Ecological networks of an Antarctic ecosystem: a full description of non-trophic interactions

Vanesa Salinas[1], Tomás Ignacio Marina[2], Georgina Cordone[3], Fernando Momo[1]

1 Instituto de Ciencias, Universidad Nacional de General Sarmiento, Buenos Aires, Argentina

2 Centro Austral de Investigaciones Científicas (CADIC-CONICET), Ushuaia, Argentina

3 Centro para el Estudio de Sistemas Marinos (CESIMAR, CCT-CONICET CENPAT), Puerto Madryn, Argentina

ABSTRACT

Interactions between organisms are very diverse and attend to multiple biological demands, hence understanding ecological communities requires considering different types of species interactions beyond predation. In this work, we assemble for the first time the non-trophic networks of an Antarctic ecosystem. We report mutualistic (+/+), competitive (-/-), commensalistic (+/0) and amensalistic (-/0) interactions between species of Potter Cove marine community (South Shetland Is., Antarctica). Based on network approach we present a full description of each type of interaction and analyze its distribution according to different species-level properties. Also, we construct a multiple interactions network including trophic and non-trophic interactions and study networks-level properties. We found more than double non-trophic interactions than trophic ones mostly corresponding to competitive interactions involving mid-trophic level species. Low-trophic level species were mainly involved in mutualistic and amensalistic interactions. We observed that interactions networks display differences of its structural properties. Finally, we study the importance of adding non-trophic interactions to gain insight into the function of the whole community. We show that including a description of species interactions in ecological networks analysis provides a better understanding of ecosystems as a whole which could be crucial to comprehend and predict ecosystems' responses to environmental disturbances.

Key words: non-trophic interactions, ecological networks, multiple interactions network, species-level properties, networks-level properties.

INTRODUCTION

Trophic interactions among species and topological analyses of food webs have lead multiple applications in ecological communities and many advances have been developed in this regard (Paine 1966, Cohen 1977, Post & Pimm 1983, Cohen & Briand 1984, McCann et al. 1998, Martinez et al. 1999, Williams & Martinez 2000, Dunne et al. 2002, Netuel et al. 2002, Pascual & Dunne 2006, Albouy et al. 2014, among many others). Nevertheless, it is widely known that interactions between co-occurring species of an ecological community involve much more than just trophic interactions (Kéfi et al. 2012, Pocock et al. 2012, Kéfi et al. 2015, 2016, Mougi 2016a). Indeed, many studies have reported different types of associations between species and consequently different types of non-trophic interactions in a given community (Bloom 1975, Kneib 1991, Amsler et al. 1999, McClintock et al. 2005, Bascompte & Jordano 2008). A particular example of this occurs in the West Antarctic Peninsula (WAP), one of the most affected places on earth by climate change, where a large number of species that are directly (or indirectly) related have been reported for mutual benefit – such as macroalgae species and amphipods through chemical mediation - and epibiotic interactions (Dayton et al. 1974, Gutt 1998, 2000, Aumack et al. 2010, Amsler & McClintock 2014).

On the other hand, non-trophic interactions have been studied in many communities considering different approaches, but their role on ecosystem structure and function was scarcely addressed. For example, Hacker & Gaines (1997) presented a qualitative theoretical model that considers how direct positive interactions (mutualism and commensalism) affect community species diversity. Mougi & Kondoh (2012) showed that multiple interaction types hold the key to understand community dynamics and suggested that antagonistic and mutualistic interactions can stabilize population dynamics. Also, Mougi (2016a, b) showed that non-trophic interactions such as amensalistic, commensalistic and mutualistic play a crucial role in communities' persistence. More recently, Guerrero-Ramírez & Eisenhauer (2017) assessed the influence of non-trophic interactions on biodiversity–ecosystem functioning relationships. Non-trophic interactions have also been studied from a network perspective, considering different types of interactions among species and different community traits. For instance, Bascompte & Jordano (2007, 2008, 2009) studied the structure and complexity of mutualistic networks suggesting that these networks can be regarded as the architecture of biodiversity. Furthermore, Bastolla et al. (2009) showed that the number of co-existing species in a community can be determined by both the structure of mutualistic networks and the structure of competition for common resources networks. Recently, some studies have analyzed trophic and non-trophic networks in order to understand the patterns and dynamics of diverse species interactions in nature (Kéfi et al. 2012, Pocock et al. 2012, Kéfi et al. 2015, 2018). Some works focused on ecosystems´ stability or persistence by developing theoretical

(Thébault & Fontaine 2010) or analytical approaches (Allesina & Tang 2012) while others developed dynamical modeling (Kéfi et al. 2016). More recently, few studies have incorporated multiple interactions networks integrating more than two interactions types in the same network (Kéfi et al. 2016, Pilosof et al. 2017, García Callejas et al. 2018, Hervías-Parejo et al. 2020). So far, studies on species interactions in Antarctic ecosystems have focused on trophic interactions without considering non-trophic relationships and their importance in the structure and function of communities (Marina et al. 2018a, Cordone et al. 2020, McCormack et al. 2021).

Regarding Antarctic ecosystems, Potter Cove (25 de Mayo/King George Is., South Shetlands Is.) is one of the most biodiverse fjords of the WAP (Grange & Smith 2013). It is not only a biodiversity hotspot but also one of the ecosystems where drastic environmental and ecological changes are happening due to climate change (Schloss et al. 2012, Quartino et al. 2013, Sahade et al. 2015, Hernández et al. 2019). In this sense, an accurate assessment of the structure and function of Potter Cove is crucial to understand how WAP fjord ecosystems could respond to climate change (Vaughan et al. 2003, Turner et al. 2005, Meredith & King 2005, Bromwich et al. 2013, Nicolas & Bromwich, 2014). Potter Cove food web has been recently described and analyzed with a high-resolution level (Marina et al. 2018a, Cordone et al. 2020) and previous studies showed that this ecosystem is relatively robust to perturbations on macroalgae species (Cordone et al. 2018). However, little is known about the structure of non-trophic ecological networks in Potter Cove. Incorporating non-trophic interactions could add a new perspective and yield unexpected results about species role and ecosystem function (Kefi et al. 2012, Mougi 2016a, b).

In this work we present and characterize the networks describing the non-trophic interactions among species from Potter Cove marine ecosystem and describe the organization of the identified interactions in relation to species properties. We: 1) provide a detailed description of each type of interactions among species 2) analyze the distribution of the non-trophic interactions and 3) assemble trophic and non-trophic networks in a highly-resolved multiple interactions network. These aspects might help us to better understand the role of non-trophic interactions and community's function as a whole.

METHODS

Species Interactions

Non-trophic interactions

The identification of mutualistic (+/+), commensalistic (+/0) and amensalistic (-/0) interactions was done by compiling information through an extensive bibliographic search. More than 70 articles from Antarctic marine communities were reviewed in order to identify non-trophic interactions between species in Potter Cove marine ecosystem (25 de Mayo/King George Is., South Shetland Is.) (Appendix I).

Competitive interactions (-/-) were established from the predator secondary graph, the so-called competition network. This network was obtained from the food web (or primary graph) of Potter Cove ecosystem described in Marina et al. 2018a. We considered a competitive interaction when two predators shared at least one prey.

Overall, we assembled four networks considering the following types of interactions: mutualistic, commensalistic, amensalistic and competitive. Species (networks nodes) were identified according to their taxonomic identity. Most of them were identified at species level (e.g. *Euphausia superba*) but some were identified as a group of biological species (e.g. Phytoplankton). Every network was plotted with the software Visone 2.18.

Trophic interactions

Information of co-occurring species and their feeding habits was obtained mostly from publications resulted from a cooperation program between Argentina and Germany that started in 1994 and continued for more than 20 years (Wiencke et al. 1998, 2008). Based on these data, Marina et al. 2018a described the Potter Cove food web including 91 species and 307 interactions. Here, we incorporated such trophic relationships (+/-) for constructing the multiple interactions network described below.

Network assemblage

Non-trophic networks

We considered the same set of species interacting with each other at multiple levels when we developed the non-trophic networks. Mutualistic (+/+), commensalistic (+/0) and amensalistic (-/0) networks were first described as binary matrices representing presence (1) or absence (0) of an interaction. As mentioned above, competitive network was based on the definition of secondary graph (Box I).

Box I

We described non-trophic networks webs as complex networks defined by $n{\times}m$ binary matrices with the form

$$A = \left[\alpha_{ij}\right]^{n\times m} \quad (1)$$

The matrix A describes the interactions between the sets of species n and m and its elements, α, represent the presence or absence of an interaction in the web F as following:

$$\alpha_{i,j} = \begin{cases} 1, & k_{ij} \in (F) \\ 0, & k_{ij} \notin (F) \end{cases} \quad (2)$$

Where k_i, k_j are two any nodes of the n and m set respectively, and $k_{ij} \in F$ indicates the interaction between i and j. Note that if $n=m$, A would be an adjacency matrix that could represent, for example, a food web.

The construction of the competitive network was developed based on the definition of secondary graph and can be explained as follow:

Given the food web F, the vertices of the competition graph called $G(F)$ are the same as those of F, i.e., one vertex for each species in the community. The edges of $G(F)$ between distinct vertices i and j are undirected and represent an overlap between diets of species i and j, i.e. these edges exist if and only if there exists some third vertex k in F such that i eats k and j eats k. Thus, in $G(F)$ two vertices are linked by an edge if there are arrows in F from k to i and from k to j, for at least one k; or if one row k of the adjacency matrix has elements equal to 1 in both column i and column j (Cohen 1978).

Multiple interactions network

We constructed the multiple interactions network based on the 91 trophic species reported by Marina et al. (2018a) for Potter Cove marine ecosystem. We included five types of interactions among species: predator-prey or trophic (+/-), mutualistic (+/+), commensalistic (+/0), amensalistic (-/0) and competitive (-/-).

Network construction was developed considering a square matrix, M, where each interaction was represented by a pair of integers in the interval [-1, 1]. The sign of the non-zero elements indicates if that species benefits (+) or not (-) from the interaction. For example, a competitive interaction between nodes A and C is represented by the pair (-1; -1) in the M_{AC} and M_{CA} positions (Figure 1). A commensalistic interaction is represented by the pair (1; 0) or (0; 1) depending on which species benefits from that interaction. Analogously, an amensalistic interaction is represented by the pair (0; -1) or (-1; 0). Trophic interactions were represented considering which species is the prey and which is the predator in the feeding relationship, i.e. (1; -1) or (-1; 1), where -1 is the prey and 1 is the predator. Finally, mutualism has a single representation pair in the matrix (1; 1) since both species benefit from that interaction.

	A	B	C	D	E
A	0	1	-1	0	1
B	0	0	0	0	-1
C	-1	0	0	0	0
D	0	0	0	0	0
E	1	1	0	-1	0

Figure 1. Representation of the different types of interactions in the multiple interactions network. Each interaction was identified by a combination of integers between -1 and 1.

