

# Potter Cove's Heavyweights: Estimation of species' interaction strength of an Antarctic food web

Iara Rodriguez<sup>1</sup> and Leonardo Saravia<sup>2</sup>

<sup>1</sup>Universidad Nacional de General Sarmiento

<sup>2</sup>Centro Austral de Investigaciones Científicas

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## Abstract

Understanding the complex interplay between structure and stability of marine food webs is crucial for assessing ecosystem resilience, particularly in the context of ongoing environmental changes. In the West Antarctic Peninsula, global warming has led to severe alterations in community composition, species distribution, and abundance over the last decades. In this study, we estimate the interaction strength within the Potter Cove (South Shetland Islands, Antarctica) food web to elucidate the roles of species in its structure and functioning. We use these estimates to calculate food web stability in response to perturbations, conducting sequential extinctions to quantify the importance of individual species based on changes in stability and food web fragmentation. We explore connections between interaction strength and key topological properties of the food web. Our findings reveal an asymmetric distribution of interaction strengths, with a prevalence of weak interactions and a few strong ones. Species exerting greater influence within the food web displayed higher degree and trophic similarity but occupied lower trophic levels and displayed lower omnivory levels (e.g., macroalgae and detritus). Extinction simulations revealed the key role of certain species, particularly amphipods and the black rockcod *Notothenia coriiceps*, as their removal led to significant changes in food web stability and network fragmentation. This study highlights the importance of considering species interaction strengths in assessing the stability of polar marine ecosystems. These insights have crucial implications for guiding monitoring and conservation strategies aimed at preserving the integrity of Antarctic marine ecosystems.

1 **Abstract**

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21 preserving the integrity of Antarctic marine ecosystems.

22 **Keywords:** Antarctic ecosystem, Marine food web, Species interaction strength, Climate  
23 change.

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25 **an Antarctic food web**

26 **Introduction**

27         Within an ecosystem, species are interconnected through feeding relationships,  
28 which shape energy flows and create complex food webs. The exploration of food webs has  
29 significantly enhanced our comprehension of species' ecological roles and their impact on  
30 ecosystem functionality and resilience (Belgrano et al., 2005; Landi et al., 2018). Most food  
31 web studies have focused on binary representations, primarily examining species' presence  
32 or absence and their interactions (Dunne et al., 2002; Kortsch et al., 2015; Marina, Salinas,  
33 et al., 2018; Olivier & Planque, 2017). However, a deeper understanding recognizes that  
34 food webs possess inherent complexities in the form of weighted interactions, where the  
35 strengths of species interactions vary. Integrating weighted links based on interaction  
36 strengths in food web studies provides valuable ecological insights, especially when  
37 examining ecosystem function and stability. Understanding the pattern of these interaction  
38 strengths becomes pivotal in assessing and predicting food web stability.

39         Interaction strength in food webs estimates the magnitude of one species' effect on  
40 another and allows for differentiating the importance of species interaction. Several  
41 methodologies have been applied to estimate interaction strength in food webs that can  
42 require a great variety of empirical data, most of them using species biomass (Calizza et al.,  
43 2021; Gauzens et al., 2019; Gellner et al., 2023). Here, we applied the method proposed by  
44 Pawar et al. (2012) that combines data on consumer and resource body masses, resource  
45 density and consumer search space (interaction dimensionality) to obtain interaction  
46 strengths estimates for each pair-wise predator-prey interaction. The novelty of this method  
47 is that it changes the coefficients that relate body size to metabolism according to whether

48 the species moves in 2D or 3D, and it has the advantage that resource density and species  
49 biomass or density are not mandatory.

50 One of the greatest challenges is to predict the effect of human activity on the  
51 complex webs of interactions among species. These species interactions mediate how  
52 changes in the physical and chemical environment play out throughout the ecosystem.  
53 Impacts affecting one species can have cascade effects on others, either directly or  
54 indirectly, depending on the pattern of strength of these connections. In the face of  
55 increasing mean global temperature caused by global climate change, understanding the  
56 effect of species on the stability of ecological communities is a pressing issue.

