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Spatial Distribution Patterns of Appendicularians in the Drake Passage: Potential Indicators of Water Masses?

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Abstract: Appendicularians are one of the most common animals found within zooplankton assemblages. They play a very important role as filter feeders but are, unfortunately, inconsistently reported in the Antarctic literature. The present paper attempts to describe the zonal diversity of appendicularians and the main environmental factors influencing their communities in the Drake Passage. Samples were collected during Antarctic summer in 2009–2010. A total of eight species of larvaceans were identified. *Fritillaria borealis* was the species found in the highest numbers in almost the entire studied area, and was observed at all sampling stations. The distributions of other taxa were limited to specific hydrological zones and hydrological conditions. *F. fraudax* and *Oikopleura gaussica* were typical of the areas between the Polar Front and the Subantarctic Front zones, and their distributions were significantly correlated with temperature and salinity, likely making them good indicator species. The *F. fusiformis* distribution was strictly related to South American waters. In summary, temperature was the strongest environmental factor influencing the larvacean community structure in the Drake Passage, and we also found that testing environmental factors on larvaceans as a whole group did not give entirely reliable results.

Keywords: larvaceans; Drake Passage; latitudinal changes in assemblages; *Fritillaria borealis*; environmental conditions

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1. Introduction

Appendicularians are one of the common animals within zooplankton assemblages and are widely distributed in all oceans [1]. These animals are filter feeders, consuming small particles, such as pico- and nanoplankton [2,3]. They build complex mucous houses that serve as filtering tools [4,5]. When the filters are clogged, these houses are rejected, and new houses can be secreted by the animals, even as often as every 2 to 4 hours; the houses can be used by other animals as food or as a fixation substrate [1]. Because of the high efficiency with which appendicularians ingest nanoplankton and picoplankton [6,7], they are able to create a path through which small cells cannot sink and, consequently, can be transported out of the euphotic zone [8]. As a result, when appendicularians are abundant, small phytoplankton cells can contribute much more to vertical carbon flow than when the same community is dominated by, for example, copepods [9]. Moreover, appendicularians have higher growth rates than copepods in response to an increase in food in their waters [10], and even short-term changes in their community structure may highly affect the particle flux in the local environment [8]. It should also be pointed out that, in some regions, appendicularians can be an important source of food for economically significant fishes, e.g., herring (*Clupea harengus*), South American pilchard (*Sardinops sagax*), or the Argentinean anchovy (*Engraulis anchoita*) [11].

Studies on the diversity, distribution, and abundance of Appendicularia in the Southern Ocean are very sparse and are limited to the genus or family levels, probably due to the fragility of appendicularians and the selectivity of the nets used [12,13]. A recent study conducted by some authors [14] noted a significant occurrence of appendicularians in the seasonal ice zone (SIZ) in the Southern Ocean. Other scientists [3] also surveyed Appendicularia diversity and abundance in the SIZ; they noted unusual high abundances of appendicularians and finally suggested that these animals are probably an integral part of the community structure of the zooplankton in the SIZ. Previously, Capitanio et al. [15] analyzed the variability in the characteristics that define the *Oikopleura gaussica* group in Antarctic waters. Furthermore, published data on appendicularians mainly concerned their role and importance in the Southern Ocean zooplankton community structure in general [13,14,16–19].

During the last few decades, the Antarctic ecosystem has been changing, mainly due to climatic fluctuations and the direct impacts of human activity [20,21]. These changes are visible not only in fluctuations of abiotic factors [22,23], but also at the functional level of the pelagic communities [24–28]. The responses of zooplankton to the warming Antarctic marine environment are very difficult to characterize due to the complex interactions between predators and prey [29,30]. Appendicularians are gelatinous zooplankton and, as mentioned above, they play an important role in global biogeochemical cycles because of their high grazing rates and significant role in the export of organic carbon from the ocean surface to the sea bottom [31,32]. However, it is still not clear how the abundance or frequency of occurrence of appendicularians will be affected by climate change [32–34].

The present paper contributes to the study of the species and zonal diversity, abundance, and biomass of appendicularians in the Drake Passage. We identified the main environmental factors influencing the distributions and abundances of selected species, and qualified the species that occurred in specific zones and preferred specific environmental conditions. Our results can be considered the first detailed study of these animals in this region, and may be an important contribution to a broader understanding of this rarely studied group of animals.

2. Material and Methods

2.1. Study Area

The Drake Passage is located between the southern tip of Tierra del Fuego (South America) and the Antarctic Peninsula, connecting the Atlantic Ocean with the Pacific Ocean. The width of the strait is over 800 km, with an average depth up to 3400 m, and a maximum depth of 4700 m [35]. In the investigated area, there is no latitudinal pressure gradient, creating a natural barrier that inhibits north–south geostrophic flow [36]. One of the effects of the zone's existence is the shift of the region of deepening and deep-water-forming to the north, which is also a key process shaping the global circulation system [37]. The volume of water flowing through the Drake Passage is estimated to be 134 ± 11.2 Sv [38]. The positions of the main current changes in this Antarctic region are very dynamic [39]. The Drake Passage is considered a very productive area (mainly due to the high krill biomass), but the primary production measurements obtained in the region are considered to be rather low, with average values ranging from 0.10 to 0.30 g C m^{-2} d^{-1} [40]. In the southern part of the Drake Passage, the primary production values range from 1.7 to 3.4 g C m^{-2} d^{-1} in December to 0.070–0.210 g C m^{-2} d^{-1} in March [40]. The chlorophyll concentration in the passage during Antarctic summer ranges from 0.1 to 1.0 mg m^{-3}, and only locally reaches 2.87 mg m^{-3} (in the Subantarctic Front area and in the coastal waters of South America) [41,42].

