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Research Article

Abundance and spatial distribution of neustonic copepodits of *Microsetella rosea* (Harpacticoida: Ectinosomatidae) along the western Magellan coast, southern Chile

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ABSTRACT. The pelagic harpacticoid copepod *Microsetella rosea* inhabits the cold waters along the temperate southern coast of Chile, where its population biology and ecological role in the neuston are unknown. During a CIMAR 16 Fiordos cruise realized in the Magellan Region, 26 neustonic samples were collected to analyze the abundance, spatial distribution of copepodits and oceanographic conditions (temperature, salinity, and dissolved oxygen). *M. rosea* copepodits, the most abundant holoneustonic taxa (30% of total abundance), were present at all sampled stations and were 0.5 times more abundant than calanoids. These copepodits inhabited waters ranging between 6.5-8.5ºC and salinity of 26-33, with maximum abundances (1,000-10,000 ind/5 min horizontal drag) at means of 7.2 ± 0.6ºC and salinities of 30.7 ± 0.9. Froward Cape, Almirantazgo Sound, and Inútil Bay stations accounted for 65% of total *M. rosea* abundance, whereas Beagle Channel stations present the lowest abundances (<4%). The entire sampling area was as an oxygenated estuary (7.4 ± 0.4 mL L^{-1}). Given the abundance and recurrence of *M. rosea* in the Magellanic neuston, future research should assess the ecological functions of this species. Finally, *M. rosea* could also be used as a biotracer for processes of aggregation in other estuarine neustonic communities of southern Chile.

Keywords: *Microsetella rosea*, Copepoda, neuston, subantarctic zooplankton, estuaries, oximax zone, southern Chile.

Abundancia y distribución espacial de copepoditos neustónicos de *Microsetella rosea* (Harpacticoida: Ectinosomatidae) en la costa occidental de Magallanes, Chile

RESUMEN. El copépodo harpacticoide pelágico *Microstella rosea* habita las aguas frías a lo largo de la costa templada del sur de Chile, donde se desconoce su biología poblacional y rol ecológico en el neuston. Durante el crucero CIMAR 16 Fiordos realizado en la región de Magallanes, se recolectaron 26 muestras neustónicas para analizar la abundancia, distribución espacial de los copepodítos y condiciones oceanográficas (temperatura, salinidad y oxígeno disuelto). Los copepoditos de *M. rosea*, el taxa holoneustónico más abundante (30%), se encontraron en todas las estaciones analizadas y fueron 0,5 veces más abundantes que los copépodos calanoides. Los copepoditos habitaron aguas de 6.5-8.5ºC, con salinidades de 26-33, con máximos de abundancia (1.000-10.000 ind/5 min arrastre horizontal) con promedios de 7,2 ± 0,6ºC y 30,7 ± 0,9 de salinidad. En las estaciones localizadas en Cabo Froward, Seno Almirantazgo y Bahía Inútil se colectó el 65% de la abundancia total de copepoditos; mientras que en las estaciones del Canal Beagle se registraron las menores abundancias (<4%). Toda el área de muestreo representa un estuario oxigenado (7,4 ± 0,4 mL L^{-1}). Dada la abundancia y recurrencia

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de *M. rosea* en el neuston magallánico, se deberían efectuar futuras investigaciones para evaluar las funciones ecológicas de este copépodo. Finalmente, *M. rosea* podría ser utilizado como un biotrazador para procesos de agregación en otras comunidades estuarinas neustónicas del sur de Chile.

Palabras clave: *Microsetella rosea***,** Copepoda, neuston, zooplancton subantárctico, estuarios, zonas Oximax, sur de Chile.

INTRODUCTION

While harpacticoid copepods are primarily benthic crustaceans, a small proportion (<0.5%) of harpacticoid species inhabit the pelagic zone during their life cycle (Boxshall, 1979; Uye e*t al*., 2002). These pelagic species, which include *Microsetella* spp. and *Macrosetella* spp., have relatively strong swimming abilities and unique structural features, such as an elongated worm-like body and long caudal setae that delay sinking velocity. These copepods also show a close resemblance to floating substrates (*e.g.*, the colonial cyanobacterium *Trichodesmium*; Calef & Grice, 1966; Tokioka & Bieri, 1966; O'Neil, 1998), and suspended organic matter (Alldredge, 1972; Ohtsuka *et al*., 1993; Green & Dagg, 1997; Uye *et al*., 2002; Zaitsev, 2005).

Microsetella rosea is widely distributed in sub-antarctic waters (5-10°C), ranging from the southern end of South America to western Antarctica, in addition to inhabiting the warm, subtropical waters of the South China Sea, Mediterranean Sea, and Black Sea (Razouls *et al*., 2005-2014) (http://copepodes.obs-banyuls.fr). Adult females can reach a dry weight of 0.02 mg and a length of 800 µm.

Compared to the vast information available on the population and production dynamics of marine planktonic calanoid copepods, there are relatively few studies that focus on marine and estuarine planktonic non-calanoid copepods, particularly for *Microsetella* species (Sabatini & Kiørboe, 1994; Uye & Sano, 1998; Uye *et al*., 2002). One study focusing on a non-calanoid copepod was conducted by Uye *et al*. (2002). Specifically, these authors researched the population and production dynamics of *Microsetella norvegica* in the Sea of Japan and found that reproductive activities of this species occur in the early fall and that brooding sacs contain a maximum of 16 eggs/sac. In the Magellan Strait, typical pelagic calanoid and cyclopoid copepods have been previously studied (Marín & Antezana, 1985; Mazzocchi *et al*., 1995; Hamamé & Antezana, 1999; Marín & Delgado, 2001), and there are some references to pelagic harpacticoids (Aguirre *et al*., 2012). However, work on pelagic harpacticoid copepods is limited in regards to the waters of South America (Palma & Kaiser, 1993; Boltovskoy, 1999).