Network Analysis

We quantified a set of network-level properties to describe each studied network; properties that have been suggested to have implications for the functioning and stability of ecological communities (Pascual & Dunne 2006, Fortuna et al. 2010). Such properties are: 1) number of species (S); 2) total number of interactions or links (L), 3) density (L/S) and 4) percentage of basal (B), intermediate (I) and top (T) species.

We considered connectance (C) as the ratio between observed (L) and possible (S^2) interactions:

$$C = L/S^2 \qquad (3)$$

where L is the total number of interactions or links, S is the number of species in the interaction matrix. This property is considered as an estimator of community sensitivity to perturbations and it covaries with other network properties (Dunne et al. 2002, Poisot & Gravel 2014).

We also explored species-level properties with the aim of identifying those species that are more important considering the total number and the distribution of its (trophic and non-trophic) interactions. For this, we analyzed: 1) species degree as the sum of incoming and outcoming interactions for each species (all prey and predators of a species in the trophic network, for instance); 2) basal, intermediate and top categories and 3) trophic level for each species. Basal species are those with predators but without prey, intermediate species have prey and predators, and top species have prey but no predators. Trophic level for each species was calculated as one plus the mean trophic level of all of the species resources, where the trophic level of a resource is the chain length from the resource to a basal species (Williams & Martinez 2004). Properties 2) and 3) were included here based on the trophic network data provided by Marina et al. 2018a.

RESULTS

Non-trophic networks

In Potter Cove marine ecosystem, there were more than twice non-trophic interactions than trophic ones. Within non-trophic interactions, the majority were among predators competing for the same prey (competitive = 76%), followed by mutualistic (15%), commensalistic (5%) and amensalistic (4 %) (Table 1, Appendix II).

More than 60% of the mutualistic interactions identified corresponded to the relationship between some species of amphipods herbivorous (mesograzers) and some macroalgae. About relationships involving commensalistic and amensalistic interactions, most of them (> 90%) corresponded to epibiotic relationships, i.e. relationships between two different organisms in which one of them serves as a substrate for the other, for example ascidians and/or epiphytic diatoms using macroalgae as substrate (Appendix II). We considered this last interaction as an amensalistic interaction (0/-) because epiphytes represent a potentially harmful organism for macrophytes as they compete with them for light and nutrients (Amsler & McClintock 2014) and epiphytes do not specially need the algae to survive since they can grow on different substrate such as rocky or sediments.

Network-level properties

Regarding networks-level properties, non-trophic networks displayed relatively low number of species (S) and interactions (L). However, linkage density (L/S) and connectance (C) were higher in non-trophic networks than in the food web, where competitive (-/-) and mutualistic (+/+) networks presented the highest values for L/S (Table 1). The multiple interactions network presented the highest value for linkage density and the second lowest value of connectance (Table 1). Furthermore, non-trophic networks displayed distinctive characteristics if we consider basal/intermediate/top species categories: 1) in mutualistic and amensalistic networks no top species were involved and 2) in competitive network, interactions occurred among intermediate and top species, where intermediates dominated (Table 1).

	S	L	L/S	C	B	I	T
Mutualistic (+/+)	36	88	2.4	0.36	69	31	0
Commensalistic (0/+)	23	29	1.2	0.16	57	26	17
Amensalistic (0/-)	25	24	0.96	1	49	0	0
Competitive (-/-)	59	478	8.1	0.13	0	74	26
Trophic (+/-)	91	307	3.37	0.04	34	47	19
Multiple interactions network	91	926	10.17	0.11	34	47	19

Table 1. Complexity and structural properties of the non-trophic networks. **S** = number of species, **L**= number of links, **L/S**= density, **C**= connectance. **B, I** and **T** = percentage of basal, intermediate and top species respectively.

Topology of the non-trophic networks was very different depending on the type of interaction: the networks of mutualistic and commensalistic interactions displayed a fragmented topology (Figure 2A,2B) while the network of amensalistic interactions displayed a unique component where one species is connected with the rest (Figure 2C) and competitive interactions network showed a high-connected graph (Figure 2D). The configuration of the multiple interactions network displayed a hyper-connected web (Figure 3).

Species-level properties

When we explored species-level properties, we observed that species of Potter marine ecosystem with the highest number of non-trophic interactions were also those at mid-trophic levels (intermediate species) (Figures 4, 5). Only one species with the most (upper 10%) non-trophic interactions was not in an intermediate species due to its generalist feeding strategy (*Notothenia coriiceps*, trophic level = 2.80). This upper 10% percent is distributed between species of a variety of functional groups, all of them closely related to the benthos (Echinodermata, Amphipoda, Porifera, Gastropoda, demersal fish). For most of these species, the dominant type of non-trophic interaction was competition followed by mutualism (Figures 4, 2A-2D). On the other hand, the species with the least (bottom 10%) non-trophic interactions were mainly macroalgae, with low-trophic levels (basal species). Here mutualism ruled the relationships. Top species, without predators, exhibited a wide range in the number of non-trophic interactions (min = 8, max = 34). However, the great majority of these interactions were for competing for the same prey (Figures 5, 2D).

It is important to note that species from all trophic levels presented commensalistic interactions, although in low numbers. On the contrary, amensalistic interactions are represented by species from lowest-trophic levels (basal species) (Figure 5). Some of the species with the highest number of this type of interaction (epiphytic diatoms) were also one of the most (upper 10%) connected species regarding non-trophic interactions (Figure 4). Considering all interactions types (multiple interactions network), the species with the highest degree were also those with the highest number of non-trophic interactions, and at mid-trophic levels as mentioned above (Figure 3).

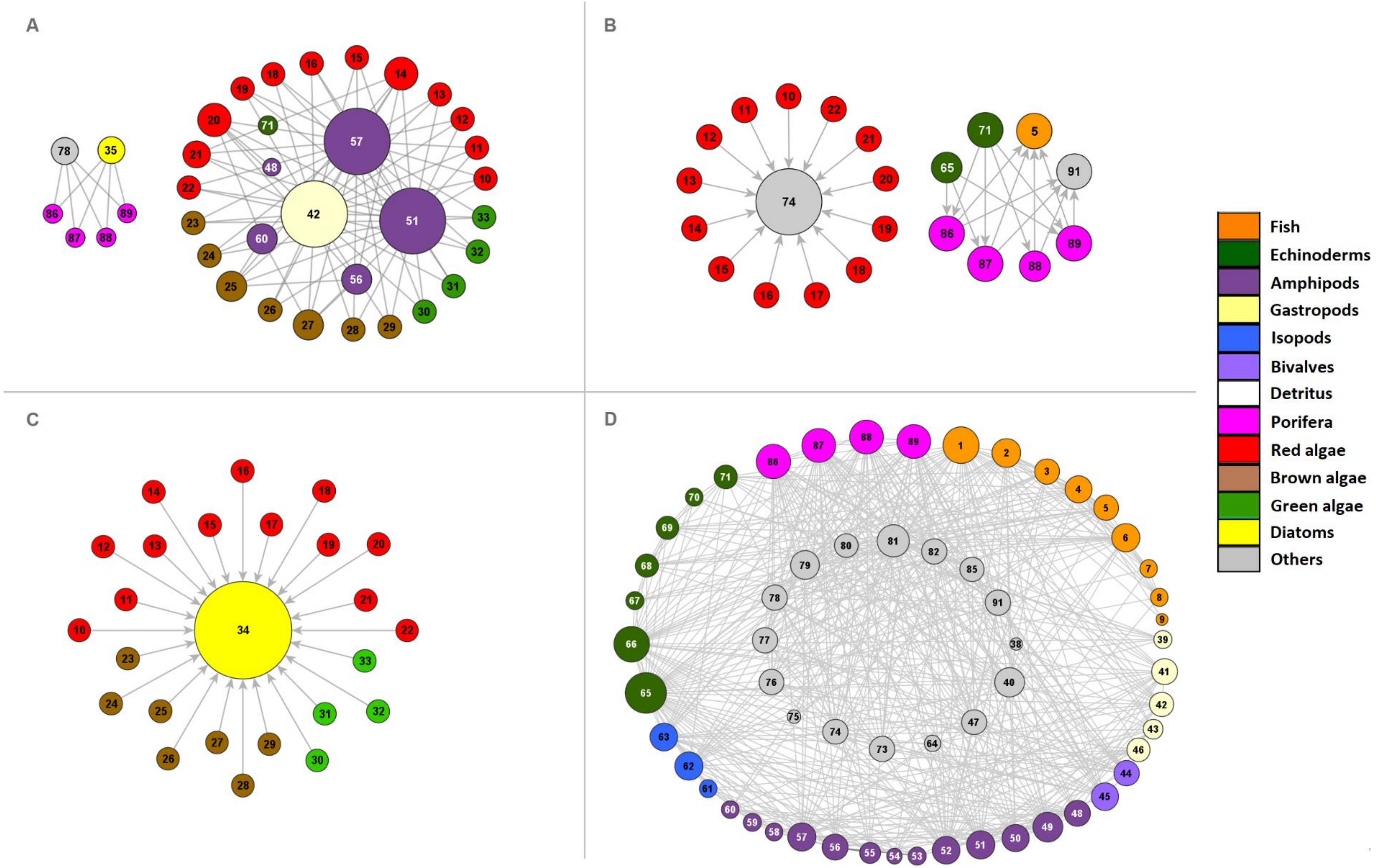

Figure 2. Representation of non-trophic networks: A) mutualistic; B) commensalistic; C) amensalistic and D) competitive network. Species (nodes) ID is represented by a number (Appendix III) and color represents functional groups.

