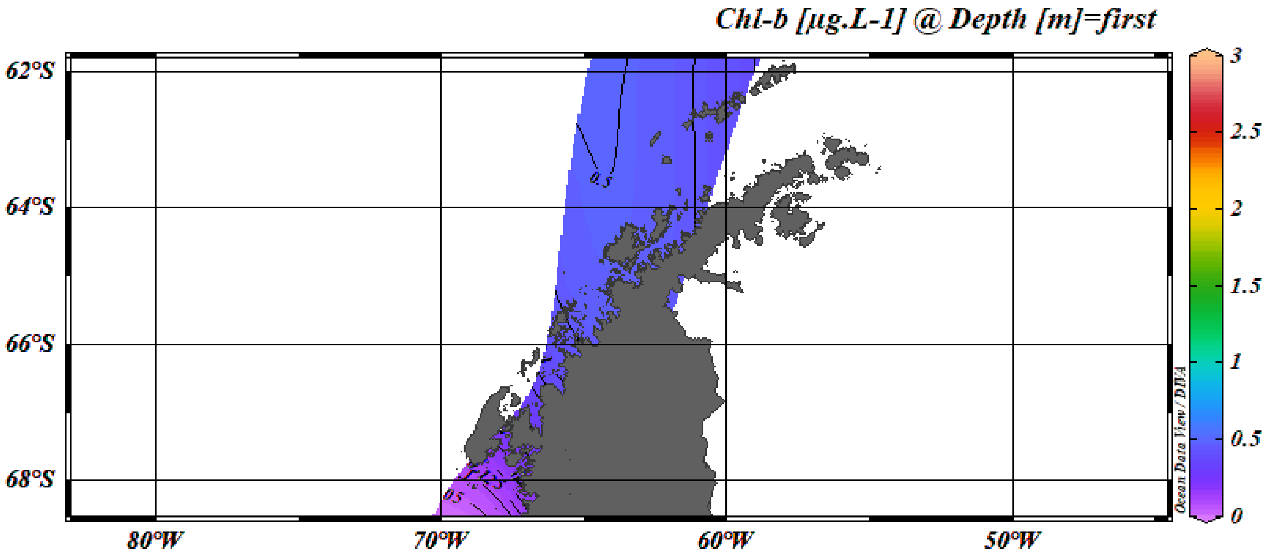

Figure 11. Temporal variation in Chl-*b* pigment concentration (µg/L) along the study area.

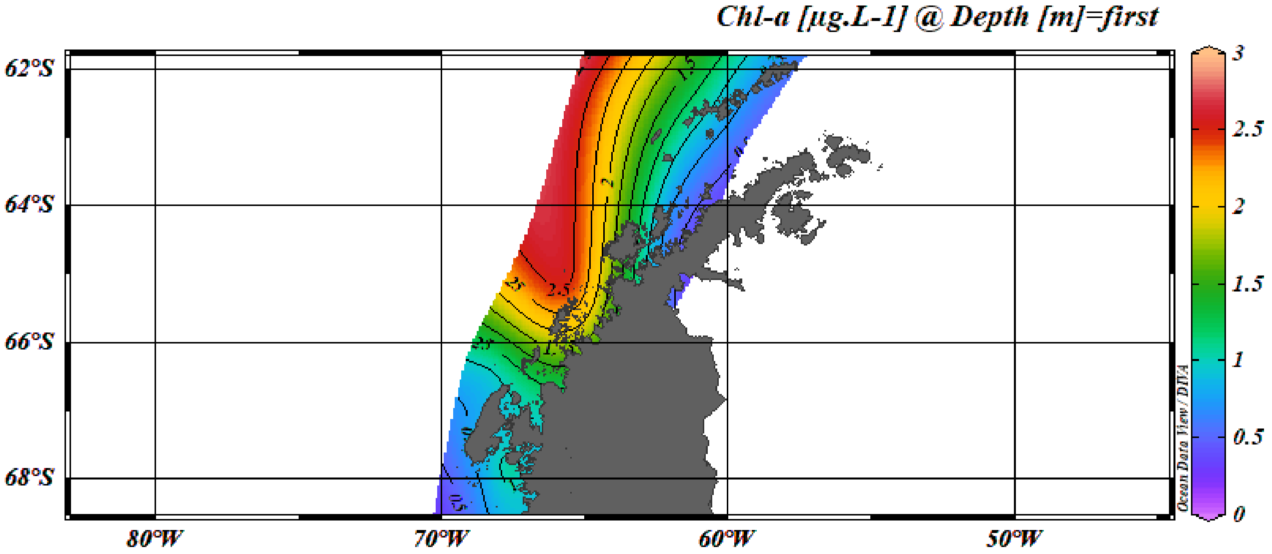

Figure 12. Temporal variation in Chl-*a* pigment concentration (µg/L) along the study area.