In addition to the lack of studies on non-calanoid species, there is also little available research regarding neustonic communities along the Chilean coast (Palma & Kaiser, 1993). In the neuston, especially in coastal waters, members of the *Microsetella* genus are numerically dominant and highly abundant (Anraku, 1975; Dugas & Koslow, 1984; Uye *et al*., 2002; Zaitsev, 2005). The community structure and biodiversity of the neuston, including copepodits of species such as *M. rosea*, are particularly relevant when considering the number of roles that neuston plays in the marine environment.

The neuston forms a boundary between the air and water that, although only of few centimeters thick (Hardy, 1991; Upstill-Goddard *et al.,* 2003), covers 71% of the planet's surface. Moreover, in temperate zones the neuston plays an important trophic role as a food source for meso and macrozooplankton, in addition to being a key component in the production of marine snow and in the vertical transport of organic material from the ocean surface to greater depths (Conte *et al*., 1998; Hays *et al*., 2005; Zaitsev, 2005; Koski *et al*., 2007). The neuston is also important to the early and larval life cycle stages of a number of commercially valuable and/or ecologically significant species in Chile, particularly in regards to larval dispersion (Scheltema, 1986; Gallardo *et al*., 2012; Cañete *et al*., 2012a).

Nevertheless, the impact of latitudinal differences on the functions of the neuston in the fragmentation and transport of organic matter to greater depths is not fully understood (Zaitsev, 2005; Koski *et al*., 2007). Further information is also needed to enhance the understanding on how the neuston is influenced by environmental and oceanographic factors, such as temperature, solar radiation, marine pollution, water salinity and density, UV radiation, acidification, and climate change, among others (Hardy, 1991; Rodríguez *et al*., 2000; Zaitsev, 2005). Therefore, the goals of the present study were to: i) record the abundance and spatial distribution of *M. rosea* neustonic copepodits along the western coast of the Magellan region; ii) connect these ecological observations with oceanographic parameters (temperature, salinity, and dissolved oxygen) in order to define the conditions under which the *M. rosea* population develops; and iii) compare *M. rosea* abundances against those of other collected neustonic taxa, thus determining their biological contributions as biotracers for processes associated with the aggregation of Magellan neustonic communities.

MATERIALS AND METHODS

Sampling was conducted onboard the RV Abate Molina as part of the CIMAR 16 Fiordos cruise during the austral spring of 2010 (October 11 to November 19). Twenty six stations were used for sampling. These stations were located along the western mouth of the Magellan Strait (Sta. 7-15) to Navarino Island in the Beagle Channel (Sta. 37-43). At stations close to Dawson Island, samples were primarily collected from the Almirantazgo Sound, Whiteside Channel, and Inútil Bay (Sta. 51-60). Additionally, the sampling area included stations near channels and islands with proximity to the Pacific Ocean (Sta. 27-35) (Fig. 1). Sampling was originally planned to include stations along the eastern margin of the Magellan Strait; however, rough weather conditions did not allowed sample collection (Sta. 1-6, not shown).

At each station, sampling was done with a neuston net (80 cm wide and 30 cm deep) with a 50 µm mesh size zooplankton net (Kršinić, 1998). The net was dragged along the surface at a speed of 0.77-1.03 m s^{-1}. At stations 7-9, the net was dragged for 8 min, but given the high amount of plankton collected, this was reduced to 5 min for all subsequent sampling stations. According to the layer classification established by Hardy (2005), the sampled layers corresponded to the centilayer and surface layer (1-100 cm depth). Only one haul per station was collected. Samples were fixed with 5% neutralized formalin.

Vertical profile of oceanographic conditions for each stations were obtained by a rosette equipped with a Sea-Bird CTD deployed to different depths according to the bottom depth of each site (Data Report CIMAR 16 Fiordos cruise). Since the neuston is in the surface layer, data for temperature, salinity, and dissolved oxygen content were recorded as average of readings between 1 to 2 m depths.

Due to the lack of a flow-meter, abundance and biomass data were standardized to the number of individuals or biomass wet-weight (g) per 5 min drag. To determine biomass wet-weight, which included phytoneuston and zooneuston, samples were filtered on a 30 µm sieve. Mainly micro- to mesoneuston (20 µm-20 mm) (Hardy, 2005) samples were collected. Folsom fractioning was used to further divide the collected biomass into 1/8th subsamples, thereby facilitating the counting of neuston holoplankton and *M. rosea* copepodits.

The copepod stages of *M. rosea* were identified following Uye *et al.* (2002). Abundance data only considered the copepodit stages of the *M. rosea* lifecycle, while nauplius and adult stages were excluded. Additionally, the methodology described by Davies & Slotwinski (2012) was used to discriminate individuals of *M. rosea* from *M. norvegica*. Other zooplankton components were identified based on Palma & Kaiser (1993) and Boltovskoy (1999). Samples were stored at the Austral Biological Oceanography Laboratory (LOBA), Department of Sciences & Natural Resources, Faculty of Sciences, Universidad de Magallanes, Punta Arenas, Chile.

The Kruskal-Wallis test was used to detect different trends in *M. rosea* abundance and differences in trends between the sampled stations, which were grouped into four geographic zones located along the Magellan and Fuegian channels (Antezana, 1999). The relationship between *M. rosea* copepodit abundance and the oceanographic parameters of temperature, salinity, and dissolved oxygen content were tested using Spearman's Rank-Order Correlation Coefficient (r_s) (Zar, 1999; Daniel, 2000).