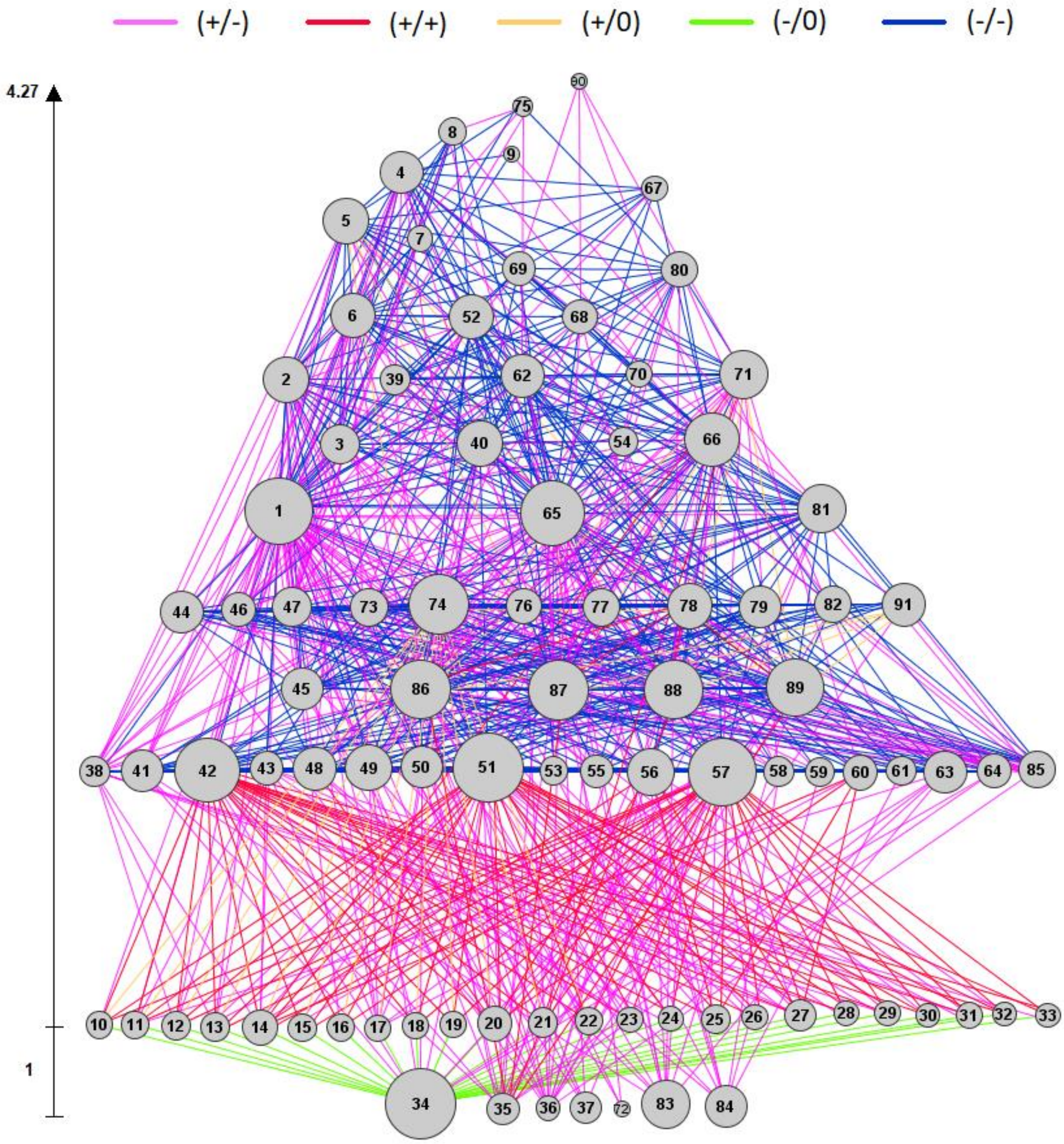

Figure 3. Multiple interactions network of Potter Cove marine ecosystem. Vertical position indicates the trophic level of each species (node) identified by a number (Appendix III) and the size is proportional to its degree (total number of interactions). Link colors indicates the type of interaction.

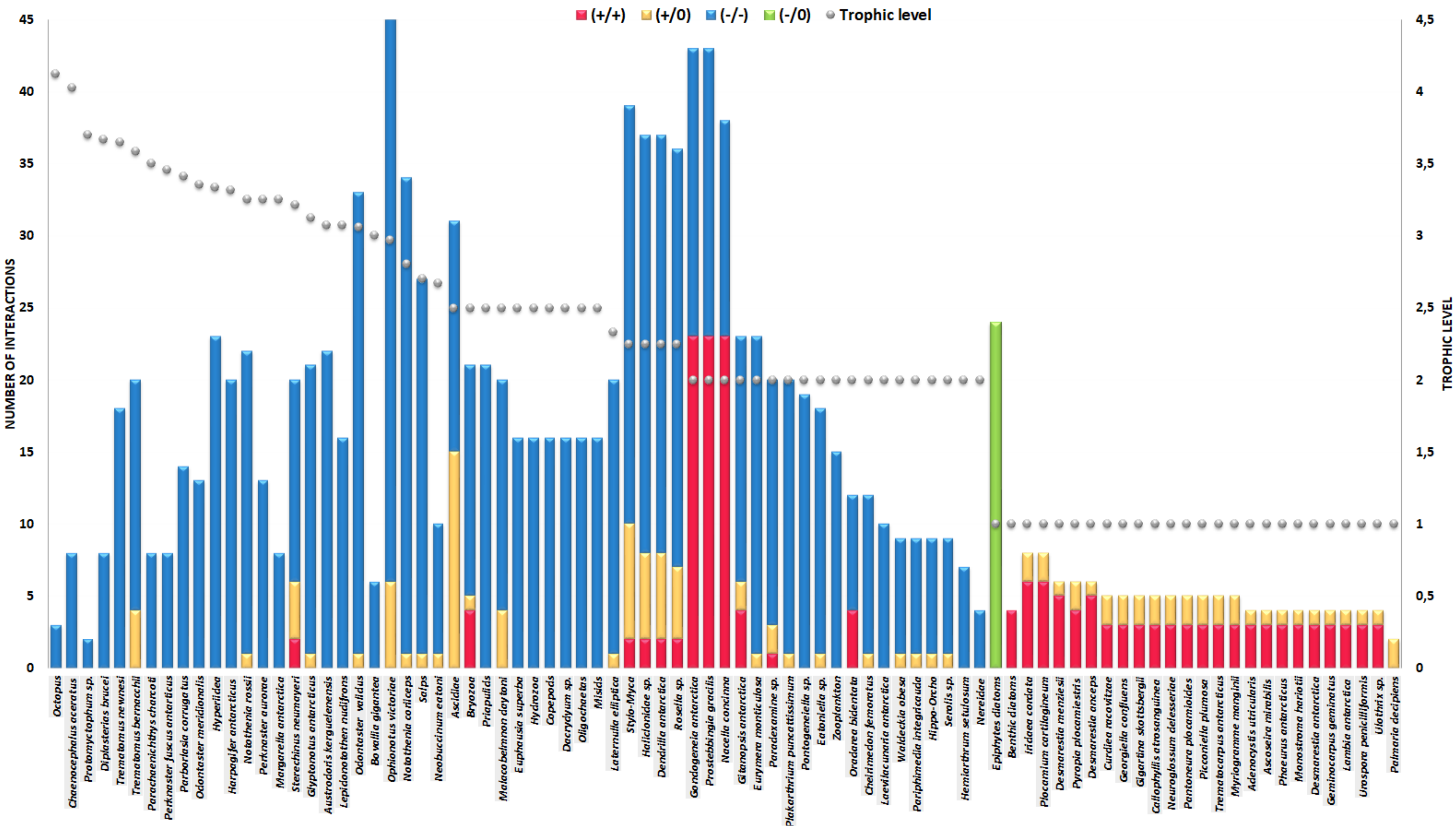

Figure 4. Number of non-trophic interactions per species. Bar colors indicates the type of interaction and grey circles represent species trophic level (decreasing order).

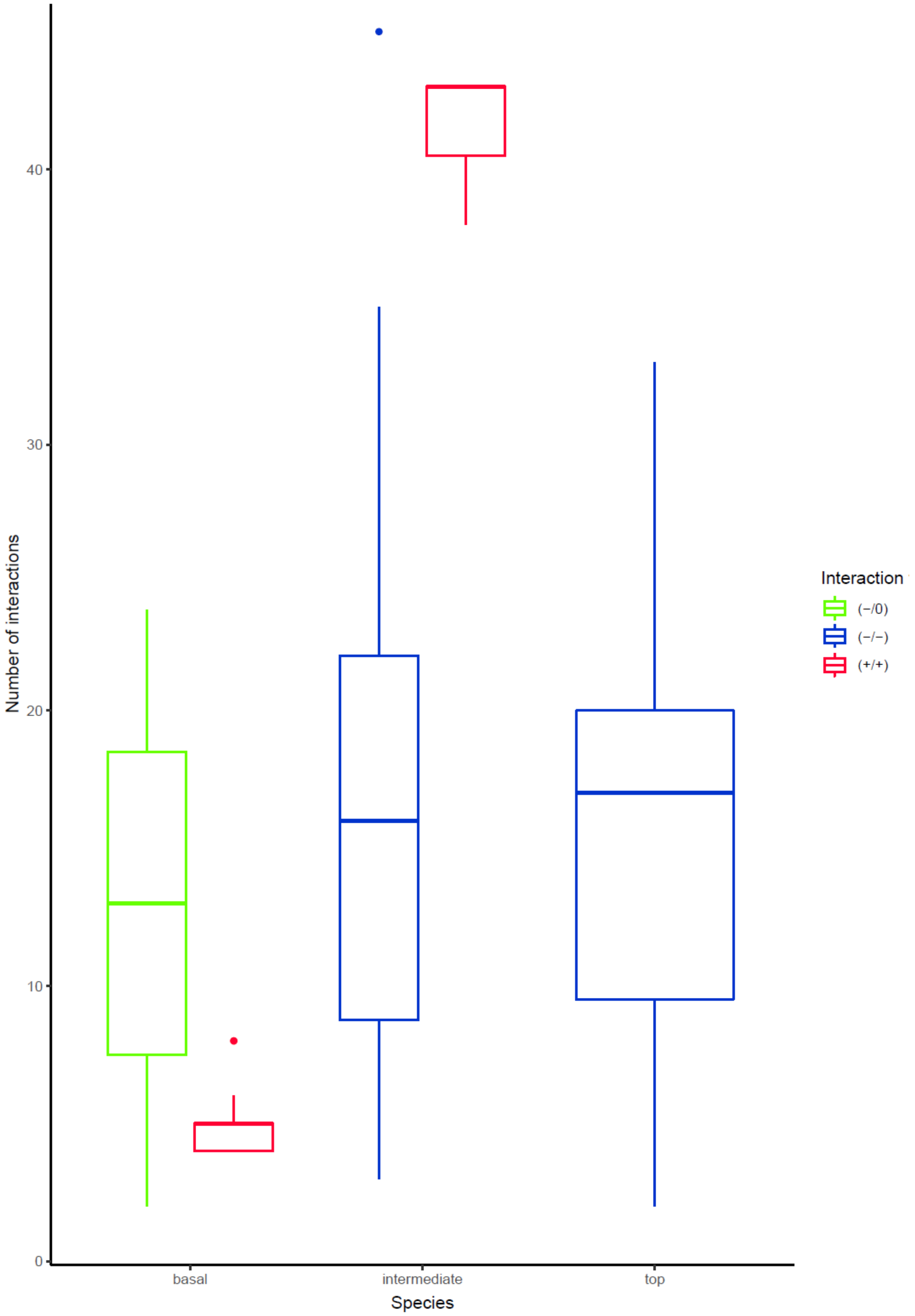

Figure 5. Distribution of non-trophic interactions among basal, intermediate and top species.

DISCUSSION

This work presents the first description of non-trophic interactions for an Antarctic ecosystem including also trophic interactions in a highly-resolved network. The network-level properties of the multiple interactions network are different from those of the single-interaction networks. This provides an overview of the species interactions in the community according with different properties and feeding strategies.