2.2. Sampling Collection and Laboratory Studies

Samples were collected randomly during the Antarctic expedition of the Russian Academy of Sciences on the R/V "Akademik Ioffe" in January 2010 (Figure 1). Zooplankton were collected with a 100 µm mesh size WP2-type net. The hauls were performed in layers from the depth ranges of 100–0 m, 200–100 m, and 300–200 m. At some research stations, it was not possible to close the net due to technical problems; therefore, at these stations, hauls were made from depth layers of 100–0 m, 200–0 m, and 300–0 m. Hydrological data, the temperature and salinity data of the surface water, as well as the concentrations of chlorophyll a, were provided by the Shirshov Institute of Oceanology of the Russian Academy of Sciences [41,42]. The investigated area was divided into seven characteristic zones [41,42] based on the phytoplankton and chlorophyll a concentration values (obtained during the same cruise). The following zones were identified (Figure 1): CAZ—Continental Antarctic Zone, SF—Southern Front, AZ—Antarctic Zone, PF—Polar Front, PFZ—Polar Frontal Zone, SAF—Subantarctic Front, SAZ—Subantarctic Zone.

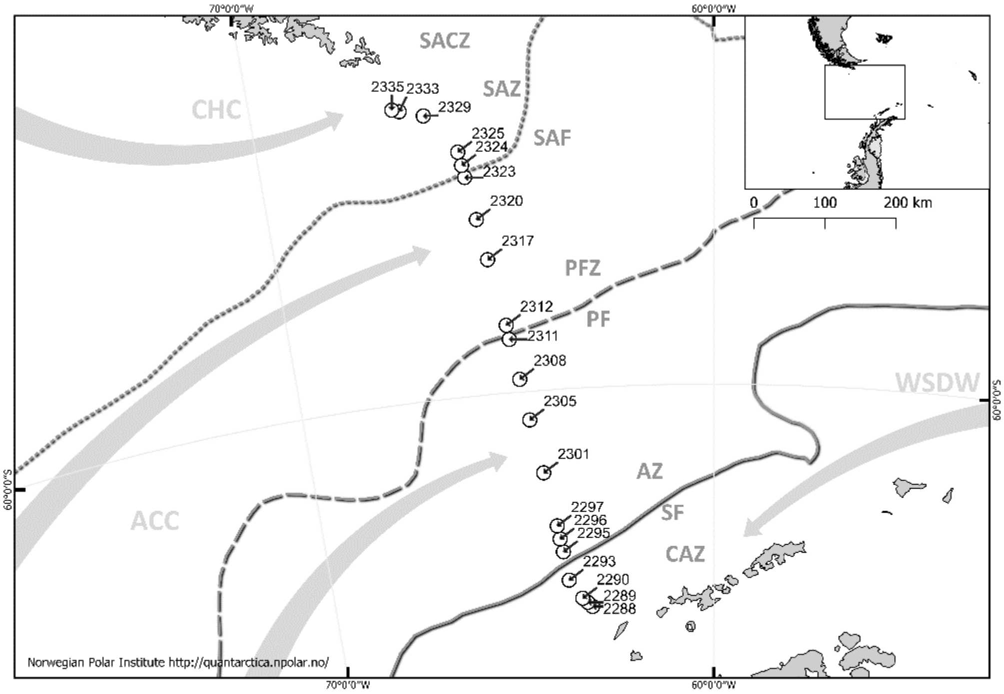


Figure 1. Geographical positions of the sampling stations, with the distinguished positions of the main hydrological zones in the Drake Passage in January 2010; ACC—Antarctic Circumpolar Current, CHC—Cape Horn Current, WSDW—Weddell Sea deep water.

In this study, collected zooplankton samples (51 in total; CAZ: 1, AZ: 16, SF: 3, PF: 3, PFZ: 12, SAF: 9, SAZ: 3, SACZ: 4) were analyzed to determine the qualitative and quantitative compositions of appendicularians that occurred in the Drake Passage. Taxonomic identifications were made to the lowest possible taxonomic level [1,4,43,44]. The obtained results were calculated as the number of individuals in 1000 m^{-3} of sea water. The biomasses of the four most common larvacean species (Table 1) were also estimated. For this purpose, morphometric measurements of all individuals identified in the samples were performed (if possible, due to the state of preservation). The length of the tail part (Lo) and length of the trunk (Lt) were measured, adding up to a total of 16,786 measurements. In the cases of *Fritillaria borealis* and *Oikopleura fusiformis*, the regression patterns developed by Capitanio et al. [45], and Sato et al. [46] were used. The measured dry weight (DW) values were then converted to carbon (C) weights using the ratio C = 0.45 DW [47]. Due to the lack of any equation in the literature representing a regression of the length of the trunk to the mass of *O. gaussica*, the Deibel formula [48] was used, which has been tested for a morphologically similar species, *O. vanhoeffeni* [43,49]. Similarly, in the case of *F. fraudax*, the equation developed for *F. borealis* [45] was used. The obtained biomass values were then converted into micrograms of carbon in a given volume of filtered water (μg C m^{-3}) and in the integrated water column (300–0 m).