Magellan plankton can be used to establish distributional trends of bio-physical interactions in estuarine ecosystems. In relation to this study, assessing only the thin neuston layer reduced the number of spatial components (x,y) and prevented constraints associated with vertical water stratification. Additionally, the spatial area of sampling was sufficiently large to cover meso-scale patterns (10-1000 km; Mann & Lazier, 1991; Garçon *et al.*, 2001). Finally, the sampled area, a heterogeneous coastal system, represents a natural laboratory for studying the population dynamics and topographic mechanism that could to produce the aggregation or clumping of the plankton (Downing, 1991).

To classify the type of spatial distribution presented by *M. rosea* copepodits within the study area, a dispersal index (I_d) was applied. This index is based on the variance to mean ratio ($s^2/\overline{x}$) and describes a trend of spatial distribution. If $I_d = 1.0$, there is random distribution ($s^2 = \overline{x}$); if $I_d < 1$, there is uniform or regular distribution ($s^2 < \overline{x}$); and if $I_d > 1$, there is clumped distribution ($s^2 > \overline{x}$) (Ludwig & Reynolds, 1988; Hulbert, 1990).

RESULTS

Oceanography

The spatial variability of ocean temperature, salinity, and dissolved oxygen content were measured for the surface layer of the analyzed stations. Water temperature

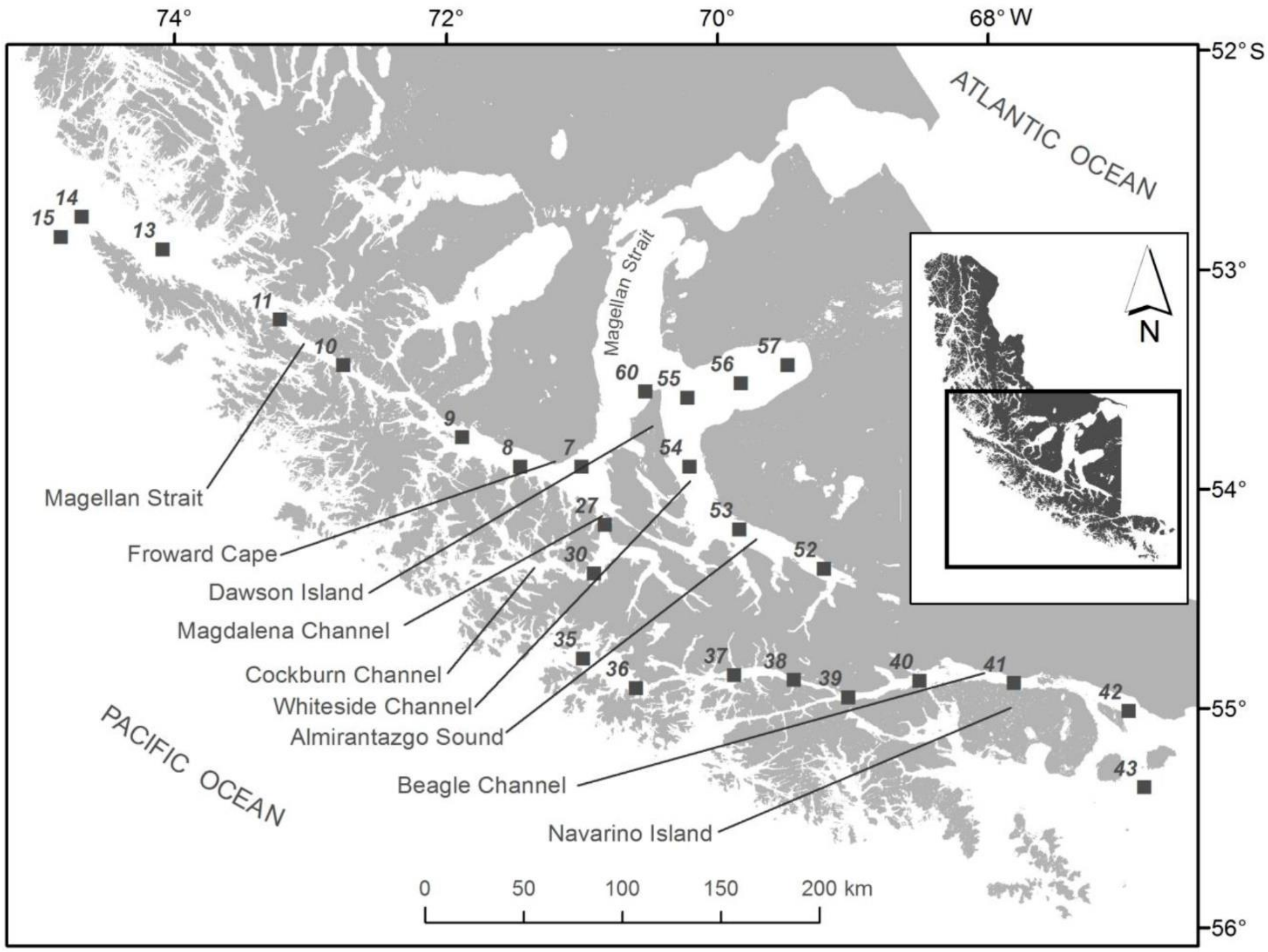

Figure 1. Geographical position of neuston sampling stations in the Magellan Region, CIMAR 16 Fjords cruise (October-November 2010).

fluctuated between 6.16ºC (St 52) and 8.42ºC (St 56), with an average water temperature of 7.2 ± 0.6ºC within the study area. The highest temperatures were detected in the Whiteside Channel and Inútil Bay, while the lowest temperatures were detected along the western side of the Magellan Strait and in Almirantazgo Sound, near the glacial discharge from the Darwin Ice Field.