Distribution of interactions

The distribution of the non-trophic interactions identified in Potter Cove community were mostly represented between intermediate trophic level species, i.e. with values in a range of [2, 3.2]. This result is related to the fact that the percentage of intermediate species in Potter Cove food web is close to 50%. However, it is not as high as other marine food webs (Dunne et al. 2004, Vermaat et al. 2009, Marina et al. 2018b). A large number of trophic interactions at this trophic level is related to a large number of competitive interactions; a large number of competitive interactions is, ultimately, related to the criterion used here to define competition (sharing at least one prey). In this sense, amphipods and demersal fish were the trophic guilds that dominated competitive interactions. Clearly, these interactions are not species-specific but comprise a large hyper-connected network dominated by intermediate species. On the other hand, the non-trophic/non-competitive interactions were mainly associated with sessile and basal species that provide habitat, shelter or facilitate feeding for other species. Mutualistic interactions involve mesograzers that are often found in close association with macroalgae. Mesograzers benefit macroalgae by removing smaller epiphytic algae that often compete with macrophytes for light and nutrients. Simultaneously, these algae present a chemical defense that makes them non-palatable and prevents them from being consumed by the mesograzers. As a benefit of this association, amphipods gain refuge and avoid predation by omnivorous fish (Aumack et al. 2010, Amsler & McClintock 2014). Furthermore, commensalistic and amensalistic interactions involve filtering organisms that take advantage of the elevated position (in relation to the sea floor) that the substrate gives. Through this elevated position they gain better access to food due to the speed of marine currents that is usually higher in elevated areas than close to the sediment (Gutt 2000).

Species properties and networks importance

As we mentioned above, in Potter Cove ecosystem the classification of species in basal, intermediate and top species, their diet, their trophic level and mobility (mobile or sessile) allowed us to describe the type of non-trophic interactions in which species participate. In this sense, it is possible to extrapolate these patterns to other marine ecosystems, for example, to polar benthic communities that are rich in basal and sessile species (Pineda-Metz et al. 2019, Bae et al. 2021). These analyses are, indeed, necessary to build realistic and reliable ecological models and gain insights into characteristics related to interaction types (Kéfi et al. 2015, 2016, Mougi 2016a, 2016b) showing, for instance, that the addition of different interaction types could expose new interacting groups of species that vary in the way they (non-trophically) interact with the whole community, leading to important functional implications related to the species roles in the community (Sanders et al 2015).

Some studies argue that studying both trophic and non-trophic networks allow us to better understand the whole community function and that the combination of different structural patterns of interactions networks is essential to comprehend, for example, the mechanisms behind communities´ stability (Mougi & Kondoh 2012, Kéfi et al. 2016, García-Callejas et al. 2017, Freilich 2018). Previous analyses of Potter Cove food web showed that there is an important energetic subsidy from detritus and basal species to the entire community and suggested that topological features such as the proportion of basal, intermediate and top species are key to understand the ecosystem response against diversity loss (Marina et al. 2018a, Cordone et al. 2018, Cordone et al. 2020). Hence, the importance of incorporating and studying different types of species interactions (trophic and non-trophic) at different trophic levels from a network perspective. More specifically, adding non-trophic interactions and its distribution among species might be fundamental to understand particular topological properties exhibited by Potter Cove marine ecosystem (Marina et al. 2018a, 2018b).

Non-trophic interactions role

It is known that non-trophic interactions play a role on ecosystem function that may be ambiguous and might probably depend on many factors related with the type of community being studied, the level of resolution of the networks analyzed, the researches perspectives/objectives and the type of analyses that the studies involve (analytical, descriptive, structural, dynamical, etc.). Nonetheless, non-trophic interactions are key elements that should be considered, for example, when studying ecological communities' dynamics and stability (Kéfi et al. 2012, 2015, 2016, 2018, Mougi 2016b, García-Callejas et al. 2017, Hervías-Parejo et al. 2020). There were some attempts to address this question and the findings were very different. Allesina & Tang (2012) suggested that trophic interactions increase stability while mutualistic and competitive interactions are destabilizing. However, many real ecosystems such as Chilean rocky shores - that exhibit numerous positive and negative interactions - showed a persistent and resilient response to perturbations (Kéfi et al 2015, 2016). In this sense, the following question should be addressed: if mutualistic and competitive interactions destabilize ecosystems, why are they so commonly found in ecological communities as empirical data suggest? One possible answer could be that analytical models might not be sufficient when analyzing structural and functional aspects of real ecosystems. This is, partly, because mathematical reduction assumes an abstraction with the consequent loss of a lot of attributes and characteristics of the biological system. However, mathematical modeling of ecosystems is still useful and allows us to tackle life's complex phenomena. In this sense, increasing the realism of such models, as in this study by incorporating non-trophic interactions, will help us to better understand the structure and dynamics of ecosystems.

To resume, in this work we have collected several demands that remain unanswered about the importance of adding non-trophic interactions when studying structure and function of real ecosystems. So far, very little is known about how non-trophic interactions are distributed among species or if the amount of these interactions is related with some topological and structural features of the community, even the association between species-level properties and interaction types remains unclear. Including a full description of the species and its relationships in ecological network analyses - like presented here - is of matter importance (Kéfi et al. 2012, 2015, 2016, Moughi 2016a, 2016b, Lurgi et. al 2020) and provides an insight into the analysis of ecosystems as a whole and not as a group of individual species. Therefore, addressing species properties analysis according to the type of interaction identified is necessary because it may help us to assess and predict ecosystems' responses to environmental disturbances that cause direct consequences on biodiversity especially when it comes to ecosystems seriously affected by climate change.

AKNOWLEDGEMENTS

This research was supported by Universidad Nacional de General Sarmiento (UNGS, Argentina) and Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI, Germany). The work was partially funded by PIO 14420140100035CO CONICET Argentina and conducted in the frame of VAS Ph.D. studies. There was no additional external funding received for this study.

APPENDIX I

References of the academic articles used for the construction of the non-trophic networks of Potter Cove.

BIBLIOGRAPHIC CITATIONS (APA)
Amsler, C. D., Iken, K., McClintock, J. B., Amsler, M. O., Peters, K. J., Hubbard, J. M., ... & Baker, B. J. (2005). Comprehensive evaluation of the palatability and chemical defenses of subtidal macroalgae from the Antarctic Peninsula. *Marine Ecology Progress Series*, *294*, 141-159.
Amsler, C. D., McClintock, J. B., & Baker, B. J. (2012). Amphipods exclude filamentous algae from the Western Antarctic Peninsula benthos: experimental evidence. *Polar biology*, *35*(2), 171-177.
Amsler, C. D., Mcclintock, J. B., & Baker, B. J. (2012). Palatability of living and dead detached Antarctic macroalgae to consumers. *Antarctic Science*, *24*(6), 589.
Amsler, C. D., McClintock, J. B., & Baker, B. J. (2014). Chemical mediation of mutualistic interactions between macroalgae and mesograzers structure unique coastal communities along the western Antarctic Peninsula. *Journal of phycology*, 50(1), 1-10.
Amsler, M. O., Mcclintock, J. B., Amsler, C. D., Angus, R. A., & Baker, B. J. (2009). An evaluation of sponge-associated amphipods from the Antarctic Peninsula. *Antarctic Science*, *21*(6), 579.
Arnaud, P. M. "Adaptations within the Antarctic Marine Benthic Ecosystem (In: Adaptations within Antarctic Ecosystems, Proc. Third SCAR Symposium on Antarctic Biology, Ed. GA Llano) Smithsonian Institution." (1977): 135-157.
Arntz, W. E., and V. A. Gallardo. "Antarctic benthos: present position and future prospects." *Antarctic Science*. Springer, Berlin, Heidelberg, 1994. 243-277.
Arntz, Wolf, et al. "Patterns of life history and population dynamics of benthic invertebrates under the high Antarctic conditions of the Weddell Sea." *Colombo, G., Ferrari, I., Ceccherelli, VU, Rossi, R.(eds). Marine eutrophication and population dynamics: Proc 25th European Marine Biology Symposium. Olsen & Olsen, Fredensborg, Denmark*. 1992.
Arrontes, J. (1999). On the evolution of interactions between marine mesoherbivores and algae. *Botanica Marina*, *42*(2), 137-155.
Aumack, C. F. (2010). Chemically mediated macroalgal-mesograzer interactions along the Western Antarctic Peninsula (Doctoral dissertation, The University of Alabama at Birmingham).
Aumack, C. F., Amsler, C. D., McClintock, J. B., & Baker, B. J. (2011). Impact of mesograzers on epiphyte and endophyte growth associated with chemical defended macroalgae from the western antarctic peninsula: a mesocosm experiment. *Journal of Phycology*, *47*(1), 36-41.
Baker, B. J., Amsler, C. D., & McClintock, J. B. (2008). Macroalgal chemical defenses in polar marine communities. In *Algal chemical ecology* (pp. 91-103). Springer, Berlin, Heidelberg.
Baker, B. J., Kopitzke, R. W., Yoshida, W. Y., & McClintock, J. B. (1995). Chemical and ecological studies of the Antarctic sponge Dendrilla membranosa. *Journal of Natural Products*, *58*(9), 1459-1462.
Barnes, David KA, and Andrew Clarke. "Epibiotic communities on sublittoral macroinvertebrates at Signy Island, Antarctica." *Journal of the Marine Biological Association of the United Kingdom* 75.3 (1995): 689-703.
Barthel, Dagmar, and Julian Gutt. "Sponge associations in the eastern Weddell Sea." *Antarctic science* 4.2 (1992): 137-150.
Barthel, Dagmar. "Do hexactinellids structure Antarctic sponge associations?" *Ophelia* 36.2 (1992): 111-118.
Bavestrello, G., Arillo, A., Calcinai, B., Cattaneo-Vietti, R., Cerrano, C., Gaino, E., ... & Sara, M. (2000). Parasitic diatoms inside Antarctic sponges. *The Biological Bulletin*, 198(1), 29-33.
Bloom, S. A. (1975). The motile escape response of a sessile prey: a sponge-scallop mutualism. *Journal of Experimental Marine Biology and Ecology*, *17*(3), 311-321.
Brey, Thomas, et al. "Growth and productivity of the high Antarctic bryozoan Melicerita obliqua." *Marine Biology* 132.2 (1998): 327-333.
Bruchhausen, P. M., et al. "Fish, crustaceans, and the sea floor under the Ross Ice Shelf." *Science* 203.4379 (1979): 449-451.
Bucolo, P., Amsler, C. D., McClintock, J. B., & Baker, B. J. (2011). Palatability of the Antarctic rhodophyte Palmaria decipiens (Reinsch) RW Ricker and its endo/epiphyte Elachista antarctica

Skottsberg to sympatric amphipods. *Journal of experimental marine biology and ecology*, *396*(2), 202-206.

Bullivant, John S. "Ecology of the Ross Sea benthos." *New Zealand Department of Scientific and Industrial Research Bulletin* 176 (1967): 49-75.

Burgos, E., Ceva, H., Perazzo, R. P., Devoto, M., Medan, D., Zimmermann, M., & Delbue, A. M. (2007). Why nestedness in mutualistic networks? *Journal of theoretical biology*, *249*(2), 307-313.

Cattaneo-Vietti, R., et al. "The role of sponges in the Terra Nova Bay ecosystem." *Ross Sea Ecology*. Springer, Berlin, Heidelberg, 2000. 539-549.

Clarke, Andrew, and Nadine M. Johnston. "Antarctic marine benthic diversity." *Oceanography and marine biology* 41 (2003): 47-114.