57 The West Antarctic Peninsula has experienced the most intense warming on the  
58 planet in the last fifty years (Ducklow et al., 2013; Turner et al., 2014), with direct impacts  
59 on the cryosphere. As a result, the glacier in Potter Cove has been rapidly receding since  
60 1950 (Rückamp et al., 2011), which has generated cascading effects in terms of freshwater  
61 input with sediment run-off (Schloss et al., 2012), leading to profound changes on the  
62 benthic and pelagic communities (Braeckman et al., 2021; Deregibus et al., 2023; Garcia  
63 et al., 2019; Sahade et al., 2015).

64 While the Potter Cove food web topology, complexity and stability have been largely  
65 studied (Cordone et al., 2018, 2020; Marina, Salinas, et al., 2018; Marina, Saravia, et al.,  
66 2018; Rodriguez et al., 2022), this study aims to go beyond a purely topological  
67 (presence/absence) assessment of who eats whom in the Potter Cove ecosystem. Our goal  
68 is to analyze the trophic network structure quantitatively by estimating the interaction  
69 strength for each trophic interaction. We aim to evaluate the species' role in the food web  
70 structure and stability, considering the strength of interactions.

## 71 **Materials and methods**

### 72 I. Description of the study area

73 Potter Cove (62° 14' S, 58° 38' W) is a ~9 km<sup>2</sup> fjord located at Isla 25 de Mayo/King  
74 George Island, South Shetland Islands, on the West Antarctic Peninsula (Figure 1). Potter  
75 Cove's high-latitude location results in fluctuating environmental conditions driven by the  
76 strong seasonality in the photoperiod length. The winter reduction in irradiance and  
77 temperature regulates several environmental variables, including incident radiation, sea-ice  
78 extent, mixing layer depth, water column particulate matter, and nutrient concentration.

### 79 II. Potter Cove food web dataset

80 We used a well-resolved food web that documents 649 feeding links between 110  
81 species that inhabit Potter Cove (Rodriguez et al., 2022). The species diet information was  
82 collected and compiled from gut content studies and personal communication with experts.  
83 The Potter Cove food web can be considered representative of the summer season since  
84 data were collected during austral summer months when most research campaigns are  
85 carried out. More detailed information on Potter Cove food web assembly can be found in  
86 Rodriguez et al. (2022) and Marina, Salinas, et al. (2018)

### 87 III. Interaction strength estimation

88 We estimated the strength of each pairwise interaction in the food web following  
89 Pawar et al. (2012) methodology, considering consumer (predator) and resource (prey)  
90 body mass and the interaction dimensionality (ID). First, we compiled information about  
91 resources and consumers' body mass  $m_R$  and  $m_C$ . Then the ID was classified as 2 or 3  
92 dimensions based on the species movement space and habitat. We assign 2D when both  
93 predator and prey move in 2D (e.g., both are benthic) or if a predator moves in 3D and a

94 prey in 2D (e.g., pelagic predator on benthic prey). The ID was classified as 3D when both  
95 predator and prey move in 3D (e.g., both pelagic) or if the predator moves in 2D and the  
96 prey in 3D (e.g., benthic predator, pelagic prey) (Pawar et al., 2012).

97 The main equation we used to estimate the interaction strength (IS) was:

$$98 \quad IS = \frac{\alpha x_R m_R}{m_C}$$

99 where  $\alpha$  is the search rate,  $x_R$  the resource density and  $m_R$  and  $m_C$  the body mass  
100 for the resource and the consumer, respectively (Pawar et al., 2012).

