IMPORTANCE OF REMOTE SENSING FOR THE STUDY OF SPATIAL DYNAMICS OF ESTUARINE NEUSTON FROM SOUTHERN CHILE

Juan I. Cañete[1*], Carlos Cárdenas[2], Máximo Frangópulos[2], Ximena Aguilar[2] & Javier Díaz-Ochoa[1]

1 Dept. Ciencias y Recursos Naturales, Facultad de Ciencias, Universidad de Magallanes, Punta Arenas, Chile
2 Centro de Investigación GAIA Antártica, Universidad de Magallanes, Punta Arenas, Chile
ivan.canete@umag.cl*

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ABSTRACT:

Zooplankton aggregation, hydrographic and remote sensing data were employed to relate the spatial dynamics of neustonic communities with chlorophyll a (Chl *a*) and suspended organic matter (SOM) at a spatial mesoscale (10 to 1000 km) in the southern Chilean fjords system along Magellan Strait, Chile (CIMAR 16: October/November 2010 and CIMAR 25; September/October 2019) in order to identify oceanographic process producing aggregation of neuston. Preliminary evidence of CIMAR 25 shows significant concentrations of Chl *a* and SOM around Dawson Island (DI), Magellan Strait. During CIMAR 16 important aggregation of specific neustonic taxa (copepodites of *Microsetella rosea*, larvae of the polychaete *Polygordius sp* and cyphonautes of the bryozoan *Membranipora isabelleana*) was observed around DI, Magellan Strait. Satelital images in the area of CIMAR 16 provide evidence of important aggregation of chlorophyll *a*/SOM around DI. CIMAR Cimar 25 showed that the Chl *a* and SOM aggregation around DI is recurrent and could to explain the high concentration of neuston around this island to spite of mesotrophic conditions. Remote sensing in this study area provides a tool to understanding oceanographic and topographic factors that potentially regulate the abundance and spatial distribution of surface zooplankton to spatial meso-scale along Magellan Strait.

1. INTRODUCTION

The biodiversity levels and densities of neustonic organisms their spatial and temporal variation, their roles in sustaining biogeochemical cycling and atmosphere-ocean exchange processes, as well as a nutritional source for important trophic networks in significant areas of the oceans, all remain unknown (Hardy, 2005). The present study describes the structure and biodiversity of neustonic communities in Southern Chile, which includes an extended estuarine environment with roughly 1,500 km of fragmented coastline.
This area is characterized by the largest fjord systems in the world where salty Subantarctic Surface Water and Modified Subantarctic Waters mix with freshwater, generating sharp vertical and horizontal salinity gradients. These salinity gradients create strong biological consequences, including a stratification effect caused by buoyancy, which is a key regulator of primary production and biomass, a limitation on the depth of turbulent mixing, keeping algal cells within the photic zone; the concentration of an important fraction of organic matter and planktonic communities; and a change in the abundance and spatial distribution of the neuston (Dávila et al., 2002; Silva, Palma, 2008; Pantoja *et al.*, 2011; Iriarte *et al.*, 2014; Cañete *et al.*, 2016).

The neuston represents the atmospheric-oceanic interface which can be thought of as the ocean's skin, given that it is only a few centimeters thick (Hardy, 1991), and covers 71% of the planet's surface. The physical processes occurring there are critical to the global conservation of biogeochemical cycles, but latitudinal differences in the neuston's environmental functions, such as fragmentation and transport of organic matter to greater depths, are not well understood (Zaitsev, 2005; Koski *et al*., 2007).

In temperate zones, the neuston plays an important trophic role as a food source for meso- and macro-zooplankton and is a key component in the production of "marine snow" and the vertical transport of organic material from the ocean surface to greater depths (Zaitsev, 2005; Hays *et al*., 2005). Mesozooplankton living here are crucial to the sustenance and survival of important fisheries (Zaitsev, 2005). For these reasons, it would be very useful to understand how the neuston is influenced by environmental and oceanographic factors, including temperature, solar radiation, salinity, and acidification (Hardy, 1991; Zaitzev, 2005) and are important themes in oceanographic research that are associated with climatic warming and oceanographic change in sub-polar marine ecosystems (Zaitsev, 2005, Cañete et al., 2019).