Dayton, P. K., and J. S. Oliver. "An evaluation of experimental analyses of population and community patterns in benthic marine environments. In, Marine benthic dynamics, edited by KR Tenore & BC Coull." *Baruch Libr. Mar. Sci* 11 (1980): 93-120.

Dayton, P. K., G. A. Robilliard, and R. T. Paine. "Benthic faunal zonation as a result of anchor ice at McMurdo Sound, Antarctica." *Antarctic ecology* 1 (1970): 244-258.

Dayton, P. K., Robilliard, G. A., Paine, R. T., & Dayton, L. B. (1974). Biological accommodation in the benthic community at McMurdo Sound, Antarctica. *Ecological Monographs*, 44(1), 105-128.

Dearborn, J. H. "Foods and feeding characteristics of Antarctic asteroids and ophiuroids." *Adaptations within Antarctic ecosystems* (1977): 293-326.

Dearborn, J., Frank D. Ferrari, and K. Edwards. "Can pelagic aggregations cause benthic satiation? Feeding biology of the Antarctic brittle star Astrotoma agassizii (Echinodermata: Ophiuroidea)." *Antarctic Research Series* (1986).

Dearborn, John H., et al. "Ecological studies od echinoderms and general marine collecting along antarctic peninsula." *Antarctic Journal of the United States* 8.4 (1973): 206-208.

Duffy, J. E., & Hay, M. E. (1994). Herbivore resistance to seaweed chemical defense: the roles of mobility and predation risk. *Ecology*, *75*(5), 1304-1319.

Gambi, Maria Cristina, et al. "Benthic associations of the shallow hard bottoms off Terra Nova Bay, Ross Sea: zonation, biomass and population structure." *Antarctic Science* 6.4 (1994): 449-462.

Gili, J. M., Coma, R., Orejas, C., López-González, P. J., & Zabala, M. (2001). Are Antarctic suspension-feeding communities different from those elsewhere in the world?. *Polar Biology*, *24*(7), 473-485.

Guerrero-Ramírez, N. R., & Eisenhauer, N. (2017). Trophic and non-trophic interactions influence the mechanisms underlying biodiversity–ecosystem functioning relationships under different abiotic conditions. *Oikos*, *126*(12), 1748-1759.

Gutt, J. (2000). Some “driving forces” structuring communities of the sublittoral Antarctic macrobenthos. *Antarctic Science*, 12(03), 297-313.

Gutt, J., & Schickan, T. (1998). Epibiotic relationships in the Antarctic benthos. *Antarctic Science*, 10(04), 398-405.

Gutt, Julian. "Antarctic macro-zoobenthic communities: a review and an ecological classification." *Antarctic Science* 19.2 (2007): 165.

Hacker, S. D., & Gaines, S. D. (1997). Some implications of direct positive interactions for community species diversity. *Ecology*, *78*(7), 1990-2003.

Hay, M. E., & Fenical, W. (1988). Marine plant-herbivore interactions: the ecology of chemical defense. *Annual review of ecology and systematics*, *19*(1), 111-145.

Hay, M. E., Duffy, J. E., Pfister, C. A., & Fenical, W. (1987). Chemical defense against different marine herbivores: are amphipods insect equivalents? *Ecology*, *68*(6), 1567-1580.

Hay, M. E., Pawlik, J. R., Duffy, J. E., & Fenical, W. (1989). Seaweed-herbivore-predator interactions: host-plant specialization reduces predation on small herbivores. *Oecologia*, *81*(3), 418-427.

Hedgpeth, Joel Walker. "Perspectives of benthic ecology in Antarctica." American association for the Advancement of Science, 1971.

Henkel, T. P., & Pawlik, J. R. (2005). Habitat use by sponge-dwelling brittlestars. *Marine Biology*, *146*(2), 301-313.

Huang, Y. M., Amsler, M. O., McClintock, J. B., Amsler, C. D., & Baker, B. J. (2007). Patterns of gammaridean amphipod abundance and species composition associated with dominant subtidal macroalgae from the western Antarctic Peninsula. *Polar Biology*, *30*(11), 1417-1430.

Hubold, G. "Ecology of notothenioid fish in the Weddell Sea." *Biology of Antarctic fish*. Springer, Berlin, Heidelberg, 1991. 3-22.

Kneib, R. T. (1991). Indirect effects in experimental studies of marine soft-sediment communities. *American Zoologist*, *31*(6), 874-885.

Knox, G. A., and J. K. Lowry. "A comparison between the benthos of the Southern Ocean and the North Polar Ocean with special reference to the Amphipoda and the Polychaeta." *Polar oceans. Arctic Institute of North America, Calgary* (1977): 423-462.

Kott, P. (1969). *Antarctic ascidiacea* (Vol. 13). American Geophysical Union.

Lee, K. M., Min, B., & Goh, K. I. (2015). Towards real-world complexity: an introduction to multiplex networks. *The European Physical Journal B*, *88*(2), 48.

Majdi, N., Boiché, A., Traunspurger, W., & Lecerf, A. (2014). Predator effects on a detritus-based food web are primarily mediated by non-trophic interactions. *Journal of Animal Ecology*, *83*(4), 953-962.

Marine benthos. In LAWS, R. M., ed. Antarctic Ecology, vol. 2. London: Academic Press, 421-461.

McClintock, J. B. (1987). Investigation of the relationship between invertebrate predation and biochemical composition, energy content, spicule armament and toxicity of benthic sponges at McMurdo Sound, Antarctica. *Marine Biology*, *94*(3), 479-487.

McClintock, James B., et al. "Ecology of Antarctic marine sponges: an overview." *Integrative and Comparative Biology* 45.2 (2005): 359-368.

Moreno, Carlos A. "Observations on food and reproduction in Trematomus bernacchii (Pisces: Nototheniidae) from the Palmer Archipelago, Antarctica." *Copeia* 1980.1 (1980): 171-173.

O'Gorman, E. J., Jacob, U., Jonsson, T., & Emmerson, M. C. (2010). Interaction strength, food web topology and the relative importance of species in food webs. *Journal of animal Ecology*, *79*(3), 682-692.

Ohgushi, T. (2008). Herbivore-induced indirect interaction webs on terrestrial plants: the importance of non-trophic, indirect, and facilitative interactions. *Entomologia experimentalis et applicata*, *128*(1), 217-229.

Oliver, John S., and Peter N. Slattery. "Effects of crustacean predators on species composition and population structure of soft-bodied infauna from McMurdo Sound, Antarctica." *Ophelia* 24.3 (1985): 155-175.

Piepenburg, Dieter, Jochen Voß, and Julian Gutt. "Assemblages of sea stars (Echinodermata: Asteroidea) and brittle stars (Echinodermata: Ophiuroidea) in the Weddell Sea (Antarctica) and off Northeast Greenland (Arctic): a comparison of diversity and abundance." *Polar Biology* 17.4 (1997): 305-322.

Sahade, R., et al. "Benthic faunal associations on soft substrates at Potter Cove, King George Island, Antarctica." *Polar Biology* 19.2 (1998): 85-91.

Schoenrock, K. M., Amsler, C. D., McClintock, J. B., & Baker, B. J. (2013). Endophyte presence as a potential stressor on growth and survival in Antarctic macroalgal hosts. *Phycologia*, *52*(6), 595-599.

Stanwell-Smith, D., and A. Clarke. "Seasonality of reproduction in the cushion star Odontaster validus at Signy Island, Antarctica." *Marine biology* 131.3 (1998): 479-487.

Tatián, M., Sahade, R. J., Doucet, M. E., & Esnal, G. B. (1998). Ascidians (Tunicata, Ascidiacea) of Potter Cove, South Shetland Islands, Antarctica. *Antarctic science*, 10(02), 147-152

Toth, G. B., & Pavia, H. (2007). Induced herbivore resistance in seaweeds: a meta-analysis. *Journal of Ecology*, *95*(3), 425-434.

Wiencke, C., Clayton, M. N., Gómez, I., Iken, K., Lüder, U. H., Amsler, C. D., ... & Dunton, K. (2007). Life strategy, ecophysiology and ecology of seaweeds in polar waters. *Reviews in Environmental Science and Bio/Technology*, *6*(1-3), 95-126.

Wulff, J. L. (2006). Ecological interactions of marine sponges. *Canadian Journal of Zoology,* 84(2), 146-166.

Zamzow, J. P., Amsler, C. D., McClintock, J. B., & Baker, B. J. (2010). Habitat choice and predator avoidance by Antarctic amphipods: the roles of algal chemistry and morphology. *Marine Ecology Progress Series*, *400*, 155-163.

APPENDIX II

Description of the interactions identified for the Potter Cove marine ecosystem: mutualistic (+/+), competitive (-/-), commensalistic (0/+) and amensalistic (0/-). Each species in the column interact with each species in the row.

Types of Non-trophic Interactions	
+	**+**
Amphipods: *Gondogeneia antárctica. Prostebbingia gracilis* **Gastropod**: *Nacella concinna*	**Macroalgae:** *Callophyllis atrosanguinea, Curdiea racovitzae, Georgiella confluens, Gigartina skottsbergii, Iridaea cordata, Myriogramme manginii, Neuroglossum delesseriae, Pantoneura plocamioides, Picconiella plumosa, Plocamium cartilagineum, Pyropia plocamiestris, Trematocarpus antarcticus, Adenocystis utricularis, Ascoseira mirabilis, Desmarestia anceps, Desmarestia antárctica, Desmarestia menziesii, Geminocarpus geminatus, Phaeurus antarcticus, Lambia antárctica, Monostroma hariotii, Urospora penicilliformis, Ulothrix sp.*
Amphipods: *Gitanopsis antárctica. Oradarea bidentata*	**Macroalgae:** *Iridaea cordata, Desmarestia menziesii, Desmarestia anceps, Plocamium cartilagineum*
Briozoos **Benthic diatoms**	**Porifera:** *Haliclonidae sp.,* Stylo-Myca, *Rosella sp., Dendrilla antarctica*
Amphipod: *Paradexamine sp.*	**Macroalgae:** *Plocamium cartilagineum*
Echinoderm: *Sterechinus neumayeri*	**Macroalgae:** *Iridaea cordata* *Pyropia plocamiestris*
0	**+**
Macroalgae: *Callophyllis atrosanguinea, Curdiea racovitzae, Georgiella confluens, Gigartina skottsbergii, Iridaea cordata, Myriogramme manginii, Neuroglossum delesseriae, Palmaria decipiens, Pantoneura plocamioides, Picconiella plumosa, Plocamium cartilagineum, Pyropia plocamiestris, Trematocarpus antarcticus,* **Bryozoa**	**Ascidiae**
Porifera: *Rosella sp., Dendrilla antárctica, Haliclonidae sp., Stylo-Myca*	**Fish:** *Trematomus bernacchi,* **Pennatulacea:** *Malacobelmnon daytoni*
Echinoderm: *Sterechinus neumayeri, Ophionotus victoriae*	**Porifera:** *Rosella sp., Dendrilla antárctica, Haliclonidae sp.,* Stylo-Myca
0	**-**
Epiphytic Diatoms	**Macroalgae:** *Callophyllis atrosanguinea, Curdiea racovitzae, Georgiella confluens, Gigartina skottsbergii, Iridaea cordata, Myriogramme manginii, Neuroglossum delesseriae, Palmaria decipiens, Pantoneura plocamioides, Picconiella plumosa, Plocamium cartilagineum, Pyropia plocamiestris,*

