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Northern Antarctic Peninsula: a marine climate hotspot of rapid changes on ecosystems and ocean dynamics

The Northern Antarctic Peninsula (NAP; Fig. 1), which encompasses the Bransfield Strait, the southernmost part of the Drake Passage, the northwestern Weddell Sea and the region north of the Western Antarctic Peninsula (WAP) shelf, is primarily important because of the evolving changes on ecosystems and ocean-atmosphere-cryosphere dynamics related to climate changes issues. The NAP is considered one of the main gateways to the Southern Ocean and Antarctic continent, located in a transition environment from sub-polar to polar influence (see the inset map in Fig. 1). Additionally, many of the Antarctic research stations are located in the NAP surroundings and most of the polar vessels start their Antarctic campaigns from this part of the Southern Ocean.

1. Why does the Northern Antarctic Peninsula demand attention?

It is widely known that the NAP has been experiencing drastic changes on ecosystems, sea ice and ocean dynamics, which are mostly attributed to climate alterations (Fig. 2; e.g., Atkinson et al., 2004; Meredith and King, 2005; Turner et al., 2005; Parkinson and Cavalieri, 2012). In this sense, sea surface temperature has increased by more than 1°C over the last 50 years or so (Meredith and King, 2005) and near 90% of WAP glaciers are shrinking (Cook et al., 2005, 2016). The extent of sea ice has reduced, its average duration shortened by about 90 days, and the perennial ice is no longer a feature of this environment (Martinson et al., 2008; Stammerjohn et al., 2008, 2012). This pattern contrasts with other regions of Antarctica, including nearby sites, such as the eastern side of the Antarctic Peninsula (Weddell Sea), which is clearly more stable (e.g., Pritchard et al., 2012). These changes in the regional climate and sea ice dynamics affect all levels of the food web, from microbial communities, primary producers (phytoplankton), krill and other zooplanktonic organisms, fish to top predators whose life histories have different degrees of affinity with the ice (e.g., Ducklow et al., 2007). Nevertheless, those changes have been clearly documented for the southernmost section of the NAP, mainly in the WAP shelf zone (e.g., Anadón and Estrada, 2002; Clarke et al., 2007; Martinson et al., 2008; Ducklow et al., 2012, 2013; Meredith et al., 2017). However, several NAP key-areas still lack the basic understanding on ocean variability and changes (both natural and anthropogenic), which in certain cases pose as challenges due to the absence of continuous monitoring programs and scarcity of fundamental studies.

This Special Issue focuses on studies carried out in the NAP, a region being intensively studied by the Brazilian High Latitude Oceanography Group (GOAL) since the 2000s, thus helping to shed light on the intriguing climate and ecology puzzle still unsolved for that region and important in a broader circumpolar scenario of ocean and environmental changes. As a boundary region between the sub-Antarctic and Antarctic zones in the Southern Ocean, the NAP is characterized both as a global climate hotspot and a natural laboratory to first identify changes, variability and vulnerability of marine ecosystems of vital ecological importance to sustain the Antarctic and Southern Ocean food webs. Ecosystem changes, in turn, are linked to the region intrinsic physico-chemical properties, ocean circulation patterns and dynamics influenced by both the Atlantic and Pacific Southern Ocean sectors. In this sense, the NAP is a key-region for better understanding and predicting the likely effects of anthropogenic actions in a variety of distinct transition zones in the Southern Ocean.