Salinity was the most variable among all measured parameters. Salinities ranged from 26.4 (Sta. 10) to 32.78 (Sta. 15), with an average salinity of 30.7 ± 0.91. Based on the classification criteria proposed by Valdenegro & Silva (2003) for southern Chile, all samples in the study area were taken from estuarine (1-32) or modified subantarctic waters (32-33). Values corresponding to 32-33 were recorded for stations in the Magellan and Fuegian channels.

Dissolved oxygen content ranged from 6.65 mL L^{-1} (Sta. 15) to 8.27 mL L^{-1} (Sta. 55), with an average of 7.4 ± 0.4 mL L^{-1}. The surface layer was oxygenated throughout the study area, with a maximum value recorded in a glacial area of the Almirantazgo Sound. According to Cañete *et al.* (2012b), the surveyed area can be classified as an oximax or normoxic condition (maximum oxygen zone; values > 2 mL O_2 L^{-1}).

Neuston biomass and abundance

The collected neuston biomass fluctuated by up to two orders of magnitude, ranging from 0.7 g 5 min^{-1} of horizontal drag (Mhd) (Sta. 39) to 31.89 g 5 Mhd (Sta. 52), with an average of 8.55 ± 7.33 g 5 Mhd (Fig. 2). Neuston biomass was highest in wind protected areas, such as in Froward Cape, Almirantazgo Sound, and Inútil Bay (average = 12.3 g 5 Mhd^{-1}) and along the western arm of the Magellan Strait, between Capitán Aracena Island and the western mouth of Magellan Strait (average = 11.1 g 5 Mhd^{-1}). The lowest neuston biomass measurements were recorded along the Beagle Channel (average = 5.5 g Mhd^{-1}; Table 1).

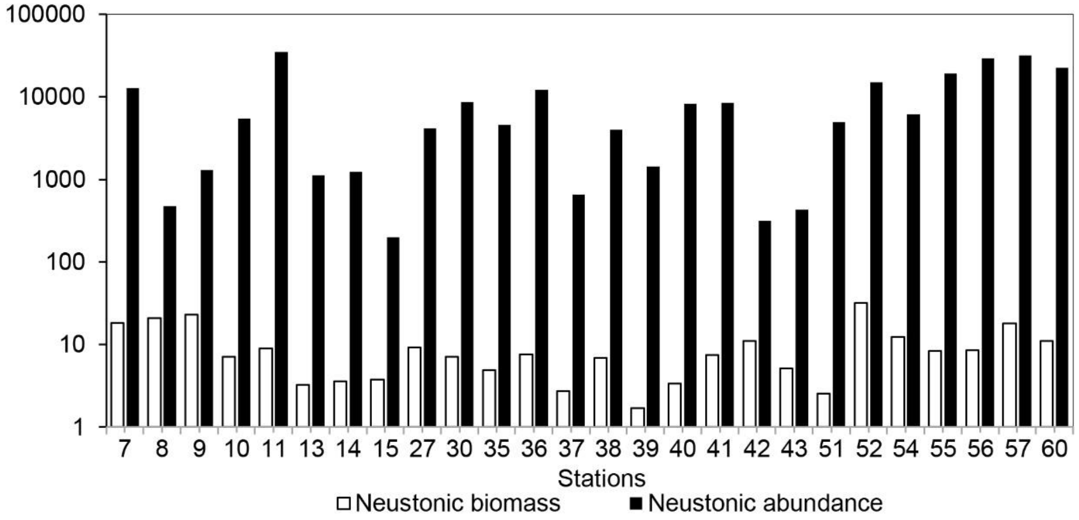

Figure 2. Neustonic biomass (g 5 Mhd^{-1}) and neustonic abundance (ind 5 Mhd^{-1}) in the western Magellan coast. Both measurements are expressed in log scale and include phytoneuston and zooneuston together. The average and standard deviation of neustonic biomass and abundance were 8.55 ± 7.33 g 5 Mhd^{-1} and 9,179 ± 10,281 ind 5 Mhd^{-1}, respectively. The function log (x+1) was applied to the original abundance data to obtain only values >0 in the axis. Mhd: minutes of horizontal dragging.

Table 1. Total neustonic biomass and abundance and *Microsetella rosea* abundance collected from four macrozones along the western margin of the Magellan Region during the CIMAR 16 Fjord cruice (Oct-Nov 2010). Average values ± standard deviation. Mhd: minutes of horizontal drag. Significant differences (*) were detected between macrozones using the Kruskal-Wallis test ($F_{3,25} = 8.63$; $P < 0.05$).