	Trematocarpus antarcticus, Adenocystis utricularis, Ascoseira mirabilis, Desmarestia anceps, Desmarestia antárctica, Desmarestia menziesii, Geminocarpus geminatus, Phaeurus antarcticus, Lambia antárctica, Monostroma hariotii, Urospora penicilliformis, Ulothrix sp.
-	**-**
Notothenia coriiceps	*Notothenia rossii* *Lepidonotothen nudifrons* *Trematomus newnesi* *Trematomus bernacchi* *Harpagifer antarcticus* *Parachaenichthys charcoti* *Chaenocephalus aceratus* *Protomyctophum* Nereidae *Austrodoris kerguelensis* *Nacella concinna* *Laevilacunaria antarctica* *Laternulla elliptica* *Neobuccinum eatoni* *Eurymera monticulosa* *Pontogeneiella sp.* *Gondogeneia antarctica* Hyperiidea *Bovallia gigantea* *Prostebbingia gracilis* *Oradarea bidentata* *Glyptonotus antarcticus* *Plakarthrium puncattissimum* *Ophionotus victoriae* *Odontaster validus* *Diplasterias brucei* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Sterechinus neumayeri* *Octopus sp.* Priapúlida *Parborlasia corrugatus* Salpidae
Notothenia rossii	*Lepidonotothen nudifrons* *Trematomus newnesi* *Trematomus bernacchi* *Harpagifer antarcticus* *Parachaenichthys charcoti* *Chaenocephalus ceratus* *Austrodoris kerguelensis* *Laevilacunaria antarctica* *Laternulla elliptica* *Eurymera monticulosa* *Pontogeneiella sp.* *Gondogeneia antarctica*

	Hyperiidea *Prostebbingia gracilis* *Oradarea bidentata* *Glyptonotus antarcticus* *Ophionotus victoriae* *Odontaster validus* Priapúlida Salpidae
Lepidonotothen nudifrons	*Trematomus newnesi* *Trematomus bernacchi* *Harpagifer antarcticus* *Parachaenichthys charcoti* *Chaenocephalus aceratus* *Austrodoris kerguelensis* Hyperiidea *Bovallia gigantea* *Glyptonotus antarcticus* *Ophionotus victoriae* *Odontaster validus* *Sterechinus neumayeri* Priapúlida Salpidae
Trematomus newnesi	*Trematomus bernacchi* *Harpagifer antarcticus* *Parachaenichthys charcoti* *Chaenocephalus aceratus* *Protomyctophum* Hyperiidea *Bovallia gigantea* *Glyptonotus antarcticus* *Ophionotus victoriae* *Odontaster validus* *Diplasterias brucei* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Sterechinus neumayeri* *Parborlasia corrugatus*
Trematomus bernacchi	*Harpagifer antarcticus* *Austrodoris kerguelensis* *Glyptonotus antarcticus* *Ophionotus victoriae* *Odontaster validus* *Diplasterias brucei* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Octopus sp.* Priapúlida *Parborlasia corrugatus* Salpidae

Harpagifer antarcticus	*Parachaenichthys charcoti* *Chaenocephalus aceratus* *Austrodoris kerguelensis* Hyperiidea *Bovallia gigantea* *Glyptonotus antarcticus* *Ophionotus victoriae* *Odontaster validus* *Diplasterias brucei* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Sterechinus neumayeri* Priapúlida *Parborlasia corrugatus* Salpidae
Parachaenichthys charcoti	*Chaenocephalus aceratus* Hyperiidea *Ophionotus victoriae*
Chaenocephalus aceratus	Hyperiidea *Ophionotus victoriae*
Nereidae	*Laevilacunaria antarctica* *Gondogeneia antarctica* *Prostebbingia gracilis*
Margarella antarctica	*Austrodoris kerguelensis* *Ophionotus victoriae* *Odontaster validus* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Perknaster aurorae* *Sterechinus neumayeri* *Parborlasia corrugatus*
Austrodoris kerguelensis	*Laevilacunaria antarctica* *Eurymera monticulosa* *Pontogeneiella sp.* *Gondogeneia antarctica* *Prostebbingia gracilis* *Oradarea bidentata* *Glyptonotus antarcticus* *Ophionotus victoriae* *Odontaster validus* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Perknaster aurorae* *Sterechinus neumayeri* Priapúlida *Parborlasia corrugatus* Salpidae
Eatoniella sp.	*Nacella concinna* *Paradexamine sp.* *Eurymera monticulosa*

	Pontogeneiella sp. *Gondogeneia antarctica* *Cheirimedon femoratus* *Gitanopsis antarctica* *Prostebbingia gracilis* *Plakarthrium puncattissimum* *Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Nacella concinna	*Eurymera monticulosa* *Pontogeneiella sp.* *Gondogeneia antarctica* *Prostebbingia gracilis* *Plakarthrium puncattissimum* *Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Laevilacunaria antarctica	*Eurymera monticulosa* *Pontogeneiella sp.* *Gondogeneia antarctica* *Prostebbingia gracilis* *Oradarea bidentata* *Plakarthrium puncattissimum*
Dacrydyum sp.	*Laternulla elliptica* *Euphausia superba* Hyperiidea Copépoda Ascidiae Oligochaeta Hydrozoa Bryozoa Salpidae Misidáceos Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Laternulla elliptica	*Euphausia superba* Hyperidea *Ophionotus victoriae*

	Copepoda Ascidiae Oligochaeta Hydrozoa Bryozoa Salpidae Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Neobuccinum eatoni	*Paradexamine sp.* *Pariphimedia integricauda* *Gitanopsis antarctica* *Waldeckia obesa* Hippo-Orcho *Serolis sp.* *Glyptonotus antarcticus* *Ophionotus victoriae*
Euphausia superba	Hyperiidea Copepoda Ascidiae Oligochaeta Hydrozoa Bryozoa Salpidae Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Paradexamine sp.	*Eurymera monticulosa* *Pariphimedia integricauda* *Cheirimedon femoratus* *Gitanopsis antarctica* *Waldeckia obesa* *Hippo-Orcho* *Serolis sp.* *Glyptonotus antarcticus* *Plakarthrium puncattissimum* *Ophionotus victoriae* *Odontaster validus* *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Eurymera monticulosa	*Pontogeneiella sp.*

	Gondogeneia antarctica *Cheirimedon femoratus* *Gitanopsis antarctica* *Prostebbingia gracilis* *Oradarea bidentata* *Plakarthrium puncattissimum* *Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Pontogeneiella sp.	*Gondogeneia antarctica* *Prostebbingia gracilis* *Oradarea bidentata* *Plakarthrium puncattissimum* *Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Gondogeneia antarctica	*Prostebbingia gracilis* *Oradarea bidentata* *Plakarthrium puncattissimum* *Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Hyperiidea	*Ophionotus victoriae* Copépoda Ascidiae Oligochaeta Hydrozoa Bryozoa Salpidae *Misidáceos* *Haliclonidae sp.* *Stylo-Myca* *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Pariphimedia integricauda	*Gitanopsis antarctica* *Waldeckia obesa*

	Hippo-Orcho *Serolis sp.* *Glyptonotus antarcticus* *Ophionotus victoriae*
Bovallia gigantea	*Ophionotus victoriae* *Sterechinus neumayeri*
Cheirimedon femoratus	*Gitanopsis antarctica* *Plakarthrium puncattissimum* *Ophionotus victoriae* *Odontaster validus* *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Gitanopsis antarctica	*Waldeckia obesa* Hippo-Orcho *Serolis sp.* *Glyptonotus antarcticus* *Plakarthrium puncattissimum* *Ophionotus victoriae* *Odontaster validus* *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Prostebbingia gracilis	*Oradarea bidentata* *Plakarthrium puncattissimum* *Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Waldeckia obesa	Hippo-Orcho *Serolis sp.* *Glyptonotus antarcticus* *Ophionotus victoriae*
Hippo-Orcho	*Serolis sp.* *Glyptonotus antarcticus* *Ophionotus victoriae*
Serolis sp.	*Glyptonotus antarcticus* *Ophionotus victoriae*
Glyptonotus antarcticus	*Ophionotus victoriae* *Odontaster validus* *Sterechinus neumayeri* Priapúlida *Parborlasia corrugatus* Salpidae
Plakarthrium puncattissimum	*Hemiarthrum setulosum* *Ophionotus victoriae* *Odontaster validus* Priapúlida *Haliclonidae sp.* Stylo-Myca

	Rosella sp. *Dendrilla antarctica*
Ophionotus victoriae	*Odontaster validus* *Diplasterias brucei* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Perknaster aurorae* *Sterechinus neumayeri* Priapúlida *Parborlasia corrugatus* Salpidae *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Odontaster validus	*Diplasterias brucei* *Odontaster meridionalis* *Perknaster fuscus antarticus* *Perknaster aurorae* *Sterechinus neumayeri* Priapúlida *Parborlasia corrugatus* Salpidae *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Diplasterias brucei	*Odontaster meridionalis* *Perknaster fuscus antarticus*
Odontaster meridionalis	*Perknaster fuscus antarticus* *Perknaster aurorae* *Sterechinus neumayeri* *Parborlasia corrugatus*
Perknaster fuscus antarticus	*Perknaster aurorae* *Sterechinus neumayeri* *Parborlasia corrugatus*
Perknaster aurorae	*Sterechinus neumayeri* *Parborlasia corrugatus*
Sterechinus neumayeri	*Parborlasia corrugatus*
Copepoda	Ascidiae Oligochaeta Hydrozoa Bryozoa Salpidae Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Ascidiae	Oligochaeta Hydrozoa Bryozoa Salpidae Mysidacea Zooplankton

	Haliclonidae sp. Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Octopus	*Parborlasia corrugatus*
Oligochaeta	Hydrozoa Bryozoa Salpidae Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Hydrozoa	Bryozoa Salpidae Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Bryozoa	Salpidae Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Priapulida	Salpidae *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica*
Salpidae	Mysidacea Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Mysidacea	Zooplankton *Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Zooplankton	*Haliclonidae sp.* Stylo-Myca *Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Haliclonidae sp.	Stylo-Myca

	Rosella sp. *Dendrilla antarctica* *Malacobelmnon daytoni*
Stylo-Myca	*Rosella sp.* *Dendrilla antarctica* *Malacobelmnon daytoni*
Rosella sp.	*Dendrilla antarctica* *Malacobelmnon daytoni*
Dendrilla antarctica	*Malacobelmnon daytoni*

APPENDIX III: Species numeric identification and trophic level of each species.