Discussion

Phytoplankton size classes (PSCs) estimated by using HPLC pigment data combined with microscopy and hydrography along the western Antarctic Peninsula (WAP) were used to characterize phytoplankton structure during Turkish Antarctic Expedition (TAE-III) of 2019. The findings revealed significant regional variation in PSCs across the WAP, with ranges from 1 to 69%; from 23 to 78%; and from 3 to 53% for picophytoplankton, nanophytoplankton and microphytoplankton, respectively. Microscopic investigations further indicated that diatoms were major groups (75 %) of total phytoplankton along the study area (please see Table 4).

The community composition, diversity indices, and seasonal dynamics of the phytoplankton community can exhibit considerable variability in marine ecosystems (Fishwick et al., 2006). This variability also reflects spatial heterogeneity in the phytoplankton community. The composition of the phytoplankton community, and thus the ratios of pigments (or the properties of pigments), regulate the response of these organisms to changing environmental factors (Trees et al., 2000). In marine ecosystems, the surface layers of warm, oligotrophic, and nutrient-depleted waters are generally dominated by picophytoplankton communities. Conversely, nanophytoplankton are more abundant in mesotrophic waters characterised by moderate nitrogen levels, while microphytoplankton prevail in eutrophic waters with high nitrogen (Aiken et al., 2009). The responses of phytoplankton to environmental changes have been observed to vary between different groups and individual species (Rose et al., 2009; Xu et al., 2014). Consequently, there is an urgent need to develop a comprehensive understanding of the distribution and response of entire phytoplankton groups, including minor groups, in the Antarctic region, to facilitate accurate prediction of phytoplankton responses to rapid climate change. Pigment-based taxonomy offers insights into minor phytoplankton groups, superseding the conventional approach of microscopy.

The physical, chemical, and biological aspects of the WAP have changed considerably over the past decade (Stammerjohn et al., 2008; Montes-Hugo et al., 2009; Ducklow et al., 2012). The studies on the phytoplankton dynamics in Antarctic coastal waters have revealed the formation of extensive blooms of diatoms and the prymnesiophyte during different seasons and in different locations (Arrigo et al., 1999; Smith et al., 2010; Mendes et al., 2013). Concurrently, various research groups have reported that the phytoplankton community in the WAP is dominated by large diatoms (>20 µm) (Hart, 1942; Holm-Hansen and Mitchell, 1991; Nelson and Smith, 1991; Prézelin et al., 2000, 2004; Smith et al., 2008; Heidemann et al., 2024). However, over the last three decades, a notable shift in the pattern of phytoplankton communities has been observed, with an increased recognition of the importance of nano- (<20 µm) and picophytoplankton (<2 µm) in the WAP phytoplankton community (Whitaker, 1982; Krebs, 1983; Buma et al., 1991; Jacques and Panouse, 1991). Information on phytoplankton communities can be facilitated through the utilisation of microscopic analysis. Despite the time-consuming nature of this approach and the requirement of a high level of expertise, it provides fundamental and detailed information about phytoplankton ecology and physiology (Lee et al., 2016). The responses of phytoplankton to environmental changes have been observed to vary between different groups and individual species (Rose et al., 2009; Xu et al., 2014). In many studies, HPLC has been utilised for the examination of major species, including nanophytoplankton (e.g. *Phaeocystis antarctica*) and microphytoplankton (mainly diatoms) in the Antarctic region (Lee et al., 2016). The present study revealed that the pigment-based phytoplankton community was predominantly composed of nanophytoplankton and microphytoplankton along the study area. The results obtained from the analysis of piment signatures have been found to be in agreement with the hypothesis that nano- and microphytoplankton are dominant. Moreover, microscopic investigation also revealed that microphytoplankton (mainly diatoms) constituted the dominant group along the WAP. *Corethron pennatum, Odontella weissflogii, Cyclotella* sp.*, Lauderia borealis, Navicula* sp.*, Tropidoneis antarctica* were the most prominent diatom species, and *Gyrodinium lacryma, Phalacroma oxytoxoides* were the dominant dinoflagellate groups along the study area. However, the findings contrast with those reported by Wright et al. (2010), who reported a significant contribution of *Phaeocystis antarctica* in secondary blooms, our study found limited representation of this species. The observed difference in species representation could be attributed to variations in regional iron availability or bloom timing.