Macrozones	Neuston biomass (g 5 Mhd^{-1})	Neuston abundance (ind 5 Mhd^{-1})	*Microsetella rosea* abundance (ind 5 Mhd^{-1})
Almirantazgo Sound to Inútil Bay (7 stations; 29.6 ± 1.64)	12.4 ± 9.4	18,350 ± 11,594	6,307 ± 5,993*
Western arm of the Magellan Strait (8 stations; 30.6 ± 0.46)	6.7 ± 8.2	7,172 ± 3,888	2,225 ± 3,693*
Western islands between Dawson Island and the Pacific Ocean (4 stations; 30.7 ± 0.17)	4.7 ± 2.7	7,337 ± 5,263	1,210 ± 1,226*
Southern branch of the Beagle Channel and Navarino Island (7 stations; 31.1 ± 0.92)	5.8 ± 3.2	3,358 ± 4,321	342 ± 264 *

The spatial pattern of neuston abundance followed a trend similar to that of biomass, with maximum abundances in the Almirantazgo Sound and Inútil Bay (average = 18,350 ind 5 Mhd^{-1}), and minimum abundances in the Beagle Channel (average = 3,358 ind 5 Mhd^{-1}). The average abundances of stations located along the western arm of the Magellan Strait and between the western side of Dawson Island and the Pacific Ocean varied between 7,172 and 7,337 ind 5 Mhd^{-1} (Table 1). Average neuston abundance for the entire study area was 9,179 ± 10,281 ind 5 Mhd^{-1}, which is indicative of clumped distribution with a variation coefficient of 112% (Fig. 3).

Abundance and spatial distribution of *Microsetella rosea*

Copepodits of *M. rosea* were collected at all studied stations (Fig. 3). However, there were evident differences between zones that indicated wide spatial variability along the western margin of the Magellan Region. Specifically, maximal abundance of *M. rosea* was recorded in the Almirantazgo Sound, Inútil Bay, the Paso Ancho zone, and Froward Cape (mid-Magellan Strait, average = 6307 ± 5993 ind 5 Mhd^{-1}), while the lowest abundances were recorded at stations along the Beagle Channel and in open areas near Navarino Island (average = 362 ind 5 Mhd^{-1}; Table 1).

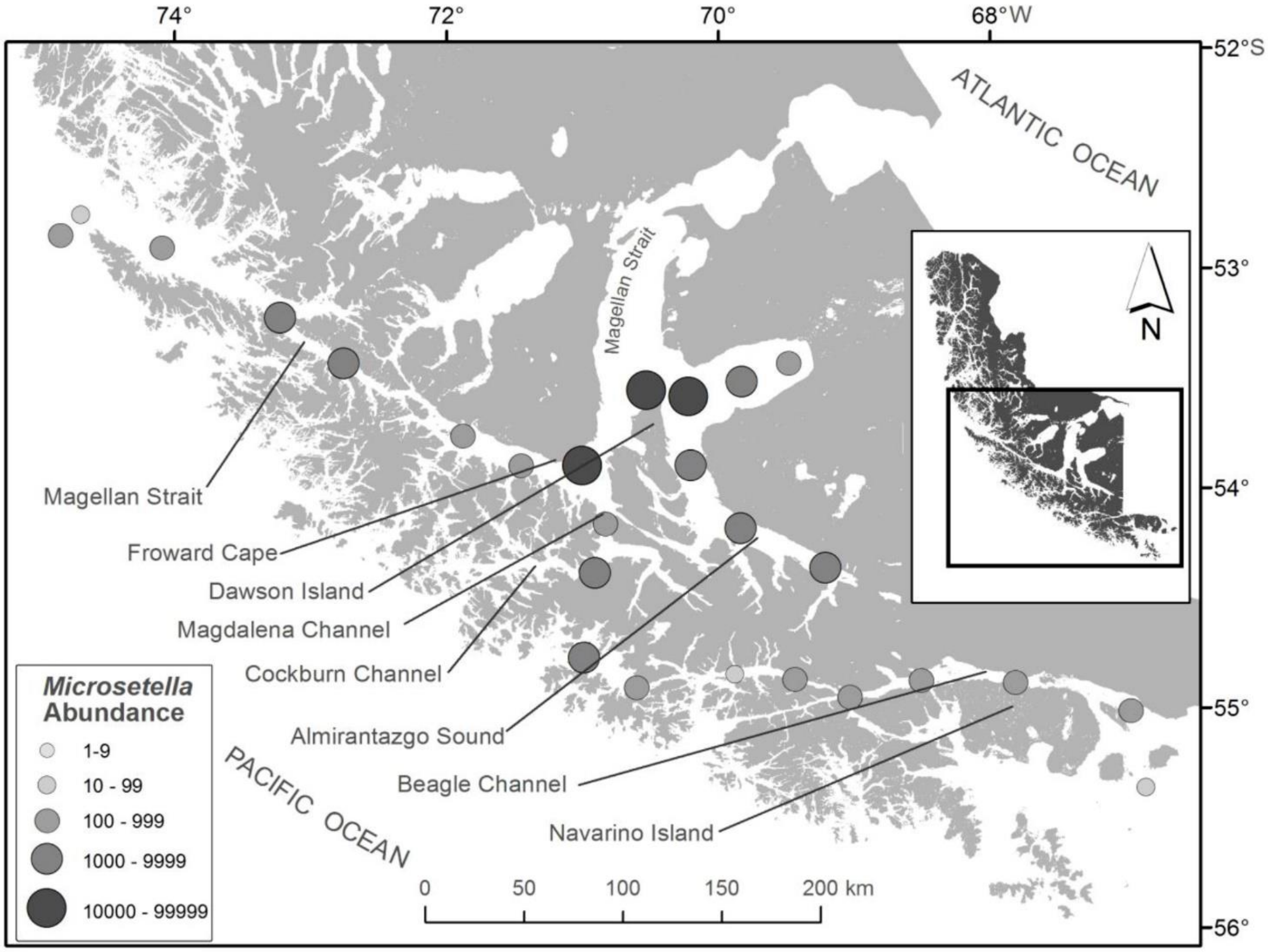

Figure 3. Spatial distribution of *Microsetella rosea* copepodits collected along the western margin of the Magellan coast. Abundances are expressed as ind 5 Mhd^{-1} (minutes of horizontal dragging). The average and standard deviation of *M. rosea* copepodit abundances were 2,761 ± 4,278 ind 5 Mhd^{-1}.