ID	Species	TL
1	*Notothenia coriiceps*	2,80
2	*Nothotenia rossii*	3,25
3	*Lepidonotothen nudifrons*	3,07
4	*Trematomus newnesi*	3,65
5	*Trematomus bernacchi*	3,59
6	*Harpagifer antarcticus*	3,32
7	*Parachaenichthys charcoti*	3,50
8	*Chaenocephalus aceratus*	4,02
9	*Protomyctophum* sp.	3,70
10	*Callophyllis atrosanguinea*	1,00
11	*Curdiea racovitzae*	1,00
12	*Georgiella confluens*	1,00
13	*Gigartina skottsbergii*	1,00
14	*Iridaea cordata*	1,00
15	*Myriogramme manginii*	1,00
16	*Neuroglossum delesseriae*	1,00
17	*Palmaria dicipiens*	1,00
18	*Pantoneura plocamioides*	1,00
19	*Picconiella plumosa*	1,00
20	*Plocamium cartilagineum*	1,00
21	*Pyropia plocamiestris*	1,00
22	*Trematocarpus antarcticus*	1,00
23	*Adenocystis utricularis*	1,00
24	*Ascoseira mirabilis*	1,00
25	*Desmarestia anceps*	1,00
26	*Desmarestia antarctica*	1,00
27	*Desmarestia menziesii*	1,00
28	*Geminocarpus geminatus*	1,00
29	*Phaeurus antarcticus*	1,00
30	*Lambia antarctica*	1,00
31	*Monostroma hariotii*	1,00
32	*Urospora penicilliformis*	1,00
33	*Ulothrix* sp.	1,00
34	Epiphytic diatoms	1,00
35	Benthic diatoms	1,00
36	Phytoplankton	1,00
37	Aged Detritus	1,00
38	Nereidae	2,00
39	*Margarella antarctica*	3,25
40	*Austrodoris kerguelenensis*	3,07
41	*Eatoniella* sp.	2,00
42	*Nacella concinna*	2,00
43	*Laevilacunaria antarctica*	2,00
44	*Dacrydium* sp.	2,50
45	*Laternula elliptica*	2,33
46	*Neobuccinum eatoni*	2,67
47	*Euphausia superba*	2,50
48	*Paradexamine* sp.	2,00
49	*Eurymera monticulosa*	2,00
50	*Pontogeneiella* sp.	2,00
51	*Gondogeneia antarctica*	2,00
52	Hyperiidea	3,33
53	*Pariphimedia integricauda*	2,00
54	*Bovallia gigantea*	3,00
55	*Cheirimedon femoratus*	2,00
56	*Gitanopsis squamosa*	2,00
57	*Prostebbingia gracilis*	2,00
58	*Waldeckia obesa*	2,00
59	Hippo-Orcho	2,00
60	*Oradarea bidentata*	2,00
61	*Serolis* sp.	2,00
62	*Glyptonotus antarcticus*	3,13
63	*Plakarthrium punctatissimum*	2,00
64	*Hemiarthrum setulosum*	2,00
65	*Ophionotus victoriae*	2,97
66	*Odontaster validus*	3,06
67	*Diplasterias brucei*	3,67
68	*Odontaster meridionalis*	3,35
69	*Perknaster fuscus antarcticus*	3,46
70	*Perknaster aurorae*	3,25
71	*Sterechinus neumayeri*	3,21
72	Squid	1,00
73	Copepoda	2,50
74	Ascidiae	2,50
75	*Octopus* sp.	4,13
76	Oligochaeta	2,50
77	Hydrozoa	2,50
78	Bryozoa	2,50
79	Priapúlida	2,50
80	*Parborlasia corrugatus*	3,41
81	Salpidae	2,70
82	Mysidacea	2,50
83	Fresh Detritus	1,00
84	Necromass	1,00
85	Zooplankton	2,00
86	*Haliclonidae* sp.	2,25
87	Stylo-Myca	2,25
88	*Rossella* sp.	2,25
89	*Dendrilla antarctica*	2,25
90	*Urticinopsis antarctica*	4,27
91	*Malacobelemnon daytoni*	2,50

REFERENCES

Albert, R., & Barabási, A. L. (2002). Statistical mechanics of complex networks. Reviews of modern physics, 74(1), 47. https://doi.org/10.1103/RevModPhys.74.47

Albouy, C., Velez, L., Coll, M., Colloca, F., Le Loc'h, F., Mouillot, D., & Gravel, D. (2014). From projected species distribution to food-web structure under climate change. Global change biology, 20(3), 730-741. https://doi.org/10.1111/gcb.12467

Allesina, S., & Tang, S. (2012). Stability criteria for complex ecosystems. *Nature*, 483(7388), 205. https://doi.org/10.1038/nature10832

Amsler, C. D., McClintock, J. B., & Baker, B. J. (1999). An Antarctic feeding triangle: defensive interactions between macroalgae, sea urchins, and sea anemones. *Marine Ecology Progress Series*, *183*, 105-114.

Amsler, C. D., McClintock, J. B., & Baker, B. J. (2014). Chemical mediation of mutualistic interactions between macroalgae and mesograzers structure unique coastal communities along the western Antarctic Peninsula. *Journal of phycology*, 50(1), 1-10. https://doi.org/10.1111/jpy.12137

Aumack, C. F. (2010). Chemically mediated macroalgal-mesograzer interactions along the Western Antarctic Peninsula (Doctoral dissertation, The University of Alabama at Birmingham).

Bae, H., Ahn, I. Y., Park, J., Song, S. J., Noh, J., Kim, H., & Khim, J. S. (2021). Shift in polar benthic community structure in a fast retreating glacial area of Marian Cove, West Antarctica. Scientific reports, 11(1), 1-10. https://doi.org/10.1038/s41598-020-80636-z

Bascompte, J., Jordano, P., Melián, C. J., & Olesen, J. M. (2003). The nested assembly of plant–animal mutualistic networks. *Proceedings of the National Academy of Sciences*, *100*(16), 9383-9387. https://doi.org/10.1073/pnas.1633576100

Bascompte, J., & Jordano, P. (2007). Plant-animal mutualistic networks: the architecture of biodiversity. *Annu. Rev. Ecol. Evol. Syst.*, *38*, 567-593. https://doi.org/10.1146/annurev.ecolsys.38.091206.095818

Bascompte, J. & Jordano, P. (2008). Redes mutualistas de especies. Investigación y Ciencia.

Bascompte, J. (2009). Mutualistic networks. Frontiers in Ecology and the Environment, 7(8), 429-436. https://doi.org/10.1890/080026

Bastolla, U., Fortuna, M. A., Pascual-García, A., Ferrera, A., Luque, B., & Bascompte, J. (2009). The architecture of mutualistic networks minimizes competition and increases biodiversity. *Nature*, *458*(7241), 1018-1020. https://doi.org/10.1038/nature07950

Bloom, S. A. (1975). The motile escape response of a sessile prey: a sponge-scallop mutualism. *Journal of Experimental Marine Biology and Ecology*, *17*(3), 311-321. https://doi.org/10.1016/0022-0981(75)90006-4

Bromwich, D. H., Nicolas, J. P., Monaghan, A. J., Lazzara, M. A., Keller, L. M., Weidner, G. A., & Wilson, A. B. (2013). Central West Antarctica among the most rapidly warming regions on Earth. Nature Geoscience, 6(2), 139-145. https://doi.org/10.1038/ngeo1671

Cohen, J. E. (1977). Food webs and the dimensionality of trophic niche space. Proceedings of the National Academy of Sciences, 74(10), 4533-4536. https://doi.org/10.1073/pnas.74.10.4533

Cohen, J. E., & Briand, F. (1984). Trophic links of community food webs. Proceedings of the National Academy of Sciences, 81(13), 4105-4109. https://doi.org/10.1073/pnas.81.13.4105

Cordone, G., Marina, T. I., Salinas, V., Doyle, S. R., Saravia, L. A., & Momo, F. R. (2018). Effects of macroalgae loss in an Antarctic marine food web: applying extinction thresholds to food web studies. *PeerJ*, *6*, e5531. https://doi.org/10.7717/peerj.5531

Cordone, G., Salinas, V., Marina, T. I., Doyle, S. R., Pasotti, F., Saravia, L. A., & Momo, F. R. (2020). Green vs brown food web: Effects of habitat type on multidimensional stability proxies for a highly-resolved Antarctic food web. *Food Webs*, e00166. https://doi.org/10.1016/j.fooweb.2020.e00166

Dayton, P. K., Robilliard, G. A., Paine, R. T., & Dayton, L. B. (1974). Biological accommodation in the benthic community at McMurdo Sound, Antarctica. Ecological Monographs, 44(1), 105-128. https://doi.org/10.2307/1942321

Dong, G., Fan, J., Shekhtman, L. M., Shai, S., Du, R., Tian, L., ... & Havlin, S. (2018). Resilience of networks with community structure behaves as if under an external field. Proceedings of the National Academy of Sciences, 115(27), 6911-6915. https://doi.org/10.1073/pnas.1801588115

Dunne, J. A., Williams, R. J., & Martinez, N. D. (2002). Food-web structure and network theory: the role of connectance and size. Proceedings of the National Academy of Sciences, 99(20), 12917-12922. https://doi.org/10.1073/pnas.192407699

Dunne, J. A., Williams, R. J., & Martinez, N. D. (2004). Network structure and robustness of marine food webs. Marine Ecology Progress Series, 273, 291-302. https://doi.org/10.3354/meps273291

Fortuna, M. A., & Bascompte, J. (2006). Habitat loss and the structure of plant–animal mutualistic networks. *Ecology letters*, *9*(3), 281-286. https://doi.org/10.1111/j.1461-0248.2005.00868.x

Freilich, M. A., Wieters, E., Broitman, B. R., Marquet, P. A., & Navarrete, S. A. (2018). Species co-occurrence networks: Can they reveal trophic and non-trophic interactions in ecological communities? Ecology, 99(3), 690-699. https://doi.org/10.1002/ecy.2142

García-Callejas, D., Molowny-Horas, R., & Araújo, M. B. (2018). Multiple interactions networks: towards more realistic descriptions of the web of life. *Oikos*, 127(1), 5-22. https://doi.org/10.1111/oik.04428

Grange, L. J., & Smith, C. R. (2013). Megafaunal communities in rapidly warming fjords along the West Antarctic Peninsula: hotspots of abundance and beta diversity. PloS one, 8(12), e77917. https://doi.org/10.1371/journal.pone.0077917

Guerrero-Ramírez, N. R., & Eisenhauer, N. (2017). Trophic and non-trophic interactions influence the mechanisms underlying biodiversity–ecosystem functioning relationships under different abiotic conditions. *Oikos*, *126*(12), 1748-1759. https://doi.org/10.1111/oik.04190

Gutt, J., & Schickan, T. (1998). Epibiotic relationships in the Antarctic benthos. *Antarctic Science*, 10(4), 398-405. https://doi.org/10.1017/S0954102098000480

Gutt, J. (2000). Some “driving forces” structuring communities of the sublittoral Antarctic macrobenthos. *Antarctic Science*, 12(3), 297-313. https://doi.org/10.1017/S0954102000000365

Hacker, S. D., & Gaines, S. D. (1997). Some implications of direct positive interactions for community species diversity. Ecology, 78(7), 1990-2003. https://doi.org/10.1890/0012-9658(1997)078[1990:SIODPI]2.0.CO;2