The NAP marine zone can be spatially split into regions of distinct importance for Antarctic biology, ecology, and climate. For example, the Bransfield Strait has confined deep basins that preserve most of the climate signals of recent changes occurring in the northwestern Weddell Sea (Dotto et al., 2016). The latter is an important ocean region where dense and deep waters are formed and/or exported to the nearby regions and the global ocean (e.g., Kerr et al., 2009; Kerr et al., 2012; Ferreira and Kerr, 2017), but also extremely impacted by recent changes in sea ice conditions and permanent ice-shelves collapse (Parkinson and Cavalieri, 2012; Cook et al., 2016). In addition, the Bransfield Strait is also influenced and impacted by relatively warm, salty and less-oxygenated intermediate waters derived from the Antarctic Circumpolar Current system (Ruiz Barlett et al., this issue). This combined influence from Weddell and Bellingshausen seas can trigger changes on the physical properties and seawater chemistry around the NAP (e.g., Azaneu et al., 2013; van Heuven et al. 2014; Dotto et al., 2016). In this sense, relatively cold and less salty Antarctic surface waters favor the uptake of atmospheric carbon dioxide (CO_2) into the region, which can further ventilate the bottom layers after intense mixing processes with other water masses (e.g., Pardo et al., 2013; van Heuven et al. 2014).

Recent warming and consequent decline in sea ice cover have been associated with changes in key food web trophic levels in the NAP region, including reduction in phytoplankton biomass, shifts in phytoplankton community composition from large diatoms to small flagel-

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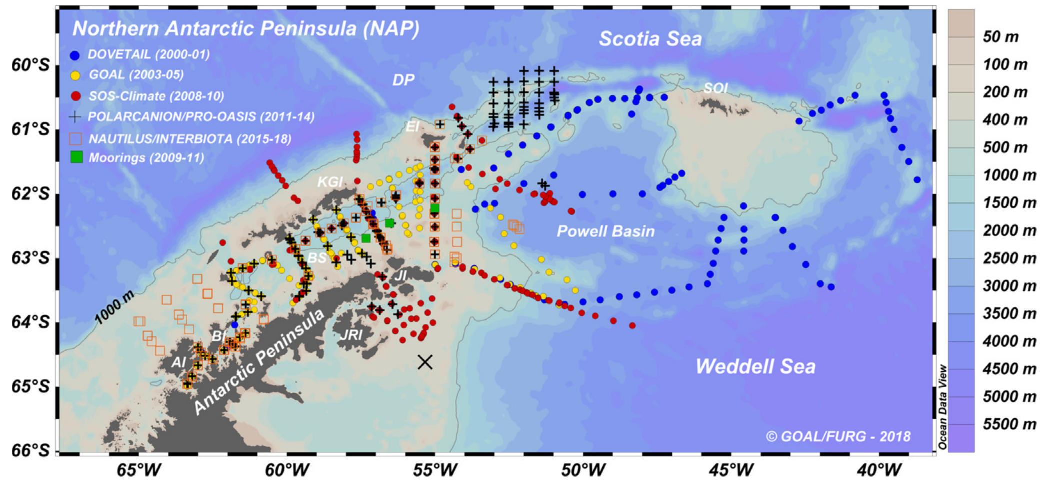

Fig. 1. Northern Antarctic Peninsula (NAP; inset map) surroundings, its main sectors and ocean circulation patterns. The red arrows denote the Bransfield Current System (BCS) circulation according to Sangrà et al. (2011, 2017). The green arrow marks the surface circulation along the Gerlache Strait according to Zhou et al. (2002). The dashed orange arrows denote the regions of warm, salty and less-oxygenated waters intrusions derived from Circumpolar Deep Water (CDW; Dotto et al., 2016; Ruiz Barlett et al., this issue). The purple arrows show the trajectory of Weddell Sea shelf waters (Sàngra et al. 2017), while the black arrow mark the schematic path of the Antarctic Slope Front (ASF; Heywood et al., 2004; Azaneu et al., 2017). AI = Anvers Island, BF = Bransfield Front, BI = Brabant Island, BS = Bellingshausen Sea, DP = Drake Passage, EI = Elephant Island, JI = Joinville Island, JRI = James Ross Island, PF = Peninsula Front, SSI = South Shetland Island, SOI= South Orkney Island.

lated cryptophytes, and decrease in the abundance of Antarctic krill (e.g., Moline et al., 2004; Ducklow et al., 2007; Montes-Hugo et al., 2009; Mendes et al., 2013). Thus, those combined processes likely impact both planktonic and benthic Antarctic organisms but also lead to changes in the marine environment used for foraging and reproduction of nektonic animals.