M. rosea copepodits accounted for 30% of all recorded neustonic taxa (238,673 ind; Table 2). Almirantazgo Sound, Inútil Bay, the Paso Ancho zone, and Froward Cape accounted for 61.5% of total *M. rosea* abundance, while sites near the Beagle Channel accounted for <4%. The western margin of the Magellan Strait accounted for nearly 25% of total *M. rosea* abundance, and the zone west of Dawson Island accounted for 10% (Fig. 3). The abundance of *M. rosea* copepodits showed a geographic trend in terms of abundance, with significant differences found mostly between the Paso Ancho microbasin and the Beagle and Fuegian Channels (Antezana, 1999) (Table 1).

The distribution pattern of *M. rosea* copepodits varied up to four orders of magnitude. Therefore, the spatial distribution pattern of copepodits along the western margin of Magellan Region was classified as clumped (Ludwig & Reynold, 1988; Hulbert, 1990; Downing, 1991) (Figs. 4a-4b). A similar trend was observed for total neuston abundance and biomass (Table 1).

Oceanographic conditions and habitat of *Microsetella rosea* copepodits

M. rosea copepodits were found inhabiting the neuston at ocean temperatures ranging between 6.5°C (Sta. 40) and 8.4°C (Sta. 56), but maximum abundance (1,000 to 10,000 ind 5 Mhd^{-1}) was only detected at stations 7, 55, and 60, which presented surface temperatures between 6.79°C and 7.69ºC. In turn, Spearman's Rank-Order Correlation Coefficient between surface temperature and *M. rosea* copepodit abundance produced a significant, negative trend between both parameters (r_s = -0.36; $P < 0.05$; n = 26) (Table 1; Figs. 2-3). The average and standard deviation of *M. rosea* copepodit abundances was 2,761 ± 4,278 ind 5 Mhd^{-1}.

Table 2. Comparative analysis of neustonic zooplankton collected along the western margin of the Magellan Region during the CIMAR 16 Fjord cruise (Oct-Nov 2010). A: Total abundance (%; n = 238.673 individuals). Larval type refers to the number of different families or orders for polychaetes and crustaceans, respectively. The total percentage of abundances is less than 100% as some larval types were unidentified or scarce.

TAXA	A (%)	Frequency (number of cases)
Holoneuston		
Cnidaria	0.200	5
Ctenophora	0.002	1
Pelagic Polychaeta	0.008	1
Calanoid copepods	16.395	26
M. rosea copepodits	29.993	26
Appendicularia	4.291	13
Fishes eggs	0.082	5
Meroneuston (larvae)		
Nemertea (Müller)	0.002	1
Polychaeta (11 types)	16.446	24
Sipunculida (pelagosphaera)	0.002	1
Barnacles (nauplius + cypris)	0.606	11
Decapod crustaceans	0.258	11
Bryozoa (cyphonaute)	2.410	19
Gastropoda (bilobed larvae)	0.007	2
Bivalvia (right charnel + umbonated)	21.118	18
Echinodermata (pluteus)	0.419	11
Total	92.243 %	

Additionally, *M. rosea* copepodits were found in salinity levels between 26.4 (Sta. 10) and 32.777 (Sta. 15) (average = 30.7 ± 0.9), with the highest *M. rosea* copepodit abundances found in waters with salinity levels between 30.37 (Sta. 55) and 30.53 (Sta. 7). The relationship between salinity and the copepodit abundance produced a significant, positive trend between both parameters ($r_s = 0.22$; $P < 0.05$; n = 26).

Finally, the area inhabited by *M. rosea* copepodits was classified as an oxygenated estuary (mean = 7.4 ± 0.4 ml O_2 L^{-1}) (Table 1). There was a significant, negative trend in the relationship between dissolved oxygen content and *M. rosea* copepodit abundance in Magellan waters ($r_s = -0.19$; $P < 0.05$; n = 26).

Overall, the limited ranges of oceanographic variables at the stations where *M. rosea* was found indicate that this pelagic harpacticoid copepod is adapted to specific estuarine environmental conditions. This situation was evidenced along of the western margin of the Magellan Region and within the limits of the Magellan Strait, where much of the water is near Dawson Island or enclosed between the Paso Ancho microbasin and the Forward Cape Channel (Fig. 3).

Contribution of *Microsetella rosea* to the neuston

During the CIMAR 16 Fjords cruise, 238,673 ind were counted from the meroplankton and holoplankton taxa (41.3% and 51.0%, respectively; Table 2). Of the holoplankton, calanoide and harpacticoide copepods, including *M. rosea*, were the most abundant. The abundance of *M. rosea* copepodits was nearly twice that of calanoide copepods (Table 2). Additionally, an important percentage of juvenile appendicularians was collected (4.3%).

Among the collected meroplankton, the numerically dominant groups included mytilid larvae (21.12%), unidentified polychaete larvae (tentatively identified as a Polygordiid exolarvae; P. Ramey-Balci, *com.pers.* from the Polygordiidae family) (16.5%), and cyphonaute larvae (2.4%). Cypris of barnacle (0.6%) and pluteus of echinoderms (0.42%) were also detected (Table 2). Decapod crustacean larvae were scarce (<0.26%). A total of seven holo- and nine meroplankton taxa of the neuston could be used as biotracers in the western Magellan Region (Table 2).

In summary, holoplankton numerically dominated meroplankton in the neuston communities along the western margin of the Magellan Region during spring oceanographic conditions.