Table 4. List of phytoplankton species identified in sampling sites

Systematic Groups	Sampling Stations
Bacillariophyceae	
Chaetoceros peruvianus Brightwell, 1856	P4
Corethron pennatum (Grunow) Ostenfeld 1902	P1-P6-P8
Coscinodiscus sp.	P6
Cyclotella sp.	P1-P3-P6
Eucampia antarctica f. recta Mangin 1915	P6
Fragilaria islandica Grunow ex Van Heurck 1881	P1
Fragilaria capucina Desmazières 1830	P8
Lauderia borealis Gran 1900	P6-P8
Licmophora abbreviata C.Agardh 1831	P1
Melosira sp.	P6
Navicula sp.	P3-P6
Nitzschia longissima (Brébisson) Ralfs, 1861	P6
Odontella weissflogii (Grunow) Grunow 1884	P1-P6
Pleurosigma sp.	P1
Rhizosolenia imbricata Brightwell, 1858	P6
Thalassiosira antarctica Comber 1896	P3
Tropidoneis antarctica (Grunow) Cleve 1894	P6-P8
Dinophyceae	
Gyrodinium lacryma (Meunier) Kofoid & Swezy 1921	P3-P6
Odontella weissflogii (Grunow) Grunow 1884	P6
Oxyphysis oxytoxoides Kofoid, 1926	P6-P8
Prasinophytes	
Phaeocystis antarctica	P6-P8
Silicoflagellates	
Dictyocha speculum Ehrenberg, 1839	P6
Cryptomonads	
Cryptomonas sp.	P4

Chlorophyll-*a* is the primary pigment that responds to environmental changes (e.g. temperature, salinity, light availability and intensity, nutrient availability etc.). Earlier studies have indicated a correlation between net community production and water temperature in the Amundsen Sea, suggesting that water temperature exerts an influence on phytoplankton metabolism (Hahm et al., 2014; Tortell et al., 2012). Furthermore, the spatial distribution of Chl-*a* exhibited a strong correlation with water temperature in the Amundsen Sea (Lee et al., 2016). Conversely, it was reported that the growth of *Phaeocystis antarctica* was not limited at temperatures below 10°C in the Southern Ocean (Buma et al., 1991), and the growth rates of diatoms and *Phaeocystis antarctica* increased as the water temperature increased to within a range of 2–4°C (Rose et al., 2009; Schoemann et al., 2005, Lee et al., 2016). The surface water temperature ranged from a minimum of −1.0 to a maximum 1.0°C during the study period. However, a robust positive correlation was identified between microphytoplankton and sea surface temperature (Spearman rank correlation*,* $p<0.05$).

Phytoplankton exhibit a rapid response to changing environmental conditions, which also affect the variation in pigment composition and size classes (Gibb et al., 2000; Trees et al., 2000; Barlow et al., 2004). Notwithstanding the fact that chlorophyll-*a* is the primary photosynthetic pigment in phytoplankton, the total chlorophyll-*a* pool exhibited minimal spatio-temporal variation, ranging from 40 to 49% (Barlow et al., 2004). In contrast, accessory and carotenoid pigments play a pivotal role in the regulation of adaptive strategies in response to changing environmental factors and in photosynthesis (Trees et al., 2000). In the present study, fucoxanthin, 19-hexanoloxyfucoxanthin and zeaxanthin were identified as the most prominent carotenoid pigments in the study area. Fucoxanthin is a marker pigment for diatom groups, the concentration of fucoxanthin ranged from 0.03 to 1.12 µg/L during the study period and correlated with microscopy. Furthermore, 19-hexanoloxyfucoxanthin and alloxanthin, which are characteristic of nanophytoplanktonic groups, were also identified as prominent pigments in the study area. The zeaxanthin and chlorophyll-*b* pigments, which are indicative of picophytoplankton, were identified as prominent pigments at specific stations within the study area. It was reported that the coastal waters of the West Antarctic Peninsula (WAP) are characterised by substantial phytoplankton blooms, predominantly comprising large diatoms. However, nanoplankton are also an important component of the food web in this region (Schofield et., 2017). Similarly, nano- and picophytoplankton substantially contributed to phytoplankton community composition, which indicate changes in the food web within the Antarctic marine ecosystems.

Conclusion

In this study, pigment based-phytoplankton size classes and microscopic observations of the phytoplankton community with hydrographic data provided new insights into the biogeographic differences along the western Antarctica Peninsula in the austral summer period of 2019. The abundance of diatoms was found to be significantly higher in the western Antarctic. Global warming effects such as increased water temperature and sea ice melt will likely decrease the water salinity and thereby will detrimentally affect the community composition of phytoplankton. However, the contributions of nano- and picophytoplankton groups were also prominent. Consequently, future research should prioritize the role of phytoplanktonic organisms in the polar food chain. Additionally, studies on the relationships between phytoplankton community composition and environmental variables in the area could provide the necessary information to predict how phytoplankton will respond to climate change.

Ethical Statement

Not applicable.

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Author Contribution

Ertuğrul Ağırbaş: Conceptualization, Formal analysis, Investigation, Writing-Original Draft, Supervision; **Ali Muzaffer Feyzioğlu**: Conceptualization, Investigation, Visualization; **Rafet Çağrı Öztürk:** Investigation, Writing-Review & Editing; **Yahya Teri:** Investigation, Writing-Original Draft; **İlknur Yıldız:** Investigation; **Ersan Başar:** Investigation.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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