The aim of this study is the integration of zooplankton, hydrographic (sea surface temperature, salinity and dissolved oxygen) and remote sensing analysis (Chlorophyll a) to relate the spatial dynamics of neustonic communities with Chl a gradients to identify potential oceanographic processes of spatial mesoscale producing aggregation of zooplankton (Garcon et al., 2001) during cruise CIMAR 25 Fjord (C25F, 2019), and compare it with a previous neustonic study carried-out during CIMAR 16 Fjord (C16F, 2010), where aggregation of three taxa (copepodites of *Microsetella rosea*, larvae of the polychaete *Polygordius* sp and cyphonautes of the bryozoan *Membranipora isabelleana*) were studied.

2. STUDY AREA

Zooplankton aggregation, hydrographic and remote sensing data were employed to relate the spatial dynamics of neustonic communities with salinity, sea surface temperature (SST), chlorophyll a (Chl *a*) and suspended organic matter (SOM) at a spatial mesoscale (10 to 1000 km) in the southern Chilean fjords system along Magellan Strait, Chile (oceanographic expeditions CIMAR 16: October/November 2010 and CIMAR 25; September/October 2019) in order to identify oceanographic process producing aggregation of neuston. The spatial dynamic of oceanographic parameters in the surface pelagic zone and their relationship with some ecological variables of the neustonic layer were sampled in the area extended between 50° y 54° S, Magellan región, Chile (Fig. 1).

*Corresponding author

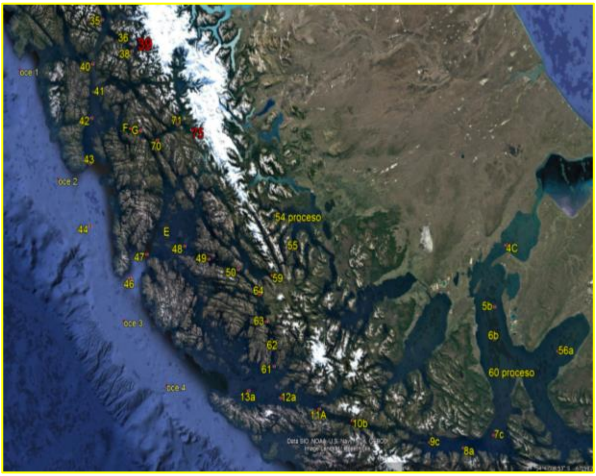

Fig. 1. Study area with oceanographic stations of CIMAR 25 cruise (September/October 2019).

3. MATERIAL AND METHODS

During the CIMAR 25 Fjord cruise, sensoring remote analysis was developed to obtain oceanographic and biological data using the following sources of information in the period September/October, 2019:

i) Oceanographic information on surface layer of water column (temperature, chlorophyll *a* and suspended organic matter) obtained throught differents satelital data base. This information was compared with oceanographic data recorded during CIMAR 16 and CIMAR 25 Fjord performed in Magellan waters.
ii) Wind data recorded onboard of AVG 61 Cabo de Hornos platform during CIMAR 16 & 25 Fjord.
iii) Oceanographic data in situ were recorded by a Sea Bird thermo-salinometer and vertical profiles of CTDO during CIMAR 16 and 25 Fjords.
iv) Data on neustonic biomass collected during CIMAR 16 (2010) and CIMAR 25 Fjord (2019).

The following information was analysed to describe the oceanographic features of the sea surface waters of Magellan area:

i) Sea surface temperature. Data obatined from Modis Data 11 µm, including all records of 2019.
ii) Chlorophyll a (Chl *a*). This information was obtained from HERMES (http://hermes.acri.fr/), Globuscolour (spatial resolution to 4 km and daily variability in the period October and November 2010 and 2018). This basis of data mixed information of SeaWIFS, MERIS, MODIS y VIIRS.
iii) Neuston and Identification of mesoscale oceanographic processes (10 a 1000 km): The Magellan Strait offer an opportunity to study the ocurrence of oceanographic front due to the mix of Atlantic and Pacific Ocean waters, presence of island of different sizes, sill under different micro basins featured by different depths, seamount, freshwater discharge and the interaction between small embayments with the strait. These process could to produce aggregation of zooplankton communities living in surface layers such as the neuston (Garcon et al., 2001).