Table 1. Trunk length—mass regression equations applied for the biomass calculations of investigated larvacean species; DW (dry weight), TL (trunk length), C (carbon content).

Species		Source
Fritillaria borealis	log DW(µg) = 3.86 log TL(µm)–11.72	[45]
Fritillaria fraudax	log DW(µg) = 3.86 log TL(µm)–11.72	[45]
Oikopleura gaussica	C(µg) = 4.59 TL(mm)	[48]
Oikopleura fusiformis	Log DW(µg) = 2.1 log TL(µm)–6.82	[46]

2.3. Statistical Analyses

Statistical data analyses were carried out in RStudio using R version 4.0.3 [50]. Multivariate statistical analyses were performed using the vegan package version 2.5–7 in R [51]. Pairwise dissimilarity matrices were obtained among samples using Bray–Curtis dissimilarity (vegdist function). Nonmetric multidimensional scaling (NMDS, function metaMDS) was carried out with the dissimilarity matrices calculated for the appendicularian abundances, biomasses, and selected environmental factors. The NMDS plot was made using environmental vectors representing temperature, salinity, and chlorophyll (function envfit). Permutational multivariate analysis of variance (PERMANOVA) was performed to identify the most important environmental factors among temperature, salinity, and chlorophyll a for larvacean abundances and biomasses.

3. Results

3.1. Hydrological Conditions

The lowest temperature (<1 °C) obtained in this study was recorded close to the CAZ. The value of this measured parameter clearly increased towards the north (min. 0.43 °C, max. 7.04 °C). The polar front zone was characterized by an increase in temperature to values above 2 °C, and, further north, the temperature rose rapidly and reached approximately 6–7 °C close to the SAF (Figure 2). The lowest salinity values (33.59) were observed within the AZ, and a minimum value was noted in the PF zone (Figure 2). The highest salinity (34.08) was observed in the SAF area, and, close to the American continent, the salinity decreased slightly again (Figure 2). The highest concentrations of chlorophyll a were recorded close to the front areas: SF, PF, and SAF (max. 0.42 mg m^{-3}, min. 0.09 mg m^{-3}) (Figure 2).

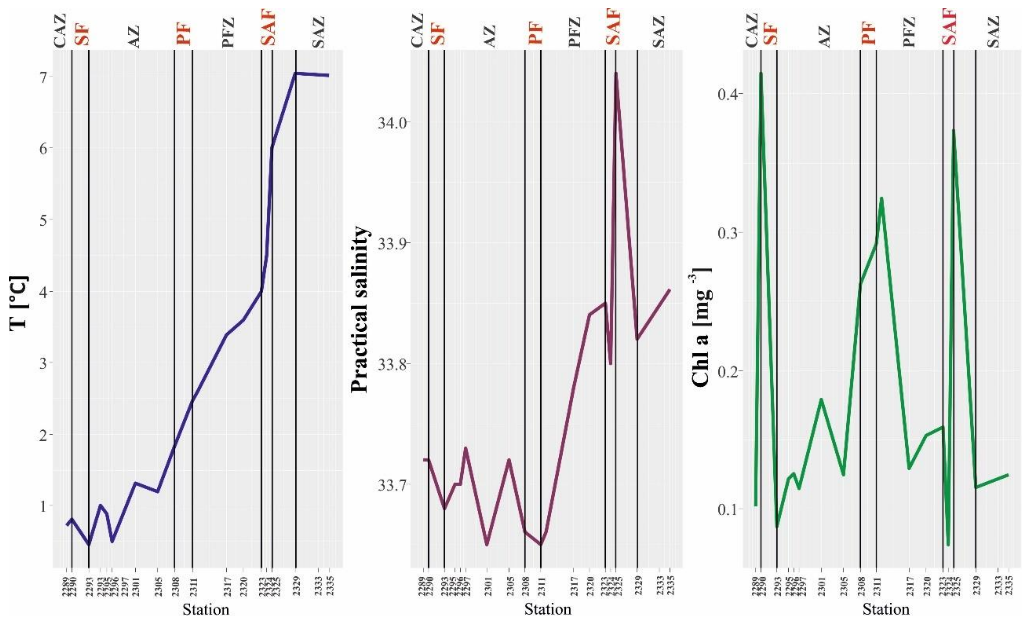


Figure 2. Variabilities in temperature (T) (°C), salinity (S), and chlorophyll a (mg m^{-3}) in the surface water layer of the Drake Passage in January 2010.