In this sense, the Gerlache Strait – a polar coastal zone in the southern limits of the NAP – is another good example of how environmental changes can alter and transform the polar coastal ecosystem through time. This is a highly productive coastal area around the Antarctic Peninsula (Holm-Hansen et al., 1989; Rodriguez et al., 2002; Parapar et al., 2011) and a very important feeding site for humpback whales and other krill-feeding predators (Dalla Rosa et al., 2001, 2008; Nowacek et al., 2011; Secchi et al., 2001, 2011). The relevance of this area as a foraging ground is probably related to high local biological productivity (Varela et al., 2002; Rodríguez et al., 2002), but can also be positively impacted or benefited from the physical complexity of hydrography and circulation, sea ice dynamics, continental meltwater input, and protection from severe weather (Prézelin et al., 2000; 2004). Nevertheless, recent studies have shown that the Gerlache Strait is being affected by several environmental factors (e.g., Moreau et al., 2015), such as early retreat of sea ice and increase in sea surface temperature, which have been associated with an increase in occurrence and abundance of certain phytoplankton groups, such as cryptophytes (Mendes et al., this issue). A persistent transition from diatoms to cryptophytes represents a fundamental decrease in the size spectrum of the phytoplankton community, which can impact grazing efficiencies of different zooplankton species, including krill, enhancing microbial activity in the region and, consequently, promoting changes in carbon fluxes within the water column (Rodríguez et al., 2002; Ducklow et al., 2013). In addition, these small phytoplankton organisms are generally less efficient in absorbing and exporting carbon when compared to diatoms (e.g., Schloss et al., 2007) and, therefore, less capable to contribute with lowering CO_2 partial pressure in surface layers (e.g., Kerr et al., this issue). As phytoplankton supports marine food webs and plays a key role on the resilience of the Antarctic marine ecosystems, changes in abundance and composition of phytoplankton assemblages may have a direct effect on the structure and functioning of the entire regional ecosystem. Those changes can lead to important alterations at various levels of the marine food web (e.g., Ducklow et al., 2007, Ross et al., 2008, Mendes et al., this issue) and further affect the abundance and availability of key-species such as krill and up to their predators, hence impacting their reproductive output and distribution patterns (e.g., Forcada et al., 2006, Ducklow et al., 2007, Costa et al., 2010, Nowacek et al., 2011, Trivelpiece et al., 2011, Seyboth et al., 2016, this issue). Therefore, understanding the effects of changes in atmospheric, cryospheric and oceanographic conditions on the marine ecosystem in the Gerlache Strait and adjacent areas is crucial for assessing the potential consequences to the local and regional biodiversity and biogeochemistry.

2. Advances in knowledge of the ecosystems and ocean dynamics changes in the NAP surroundings

The ocean areas of the NAP have been investigated in this Special Issue regarding their ecosystems, oceanographic and climate issues, taking advantage of the 15 years (since 2002) of sampling and studies conducted in the region by the Brazilian High Latitude Oceanography Group (GOAL). The issue is organized in the following way: first, we present novel results related to the NAP ocean circulation patterns and water masses variability, sea ice formation and climate variability; second, the intrinsic relationships between changes in hydrography and sea ice with changes in the primary producers and microbial community are presented, which are followed by manuscripts highlighting the phytoplankton and carbon behavior and changes in the Gerlache Strait. Finally, we address isotopic approaches used to assess the ecological implications regarding the foraging behavior of top predators, such as whales and seals.

Collares et al. (this issue) tracked several icebergs trajectories in the NAP zone, describing and quantifying their main movement patterns as well as estimating their disintegration rates and hence evaluating how much freshwater they inject in the region. Those authors also used the iceberg identification and tracking as a proxy to inform the ocean surface circulation patterns in that area. The combination of these results with those obtained by observation and modeling can contribute to the knowledge about ocean dynamics in the NAP surroundings. In this sense, van Caspel et al. (this issue) used a regional ocean model and showed that the deep basins of the Bransfield Strait are ventilated from