4. RESULTS

In reference to the neuston and the existence of oceanographic process along Magellan Strait, we consider information recorded during CIMAR16 Fjord (C16F, spring 2010), where was reported a significant aggregation de the neuston in the northeastern end of Dawson Island, off Inútil Bay, Magellan Strait (Fig. 2).

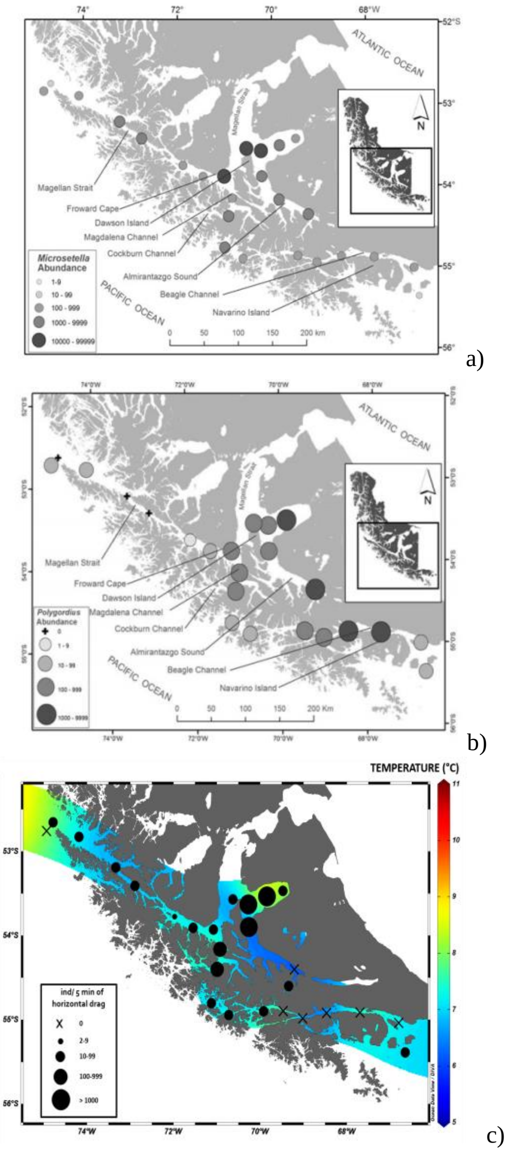

Fig. 2. Spatial distribution of total abundance of three neustonic taxa along Magellan Strait, Chile, during CIMAR 16 cruise (2010): a) copepodites of *Microsetella rosea*, b) larvae of the polychaete *Polygordius* sp, c) Cyphonautes of the bryozoan *Membranipora isabelleana*.

In this area, between 60 and 80% of the total abundance of three typical neustonic species was estimated: copepodites of pelagic harpacticoid copepod *Microsetella rosea*, larvae of the polychaete *Polygordius* sp and cyphonautes larvae of bryozoan *Membranipora isabelleana* (Cañete et al., 2016, 2019). Such spatial scale correspond to mesoscale (Mann, Lazier, 1991; Cañete et al., 2017). The neuston was collected with a net of 50 x 35 cm of mouth area, mesh net of 43 µm, which was dragged for 5 minutes with a velocity of 2 kn (horizontal drag = 500 m^2) (Cañete et al., 2016, 2019). This neustonic aggregation is supported by important concentration of chlorophyll *a* around Dawson Island during sampling of

CIMAR 16 Fjord (spring 2010) and during spring 2018 (Fig. 3) (http://hermes.acri.fr/).