3.2. Biogeographical Distribution of Appendicularia in the Drake Passage

Eight species of Appendicularia were identified in the Drake Passage area: *Fritillaria borealis*, *F. haplostoma*, *F. pellucida*, *F. fraudax*, *F. antarctica*, *Oikopleura fusiformis*, *O. parva*, and *O. gaussica*. *F. borealis* was the most abundant species in almost the entire research area and was observed at all sampling stations, although, north of the Polar Front zone, the density of this species clearly decreased (Figures 3 and 4, Table 2). In the Antarctic Zone area, *F. antarctica* was also recorded; however, this species was present in a very small abundance (Figures 3 and 4, Table 2). Other investigated larvaceans were noted only at stations located north of the Polar Front, and this barrier clearly delimited their southern distribution, and, towards the north, the extinction and succession of these species were noticed. *F. fraudax* was typical of the PFZ area, *O. gaussica* was typical further north (SAF), and the area close to the American Continent (SAZ) was clearly an area of occurrence of *O. fusiformis*, while the Subantarctic Front was a clear southern limit of its occurrence (Figures 3 and 4, Table 2). Other observed species, *F. pellucida*, *F. haplostoma*. and *O. parva*, were rarely reported, and their densities were very low (Figures 3 and 4, Table 2).

Table 2. Abundances (means ± SDs) (ind. 10^3 m^{-3}) of appendicularians in the 300–0 m water layer of the Drake Passage in January 2010.

Species	Drake Passage	Zone							
		CAZ	SF	AZ	PF	PFZ	SAF	SAZ	SACZ
Fritillaria borealis	3177 ± 4514	5684	8887	3418 ± 5242	1989	1392 ± 1153	866 ± 1108	433	2125 ± 861
Fritillaria haplostoma	1 ± 5	0	0	0	20	0	0	0	0
Fritillaria pellucida	2 ± 7	0	0	0 ± 2	0	0	0	0	20 ± 10
Fritillaria antarctica	18 ± 62	81	0	45 ± 111	0	0	0	0	0
Fritillaria fraudax	405 ± 880	0	0	0	81	1490 ± 1561	623 ± 551	68	61 ± 86
Oikopleura fusiformis	602 ± 1510	0	0	0	0	7 ± 14	821 ± 1180	284	4635 ± 1656
Oikopleura parva	1 ± 4	0	0	2 ± 0	0	3 ± 7	0	0	0
Oikopleura sp	212 ± 334	0	24	9 ± 42	183	330 ± 239	785 ± 501	122	41 ± 57
Oikopleura gaussica	321 ± 484	0	11	0	508	641 ± 652	1011 ± 353	135	61 ± 48
Appendicularia	4779 ± 4310	5765	8911	3474 ± 5278	2274	3223 ± 2523	3095 ± 536	907	6882 ± 641

The biomass of *Fritillaria borealis* grew towards the northern region of the investigated transect (in contrast to the abundance results), and the highest values were observed north of the Polar Front zone (Figure 5). The two sampling stations at which the highest biomasses of this species were recorded were in the SAZ (station 2333; 334.01 10^3 µg C m^{-3}) and within the SAF (station 2323; 259.60 10^3 µg C m^{-3}). Another *Fritillaria* species, *F. fraudax*, reached its highest biomass in the PFZ at 1.418.05 10^3 µg C m^{-3} (Figure 5). Its biomass then decreased towards the north (Figure 5). The highest biomass of *Oikopleura gaussica* was observed in the SAF zone at 12029.59 10^3 µg C m^{-3} (Figure 5). *O. fusiformis* was the species with the highest biomass among the identified taxa (Table 3). The highest values were observed in the northern part of the transect, such as the value of 2558.26 10^3 µg C m^{-3} recorded in the SAZ (station 2335), and smaller peaks were also noticeable in the SAF and PFZ (Figure 5).