DISCUSSION

Presence of *Microsetella rosea* in western Magellan waters

Microsetella rosea was found inhabiting the surface waters of all studied stations along the western margin of the Magellan Region, Chile. This species was the most numerically dominant species of the identified copepods, in addition to being the most dominant taxa of the neuston. These findings have not been previously reported, possibly due to the use of large net meshes (generally >200 µm) (Mazzocchi *et al.*, 1995; Antezana, 1999; Defren-Janson *et al.*, 1999; Marín & Delgado, 2001; Biancalana *et al.*, 2007; Guglielmo *et al.*, 2014). *M. rosea* copepodits may only inhabit surface layers of the water column, which would be mostly missed by vertical tows (Kršinić & Grbeco, 2012). Additionally, population density of *M. rosea* in the neuston was greater than that of the detected calanoid pelagic copepods. Similar abundance magnitudes were found for *M. norvegica* in the Japan Sea (Uye *et al.*, 2002), where *M. norvegica* biomass can reach up to 100 mg C m^{-3} in the fall. In contrast, copepodit and adult *Microsetella* spp. in the Adriatic Sea were less abundant than calanoid and cyclopoid (oncaeids, oithonids) copepods (Kršinić & Grbeco, 2012). Altogether, these findings represent opportunities to study mesoscale spatial variabilities of important biological phenomena arising from interactions between the physical processes, physiology, and behavior of estuarine neuston organisms (Garçón *et* *al*., 2001) along southern Chile. Additionally, the typical morphological features of the *M. rosea* copepodits could ease the identification and justify their use as biotracer.

Microsetella rosea copepodits as biotracer of brackish estuaries

Neuston spatial distribution can be influenced by diverse environmental and oceanographic factors, such as temperature, solar radiation, marine pollution, ocean salinity and density, UV radiation, acidification, and climate change (Zaitsev, 2005). Therefore, understanding the physiological requirements of the neuston, particularly in regards to salinity, is key to explaining the spatial distribution of Magellan estuarine taxa.

The observed spatial distribution of *M. rosea* appears to be regulated by changes in salinity, with greater abundances at salinities between 29 and 31 and lower numbers at salinities >31. Similar tendencies have been found for other members of the *Microsetella* genus. For example, *M. norvergica* inhabits areas near bay mouths rather than sites close to river mouths or other freshwater inputs (Yamazi, 1956). Likewise, Uye & Liang (1998) found low *M. norvegica* densities at salinities <30, which is further supported by Uye *et al.* (2002), who indicated that *M. norvegica* is a stenohaline species intolerant to large salinity variations.

The wide surface salinity variations (0-32) recorded for the Magellan Region (Valdenegro & Silva, 2003; Palma *et al*., 2014b), together with the limited salinity range (≈29-32) detected by the present study, suggest that *M. rosea* copepodits could be stenohaline organisms. Nevertheless, new experimental studies on the physiological responses to oceanographic and thermal parameters are needed to confirm.

Microsetella rosea copepodits as biotracer of neustonic aggregation

Abundant patches of small copepods could be influenced by a frontal zone (Zervoudaki *et al*., 2007). In the western Magellan, frontal zones are detected through the accumulation of ice, strings of detached macroalgae, such as of the kelp *Macrocystis pyrifera*; color changes in surface waters; and the accumulation of foam in the surface layer (Valle-Levinson *et al*., 2006). The high abundance of *M. rosea* copepodits (1,000-10,000 ind 5 Mhd^{-1}) found at some stations of the present study, especially near Dawson Island, could be due to the presence of frontal zones, especially when considering the wide differences in abundances between stations or, as previously described, the deep sill in the Whiteside Channel (Palma *et al*., 2014b).

Analyses of other meteorological, oceanographic, and topographic variables are needed to fully explain the abundance and spatial distribution patterns of the Magellan neuston (Owen, 1989), knowledge which is relevant to determining the aggregation, dispersal, and transport of small plankton in this pelagic environment. The high concentration of neustonic biomass, and of *M. rosea* in particular, near Dawson Island, may be due to the island wake effect and a coast predominantly protected from spring winds (Mann & Lazier, 1991), and future neuston sampling programs should be established for this area. Further related to the importance of Dawson Island, temperature, salinity, and dissolved oxygen content data from the present study showed uniform spatial distributions, but total neuston biomass and abundance, as well as *Microsetella* abundance, showed a clumped spatial distribution around this island. These contrasting distributions between environmental factors and neuston communities indicate that around Dawson Island may dominate processes of planktonic aggregation.

Apart from depth, another aspect that could explain the spatial pattern of *Microsetella* copepodits is the spatial distribution of chlorophyll-*a*. Indeed, four stages of chlorophyll production have been detected along the western margin of the Magellan Strait (Hamamé & Antezana, 1999) in relation to salinity, temperature, and water column stratification. These stages are as follows: i) the Paso Ancho microbasin and Magdalena Sound area, with a shallow chlorophyll maximum (≈5 mg m^{-3} at 0-20 m) in a vertically homogeneous cold and brackish water column; ii) the Magdalena, Cockburn, and Brecknock Channels area, with relatively low chlorophyll concentrations (2-3 mg m^{-3} at 0-50 m), minor salinity stratification and a surface lens of warmer water directly influenced by the Pacific Ocean; iii) the Ballenero Channel and western arm of the Magellan Strait, with high chlorophyll concentration in the subsurface layer (>4 mg m^{-3}) and a vertically stratified water column with two salinity layers and three temperature layers; and iv) the Beagle Channel area, with maximum subsurface chlorophyll concentrations (>4 mg m^{-3}) extending to the ocean floor and vertically homogeneous salinity and temperature distribution. In the present study, maximum *M. rosea* abundance was recorded in the Paso Ancho microbasin-Magdalena Sound area, including in the zone of Froward Cape (Fig. 3), where there is a shallow chlorophyll maximum, a vertically homogeneous cold and brackish water column.