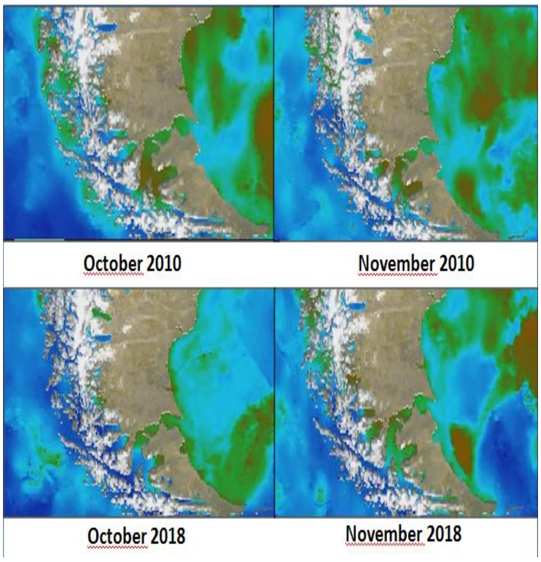

Fig. 3. Surface spatial distribution of Chlorophyll *a* along Magellan Strait in the spring of 2010 (CIMAR 16) and 2018 (modified of http://hermes.acri.fr/).

Spatial analysis of Chlorophyll *a* during spring 2019 in the Magellan Strait and around showed that a concentration of 3 mg m^{-3} is common around Dawson Island. Similar situation was observed during spring 2010 and 2018 (Fig. 4).

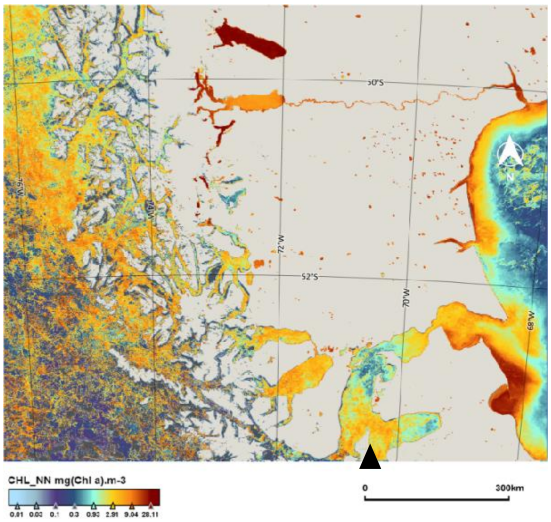

Fig. 4. Spatial distribution of Chlorophyll *a* and suspended organic matter in the Magellan región and along Magellan Strait during 2019. Black arrow showing Dawson Island. Bar scale: 200 km (Elaborated by X. Aguilar).

5. CONCLUSIONS

The remote sensing in the study area provided evidence to demonstrate that around Dawson Island there are a recurrent aggregation of chlorophyll *a* and neuston. Topographic front, presence of sill, wake island effect, cyclonic or anticyclonic eddies around island and thermal front between warmest Atlantic water and cold Pacific water near to Dawson Island could to explain this aggregation of neuston.

Variables	Cimar 16 (2010)	Cimar 20 (2014)	Cimar 25 (2019)
Temperature (ºC)	6.5 -8.5 (7.2 ± 0.6)	6.8 –10.7 (9.3 ± 0.8)	(7.3± 0.8)
Salinity (psu)	26.0-33.0 (30.5 ± 1.3)	1.0 – 31.7 (23.3 ± 7.5)	(28.7 ± 3.8)
Oxygen (mL O_2 L^{-1})	4.0 -10.0 (7.4 ± 0.4)	6.7 – 8.5 (7.5 ± 0.5)	w.i.

Table 1. Main oceanographic features of three estuaries areas of the southern Chilean coast considered to analyze the biodiversity and composition of the neustonic communities in channels and fjords. In brackets is showed the mean and standard deviation for each oceanographic parameter; w.i.: without information.

However, these levels of chlorophyll *a* is typical of a mesotrophic condition. Microbasin where is located Dawson Island is dominated by traditional trophic web sustained by phytoplankton to difference to other two microbasin of the Magellan Strait where microbial trophic web dominate (Antezana, 1999; Hamamé & Antezana, 1999). The three cruises shows typical oceanographic values of the Magellan chnnel/fjord system (Table 1), where prevails high concentration of dissolved oxygen, estuarine conditions with low salinities near to river and fjords, increasing from east to west. The average temperature is coincident with previous values recordad by differents studies (Dávila et al., 2002; Silva, Palma, 2008; Pantoja *et al.*, 2011; Iriarte *et al.*, 2014; Cañete *et al.*, 2016).

Remote sensing in this study area provides a tool to understanding oceanographic and topographic factors that potentially regulate the abundance and spatial distribution of surface zooplankton along Magellan Strait.

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