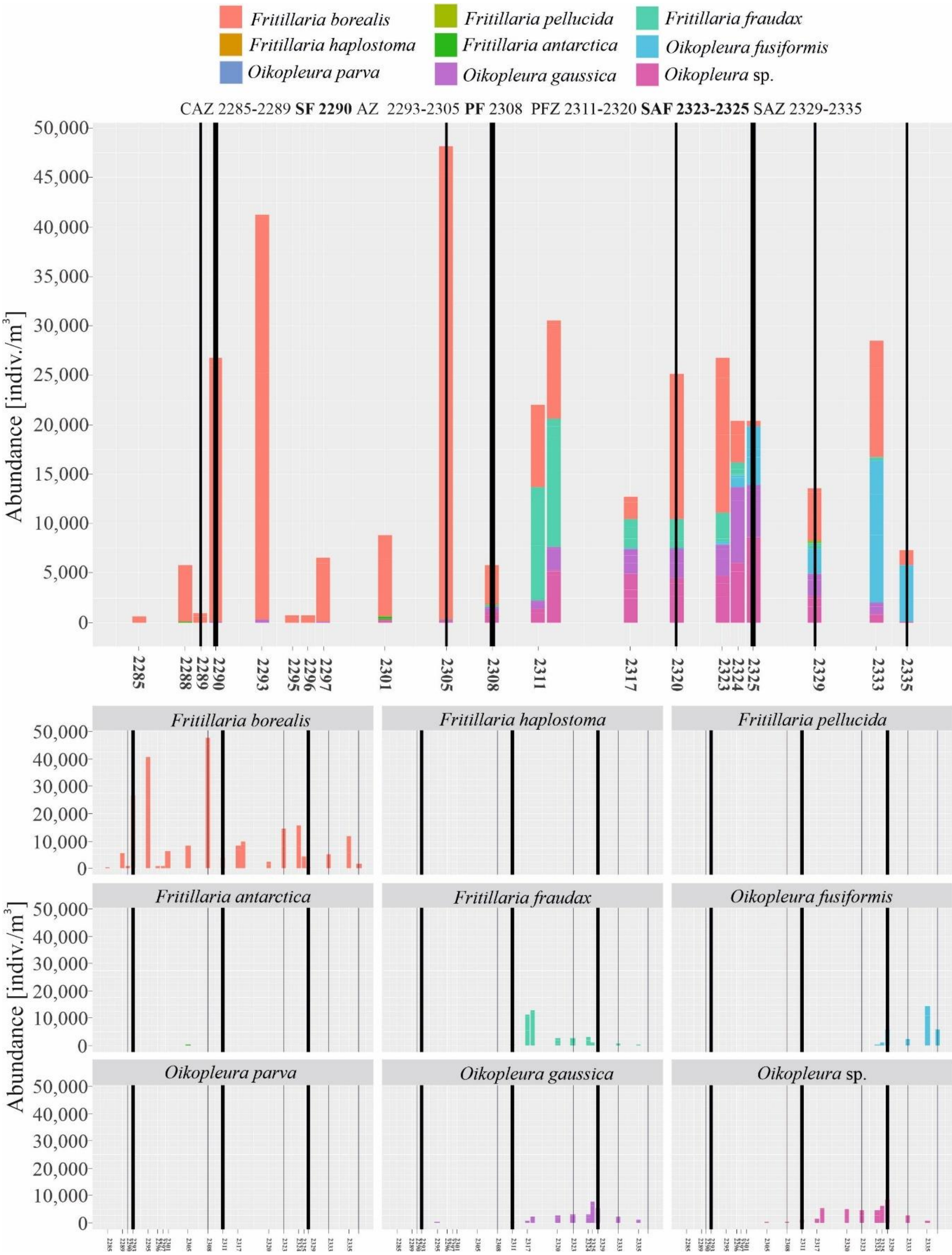


Figure 3. Diversity and abundance of Appendicularia across the investigated stations in the Drake Passage (with remarks on the biogeographical zones) in January 2010.

Figure 4. Diversity and abundance of Appendicularia across the specific biogeographical zones in the Drake Passage in January 2010.