Another aspect that should be considered is the ability of *M. rosea* and other members of the same genus to preserve the normal behaviors of harpacticoid

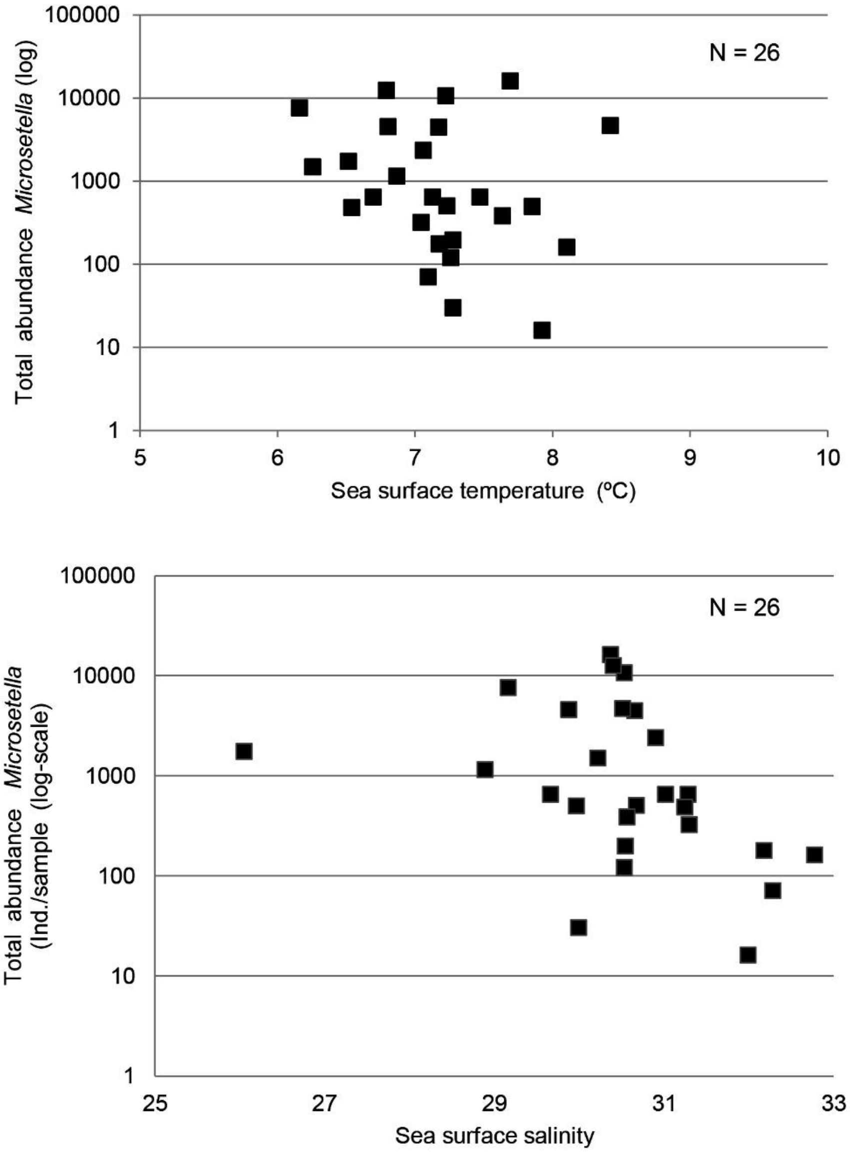

Figure 4. Temperatures and salinities recorded for the neustonic layer along the western Magellan coast. These data were used to determine the oceanographic requirements of *Microsetella rosea* copepodits. Abundances are expressed as ind 5 Mhd^{-1} (minutes of horizontal dragging). The average temperature and salinity of the neustonic layer in the study area were 7.2 ± 0.6°C and 30.7 ± 0.9, respectively.

copepods that inhabit the benthos. Recently, Pacheco *et al.* (2013) detected two *Microsetella* species in subtidal soft bottom zones of northern Chile. These species emerge from the sediment into the water column, a process defined as diel migration. Therefore, it is possible that spatial variations in the Magellan abundance of the copepod *M. rosea* could be affected by sampling time (day/night), wide of channels and bathymetry. Indeed, the *M. rosea* neuston population in Magellan waters could be supplied by shallower waters through horizontal transport due to the deepest of each microbasin (Valdenegro & Silva, 2003; Palma *et al.*, 2014b).

Applications of the Magellan neustonic studies

In the present study, no direct relationship between salinity and *M. rosea* abundance was observed, a situation possibly associated with low local variability in temperature and salinity. Cañete *et al.* (2013) demonstrated a positive and significant lineal relationship between neuston biomass and salinity (5-33 range) and abundance in southern Chile. Furthermore Johan *et al.* (2012) detected that the spatial distribution of copepods follows the salinity gradient in the tropical estuary of the Perai River, Malaysia. The neuston could be an important monitoring tool to track the flow of estuarine, brackish waters into the inner channels of southern Chile (Palma *et al.*, 2014a).

The actual spatial pattern of the estuarine neuston communities from Magellan waters could be modified if global warming directly affects the rate of melting ice and rainy conditions along the southern Chilean coast, and specifically affect to stenohaline species such as *M. rosea*. Therefore, a permanent monitoring of subantarctic neustonic communities is highly recommended.

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