Hale, K. R., Valdovinos, F. S., & Martinez, N. D. (2020). Mutualism increases diversity, stability, and function of multiplex networks that integrate pollinators into food webs. Nature communications, 11(1), 1-14. https://doi.org/10.1038/s41467-020-15688-w

Hernández, E. A., Lopez, J. L., Piquet, A. M. T., Mac Cormack, W. P., & Buma, A. G. (2019). Changes in salinity and temperature drive marine bacterial communities’ structure at Potter Cove, Antarctica. Polar Biology, 1-15. https://doi.org/10.1007/s00300-019-02590-5

Hervías-Parejo, S., Tur, C., Heleno, R., Nogales, M., Timóteo, S., & Traveset, A. (2020). Species functional traits and abundance as drivers of multiplex ecological networks: first empirical quantification of inter-layer edge weights. Proceedings of the Royal Society B, 287(1939), 20202127. https://doi.org/10.1098/rspb.2020.2127

Kéfi, S., Berlow, E. L., Wieters, E. A., Navarrete, S. A., Petchey, O. L., Wood, S. A., ... & Martinez, N. D. (2012). More than a meal… integrating non-feeding interactions into food webs. *Ecology letters*, 15(4), 291-300. https://doi.org/10.1111/j.1461-0248.2011.01732.x

Kéfi, S., Berlow, E. L., Wieters, E. A., Joppa, L. N., Wood, S. A., Brose, U., & Navarrete, S. A. (2015). Network structure beyond food webs: mapping non-trophic and trophic interactions on Chilean rocky shores. *Ecology*, 96(1), 291-303. https://doi.org/10.1890/13-1424.1

Kéfi, S., Miele, V., Wieters, E. A., Navarrete, S. A., & Berlow, E. L. (2016). How structured is the entangled bank? The surprisingly simple organization of multiplex ecological networks leads to increased persistence and resilience. *PLoS biology*, 14(8), e1002527. https://doi.org/10.1371/journal.pbio.1002527

Kéfi, S., Thébault, E., Eklof, A., Lurgi, M., & Davis, A. J. (2018). 6 Toward Multiplex Ecological Networks: Accounting for Multiple Interaction Types to Understand Community Structure and Dynamics. Food Webs, 73.

Kneib, R. T. (1991). Indirect effects in experimental studies of marine soft-sediment communities. *American Zoologist*, *31*(6), 874-885. https://doi.org/10.1093/icb/31.6.874

Lee, K. M., Min, B., & Goh, K. I. (2015). Towards real-world complexity: an introduction to multiplex networks. The European Physical Journal B, 88(2), 1-20. https://doi.org/10.1140/epjb/e2015-50742-1

Lurgi, M., Galiana, N., Broitman, B. R., Kéfi, S., Wieters, E. A., & Navarrete, S. A. (2020). Geographical variation of multiplex ecological networks in marine intertidal communities. Ecology, 101(11), e03165. https://doi.org/10.1002/ecy.3165

Marina, T. I., Salinas, V., Cordone, G., Campana, G., Moreira, E., Deregibus, D., ... & De Troch, M. (2018a). The food web of Potter Cove (Antarctica): complexity, structure and function. *Estuarine, Coastal and Shelf Science*, *200*, 141-151. https://doi.org/10.1016/j.ecss.2017.10.015

Marina, T. I., Saravia, L. A., Cordone, G., Salinas, V., Doyle, S. R., & Momo, F. R. (2018b). Architecture of marine food webs: To be or not be a ‘small-world’. *PLoS One*, *13*(5), e0198217. https://doi.org/10.1371/journal.pone.0198217

Martinez, N. D., Hawkins, B. A., Dawah, H. A., & Feifarek, B. P. (1999). Effects of sampling effort on characterization of food-web structure. Ecology, 80(3), 1044-1055. https://doi.org/10.1890/0012-9658(1999)080[1044:EOSEOC]2.0.CO;2

McCann, K., Hastings, A., & Huxel, G. R. (1998). Weak trophic interactions and the balance of nature. Nature, 395(6704), 794-798. https://doi.org/10.1038/27427

McClintock, James B., et al. Ecology of Antarctic marine sponges: an overview. *Integrative and Comparative Biology* 45.2 (2005): 359-368. https://doi.org/10.1093/icb/45.2.359

McCormack, S. A., Melbourne-Thomas, J., Trebilco, R., Griffith, G., Hill, S. L., Hoover, C., ... & Constable, A. J. (2021). Southern Ocean food web modelling: Progress, prognoses, and future priorities for research and policy makers. Frontiers in Ecology and Evolution, 626. https://doi.org/10.3389/fevo.2021.624763

Memmott, J., Waser, N. M., & Price, M. V. (2004). Tolerance of pollination networks to species extinctions. *Proceedings of the Royal Society of London B: Biological Sciences*, 271(1557), 2605-2611. https://doi.org/10.1093/icb/45.2.359

Meredith, M. P., & King, J. C. (2005). Rapid climate change in the ocean west of the Antarctic Peninsula during the second half of the 20th century. Geophysical Research Letters, 32(19). https://doi.org/10.1029/2005GL024042

Mougi, A., & Kondoh, M. (2012). Diversity of interaction types and ecological community stability. Science, 337(6092), 349-351. https://doi.org/10.1126/science.1220529

Mougi, A. (2016a). The roles of amensalistic and commensalistic interactions in large ecological network stability. Scientific Reports, 6(1), 1-6. https://doi.org/10.1038/srep29929

Mougi, A. (2016b). Stability of an adaptive hybrid community. Scientific reports, 6(1), 1-5. https://doi.org/10.1038/srep28181

Neutel, A. M., Heesterbeek, J. A., & de Ruiter, P. C. (2002). Stability in real food webs: weak links in long loops. Science, 296(5570), 1120-1123. https://doi.org/10.1126/science.1068326

Nicolas, J. P., & Bromwich, D. H. (2014). New reconstruction of Antarctic near-surface temperatures: Multidecadal trends and reliability of global reanalyses. Journal of Climate, 27(21), 8070-8093. https://doi.org/10.1175/JCLI-D-13-00733.1

Paine, R. T. (1966). Food web complexity and species diversity. The American Naturalist, 100(910), 65-75. https://doi.org/10.1086/282400

Pascual, M., & Dunne, J. A. (Eds.). (2006). Ecological networks: linking structure to dynamics in food webs. Oxford University Press.

Pilosof, S., Porter, M. A., Pascual, M., & Kéfi, S. (2017). The multilayer nature of ecological networks. *Nature Ecology & Evolution*, *1*(4), 1-9. https://doi.org/10.1038/s41559-017-0101

Pineda-Metz, S. E., Isla, E., & Gerdes, D. (2019). Benthic communities of the Filchner Region (Weddell Sea, Antarctica). Marine Ecology Progress Series, 628, 37-54. https://doi.org/10.3354/meps13093

Pocock, M. J., Evans, D. M., & Memmott, J. (2012). The robustness and restoration of a network of ecological networks. *Science*, 335(6071), 973-977. https://doi.org/10.1126/science.1214915

Poisot, T., & Gravel, D. (2014). When is an ecological network complex? Connectance drives degree distribution and emerging network properties. PeerJ, 2, e251. https://doi.org/10.7717/peerj.251

Post, W. M., & Pimm, S. L. (1983). Community assembly and food web stability. Mathematical Biosciences, 64(2), 169-192. https://doi.org/10.1016/0025-5564(83)90002-0

Quartino, M. L., Deregibus, D., Campana, G. L., Latorre, G. E. J., & Momo, F. R. (2013). Evidence of macroalgal colonization on newly ice-free areas following glacial retreat in Potter Cove (South Shetland Islands), Antarctica.PloS one, 8(3), e58223. https://doi.org/10.1371/journal.pone.0058223

Sahade, R., Lagger, C., Torre, L., Momo, F., Monien, P., Schloss, I., Barnes, D., Servetto, N., Tarantelli, S., Tatián, M., Zamboni, N., & Abele, D. (2015). Climate change and glacier retreat drive shifts in an Antarctic benthic ecosystem. Science advances, 1(10), e1500050. https://doi.org/10.1126/sciadv.1500050

Sander, E. L., Wootton, J. T., & Allesina, S. (2015). What can interaction webs tell us about species roles? PLOS computational biology, 11(7), e1004330. https://doi.org/10.1371/journal.pcbi.1004330

Schloss, I. R., Abele, D., Moreau, S., Demers, S., Bers, A. V., González, O., & Ferreyra, G. A. (2012). Response of phytoplankton dynamics to 19-year (1991–2009) climate trends in Potter Cove (Antarctica). Journal of marine Systems, 92(1), 53-66. https://doi.org/10.1016/j.jmarsys.2011.10.006

Thébault, E., & Fontaine, C. (2010). Stability of ecological communities and the architecture of mutualistic and trophic networks. *Science*, 329(5993), 853-856. https://doi.org/10.1126/science.1188321

Thébault, E., Sauve, A. M., & Fontaine, C. (2018). Merging antagonistic and mutualistic bipartite webs: A first step to integrate interaction diversity into network approaches. Adaptive Food Webs: Stability and Transitions of Real and Model Ecosystems, 62-73.

Turner, J., Colwell, S. R., Marshall, G. J., Lachlan-Cope, T. A., Carleton, A. M., Jones, P. D., Lagun V., Reid P. A., & Iagovkina, S. (2005). Antarctic climate change during the last 50 years. International journal of Climatology, 25(3), 279-294. https://doi.org/10.1002/joc.1130

Vaughan, D. G., Marshall, G. J., Connolley, W. M., Parkinson, C., Mulvaney, R., Hodgson, D. A., King J. C., Pudsey C. J., & Turner, J. (2003). Recent rapid regional climate warming on the Antarctic Peninsula. Climatic change, 60(3), 243-274. https://doi.org/10.1023/A:1026021217991

Vermaat, J. E., Dunne, J. A., & Gilbert, A. J. (2009). Major dimensions in food-web structure properties. Ecology, 90(1), 278-282. https://doi.org/10.1890/07-0978.1

Vizentin-Bugoni, J., Debastiani, V. J., Bastazini, V. A., Maruyama, P. K., & Sperry, J. H. (2020). Including rewiring in the estimation of the robustness of mutualistic networks. Methods in Ecology and Evolution, 11(1), 106-116. https://doi.org/10.1111/2041-210X.13306

Wiencke, C., Ferreyra, G., Arntz, W., & Rinaldi, C. (1998). The Potter Cove coastal ecosystem, Antarctica. Berichte zur Polarforschung, 299, 1-106.

Wiencke, C., Ferreyra, G. A., Abele, D., & Marenssi, S. (2008). The Antarctic ecosystem of Potter cove, King-George Island (Isla 25 de Mayo): Synopsis of research performed 1999-2006 at the Dallmann Laboratory and Jubany Station. Berichte zur Polar-und Meeresforschung (Reports on Polar and Marine Research), 571. http://hdl.handle.net/10013/epic.30038

Williams, R. J., & Martinez, N. D. (2000). Simple rules yield complex food webs. Nature, 404(6774), 180-183. https://doi.org/10.1038/35004572