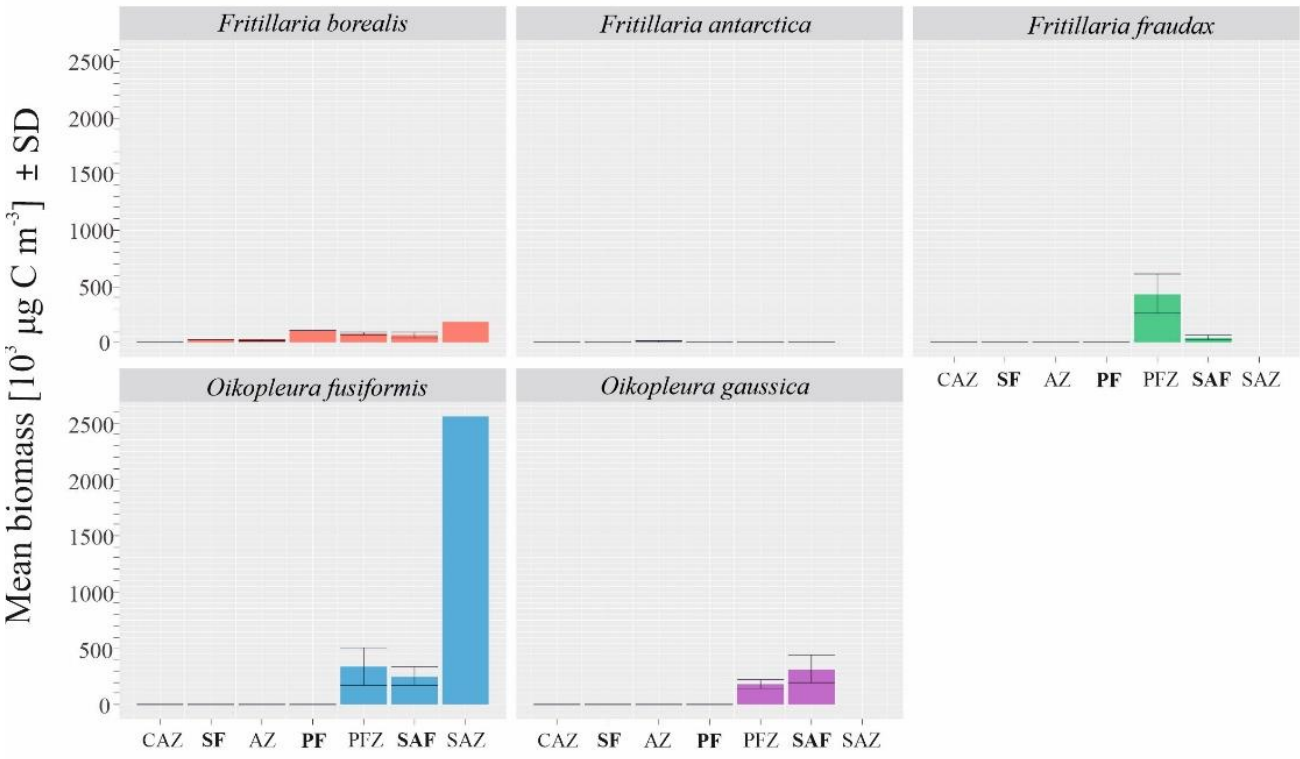


Figure 5. Mean biomasses of the most abundant Appendicularia species across the specific biogeographical zones in the Drake Passage in January 2010.

Table 3. Mean biomasses (10^3 µg C m^{-3}) of appendicularians in the 300–0 m water layer in the Drake Passage in January 2010.

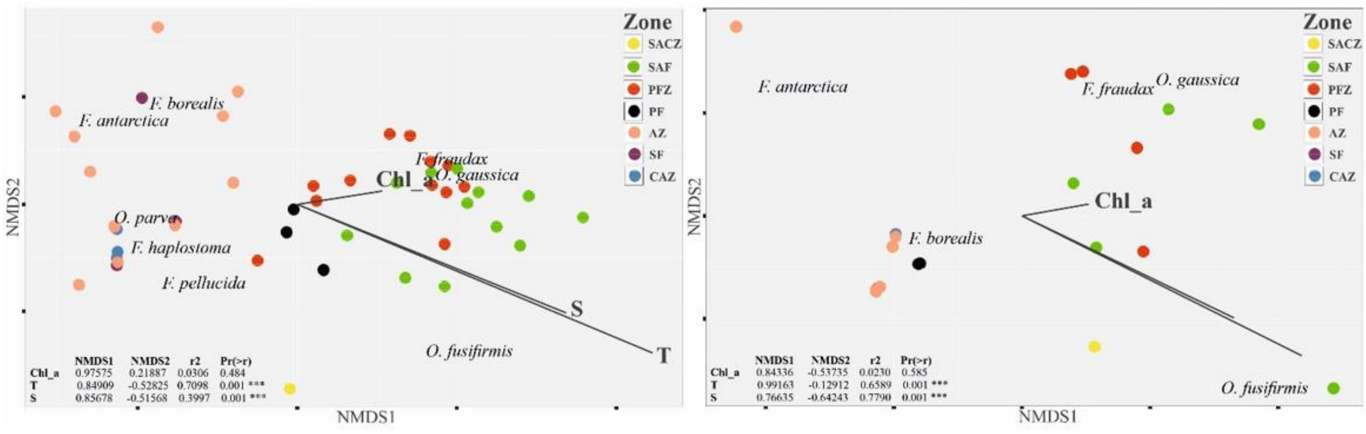
Species	Biomass (10^3 µg C m^{-3})
Fritillaria borealis	73.79 ± 90.35
Fritillaria fraudax	96.85 ± 308.26
Oikopleura gaussica	101.69 ± 232.87
Oikopleura fusiformis	321.28 ± 677.54

3.3. Environmental Factors Influencing the Zonal Distribution of Appendicularia

The influences of environmental factors on the abundance and biomass of Appendicularia in the Drake Passage were investigated based on the temperature (T), salinity (S), and chlorophyll a (Chl a) concentration in the surface water layer. The results showed that, among the tested factors, the surface water temperature (T) and salinity (S) were statistically significantly ($p < 0.05$) correlated with the abundances and biomasses of appendicularians (Table 4). Temperature was a very important factor influencing the distributions of *Fritillaria antarctica*, *F. fraudax*, *Oikopleura fusiformis*, and *O. gaussica* (Table 4). The chlorophyll a concentrations were statistically significant only in the case of *O. gaussica* (Table 4). Based on the obtained results, we were able to distinguish three types of species among the investigated larvaceans: *F. borealis*, a cold-water species that occurred in all zones of the passage and for which environmental factors were not statistically significant; *F. fraudax* and *O. gaussica*, cold-water species that occurred between the PF and the SAF, were limited by specific water masses and environmental conditions, and for which T, S, and Chl a were statistically significant; and *O. fusiformis*, a warm-water species that occurred in the SAZ, was limited by specific water masses and environmental conditions, and for which T and S were statistically significant (Table 4, Figure 6).

Table 4. The results of the 1- and 2-way PERMANOVA tests reported as pseudo-F values; significance levels are marked as follows: *** $p < 0.001$, ** $p < 0.01$, and * $p < 0.05$ (Ef – environmental factors, Chl a—chorophyll a, T—temperature, S—salinity, Z—zone, App—Appendicularia, Fb—*Fritillaria borealis*, Ff—*F. haplostoma*, Fp—*F. pellucida*, Fa—*F. antarctica*, Ff—*F. fraudax*, Of—*Oikopleura fusiformis*, Op—*O. parva*, Og—*O. gaussica*, and O—*Oikopleura* sp.).

		Abundance (ind. 10^{-3} m^3)										Biomass (10^3 μg C m^{-3})			
Ef	**Df R**	**App**	***Fb***	***Fh***	***Fp***	***Fa***	***Ff***	***Of***	***Op***	***Og***	***O***	***Fb***	***Fa***	***Of***	***Og***
Chl a	1 45	0.607	1.2827	0.4724	0.5911	0.0166	1.1251	1.3576	0.4371	3.5536 *	0.2951	2.3743	0.0193	2.4803	1.7626
T	17 29	2.0373 ***	1.1479	0.7985	2.0905	10.319 ***	8.5419 ***	6.8241 ***	0.7509	2.5872 ***	3.9824 ***	-1.7976×10^{17}	9.156×10^{17} ***	9.6813×10^{16}	36.071 ***
S	1 45	5.6876 ***	0.6531	0.9379	0.0561	2.0514	2.7163	30.529 ***	0.1458	6.4235 ***	8.2766 ***	6.1528 **	2.4086	39.397 ***	5.5897 **
T * Chl_a	17 29	2.0373 ***	1.1479	0.7985	2.0905	10.319 ***	8.5419 ***	6.8241 ***	0.7509	2.5872 ***	3.9824 ***	-1.7976×10^{17}	9.156×10^{17} ***	9.6813×10^{16}	36.071 ***
T * S	17 29	2.0373 ***	1.1479	0.7985	2.0905	10.319 ***	8.5419 ***	6.8241 ***	0.7509	2.5872 ***	3.9824 ***	-1.7976×10^{17}	9.156×10^{17} ***	9.6813×10^{16}	36.071 ***
Z	1 45	9.9469 ***	1.8119	0.0213	2.6486	1.0618	26.043 ***	27.878 ***	0.0906	16.678 ***	30.08 ***	24.818 ***	1.2421	32.616 ***	25.034 ***



(A) **(B)**

Figure 6. Ordination of the sampling plots in an NMDS space based on the Bray–Curtis dissimilarities of Appendicularia species abundances (**A**) and biomasses (**B**) measured in the Drake Passage in January 2010. The points represent the placement of plots, and the name of species represents the placement of that species within the multidimensional space. The landscape variables explaining the differences in abundance and biomass between the plots are represented as vectors and were fitted using the function envfit (R-package vegan); Signif. codes: '***' 0.001.

4. Discussion

In January 2010, during the 2009–2010 expedition to the Drake Passage area, we found eight species of larvaceans. During previous research conducted in the southern part of the Bransfield Strait (Antarctic Peninsula region), some authors [52,53] only noted the presence of unidentified appendicularians. On the western side of the Drake Passage, Takahashi et al. [54] reported the presence of species from the genus *Oikopleura*, while Capitanio et al. [15] identified *Fritillaria borealis*, *O. fusiformis*, and *O. gaussica* in the waters of the Bellingshausen Sea and around South Georgia. The abundances of appendicularians observed in the Drake Passage during our study were comparable to the results presented by Jażdżewski et al. [52], but the abundances obtained herein were significantly higher (even 100× higher) than those reported by Witek et al. [53]. It should be pointed out that the zooplankton samples analyzed in the studies of Jażdżewski et al. [52] were collected in February and March, and those analyzed by Witek et al. [53] were obtained in December and January, while, in our study conducted in 2010, samples were collected at the beginning of January. Presumably, in the case of the results of Witek et al. [53], the Appendicularia population had not yet developed, while, during our studies, most of the recorded individuals were relatively small and were supposedly at early stages of ontogenesis. Jażdżewski et al. [52] explained that large abundances of rather small appendicularians are typical for the water masses around the Bellingshausen Sea. During our study, samples were taken from a similar region—south of the PF zone—and we noted a distinct dominance of relatively small *F. borealis* individuals. In comparison to the northern parts of the Drake Passage (along Argentina's eastern coast), the abundance and biomass observations obtained in this study were approximately 1000 times lower than the values reported by, e.g., Capitanio et al. [45]. Most likely, the very high abundances observed by Capitanio et al. [45] can be explained by the high abundances of *O. dioica* reported in their study; this species was not found in the Drake Passage during our study.

4.1. Biogeographical Distribution of Appendicularia in the Drake Passage and the Main Zones of Occurrence

During our study, *Fritillaria borealis* was observed within all investigated areas; however, the highest abundances were noted in the AZ area, while, in contrast, the biomass of this species grew to the north. In our opinion, this result is mainly due to the reproductive process beginning earlier in the northern regions than in the southern regions and, hence, larger specimens were recorded in the northern regions, resulting in higher biomass measurements in these areas. In the Antarctic Zone area, many individuals were recorded, but these individuals were at an early stage of development. In the Southern Ocean region, *F. borealis* is a very common species and was previously noted by Aguirre et al. [19]. This species occurred in all zones of the Drake Passage, from the Continental Antarctic Zone to the South American Zone.

Based on our results, we were able to identify species with very narrow ranges of occurrence. During our study, *Fritillaria fraudax* was noted only in the area between the Polar Front and the Subantarctic Front zones, as was *Oikopleura gaussica*. However, *F. fraudax* appeared to be a slightly "cooler" species compared to *O. gaussica* because the former was recorded at its highest density and biomass slightly to the north of the Polar Front zone, while the latter species was abundant near the Subantarctic Front zone. In the case of *F. fraudax*, it was very difficult to compare our results with previously collected data because this species has not been registered in this region in the past. According to Esnal [1,4], this larvacean is a thermophilic and cosmopolite species; however, Aravena and Palma [2], based on results obtained from the northern waters of Chile, suggested that *F. fraudax* is a nearshore species with a preference for neritic waters, although they pointed out that this species can also occur in oceanic waters. Through analysis of our results, we can say that the presence of this species is rather limited to specific types of water masses (with specific thermal conditions). *O. gaussica* is the name used for a group of species: *O. gaussica*, *O. valdiviae*, *O. drygalski*, and *O. weddelli* [54]. This species was, for example, recorded by Lindsay and Williams [55] in the southwest Indian Ocean sector of East Antarctica, and the highest abundances obtained in their study were found north of the Antarctic Circumpolar Current. During our study, the distribution of this species was limited by the Polar Front and Subantarctic Front zones, and the area between these zones was the main area of occurrence of this larvacean.

4.2. Environmental Factors Influencing the Zonal Distribution of Appendicullaria

Primary production is mainly driven by temperature and nutrient availability, and these factors also impact appendicularian population dynamics [34,56]. During our study, the main statistically significant environmental factor responsible for variabilities in Appendicularia was the water temperature, which was consistent with the observations of Gorsky et al. [57], who recognized that temperature was the factor that most determined the structure of these animals. Consistent with previous observations by other authors e.g. [34,56], high abundances of Appendicularia should be observed in areas with very high phytoplankton biomasses and chlorophyll a contents; however, during our study, it was clear that the stations with the highest chlorophyll a concentrations did not correspond with the highest larvacean abundances or biomasses. The frontal zones, the SF, PF, and SAF, in the Drake Passage were the areas with the highest chlorophyll a concentrations, and very high densities of other zooplanktonic organisms have also often been observed in these regions by other authors e.g., [58–61]. One explanation for this phenomenon was provided by López Urrutia et al. [62], who recorded that predation by copepods on appendicularian eggs and juveniles can significantly limit their population growth rates. Hopcroft et al. [10] pointed out that both the potential size spectrum of food and its efficiency of utilization are influenced by the body size of appendicularians, and small species can obtain even very small particles so they may avoid problems with resource limitations. Importantly, we recorded that, in the case of appendicularians, all tested environmental factors were significant when all larvaceans were analyzed as a group. The results of the analyses that were performed separately for each species showed differences in the "sensitivity" of individual species to the studied factor.

According to the opinion of Atkinson et al. [12], "appendicularians are inconsistently reported in the Antarctic literature", and this is probably the result of net selectivity (usually krill or salps are the main subject of research), but the delicate body structure of these animals also makes them extremely difficult to study. The Southern Ocean and Antarctica are warming [63], and the physicochemical characteristics of their waters make this region particularly susceptible to ocean acidification [64]. According to Troedsson et al. [34], a lower pH would favor appendicularian fitness, and lead to an increase in their ecological importance. However, the increased ecological importance of these animals, along with progressive climate changes, would be in line with the general trend of the increasing importance of jellyfish organisms (e.g., tunicates and cnidarians) in all marine environments [32], including polar regions [65–69].

5. Conclusions

1. *Fritillaria borealis* was a widespread species in the Drake Passage; high abundances were noted across all investigated areas, and we did not find any significant correlation between its abundance and the tested environmental factors.

2. *F. fraudax* and *Oikopleura gaussica* were typical species in the area between the Polar Front and Subantarctic Front zones, and their distributions and abundances were significantly correlated with temperature and salinity.

3. *F. fusiformis* is a warm water species and its distribution was strictly related to South American waters.

4. Temperature was the strongest environmental factor (not the concentration of chlorophyll a) which influences the larvaceans community structure in the Drake Passage.

5. Testing environmental factors on larvaceans as a whole group cannot provide entirely reliable results; by taking into account only this approach during the research conducted in this study, all environmental factors were found to be significant.

Author Contributions: M.K. managed the laboratory analysis, dataset preparation, and the analysis and interpretation of the results, and was responsible for the management and preparation of the manuscript. A.P. was responsible for the sample collection and organizing the dataset, data analysis and interpretation, and management and preparation of the manuscript. Both authors have read and agreed to the published version of the manuscript.

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