101 We obtained estimates for the search rate ( $\alpha$ ) from the power-law scaling  
102 relationship with the consumer mass, determined by ordinary least squares regression, but  
103 with different coefficients for both dimensional search space (Pawar et al., 2012). When  
104 available, we used empirical resource density ( $x_R$ ) acquired from bibliography, otherwise,  
105 we estimated it from the scaling relationship with the resource body mass, since it scales as  
106 power-law with different exponents in 2D and in 3D (Pawar et al., 2012). For resources such  
107 as macroalgae, sponges, necromass, fresh and aged detritus, where body mass and/or  
108 density are independent from the consumer, a value of 1 was assigned  $m_R$  and  $m_C$ .  
109 Consequently, the interaction strength was solely dependent on consumer biomass (Pawar  
110 et al., 2012). The equations for estimating the search rate and the resource density are  
111 specified in the Supporting Information.

112 Since the exponents reported by Pawar et al. (2012) have associated standard  
113 deviations from the estimation through linear regressions, we used these uncertainties to  
114 measure the variability in interaction strength estimates. We generated 1000 random  
115 samples of the exponents, assuming a normal distribution with a mean based on the  
116 estimated exponent and a standard deviation equal to the reported standard error. Then, we  
117 calculated interaction strength values for each sample, leading to distributions of interaction  
118 strength estimates for each pair-wise interaction. Since these interaction strength

119 distributions showed right-skewed tendencies, we used the median IS to describe the central  
120 tendency.

121 We fitted the interaction strength distribution (i.e., medians for each interaction) to  
122 various models including exponential, gamma, log-normal, normal, power-law, and uniform  
123 using maximum likelihood (McCallum, 1999) and chose the best model using the Akaike  
124 Information Criterion (Burnham & Anderson, 2002).

#### 125 IV. Species properties

126 To characterize the species' role in food web structure and stability, we calculated  
127 unweighted food web properties. Unweighted properties are topology-based metrics applied  
128 to binary food webs that only describe species presence/absence, where all trophic links are  
129 considered equally important in the food web. We calculated four commonly used  
130 topological species properties in food web studies: a) trophic level, b) degree, c) omnivory,  
131 and d) trophic similarity. Trophic level represents the number of feeding links separating a  
132 species from the base of production in a food web. Top predators and primary producers  
133 are expected to have large effects on their communities through top-down and bottom-up  
134 control (Cirtwill et al., 2018). The degree of a species is calculated as the sum of all in-  
135 (number of prey) and out- (number of predators) trophic interactions. It has been linked to a  
136 species' importance for the structure and functioning of a food web. Species with high  
137 degree are important because perturbations can directly affect many other species (Cirtwill  
138 et al., 2018). Omnivory is a feeding strategy in which a consumer feeds at multiple trophic  
139 levels. Omnivore species can adapt faster to variation in prey abundances, and it gives  
140 trophic flexibility to an ecosystem by presenting alternative energy pathways in the face of  
141 perturbations (K. L. Wootton, 2017). Trophic similarity is an index of overlap in species  
142 feeding relationships as both consumers and resources, representing species trophic niches

143 (Delmas et al., 2019; Morlon et al., 2014). Formulas used to obtain the above species'  
144 properties are described in Supporting Information.

145 To study the relationship between species topological properties and interaction  
146 strength, we performed quantile regression at quantile 0.25, 0.5 (the median) and 0.75  
147 between the log total interaction strength, representing the sum of the interaction strength  
148 for all interactions (both in and out) involving a given species, and each of the species  
149 topological properties. Slope significance of the quantile regressions was assessed using  
150 the bootstrap method (Koenker, 2005).

## 151 V. Species impact on food web stability and fragmentation

152 To analyze the individual impact of species on food web stability, we performed  
153 species removal simulations, sequentially deleting the first 50 species in decreasing order  
154 of total interaction strength, trophic level, degree, omnivory and trophic similarity. After each  
155 species extinction, we examined the impact on food web stability and fragmentation. We did  
156 not analyze secondary extinctions after the removal of a species.

157 To estimate stability, we calculated the average of the real part of the maximum  
158 eigenvalue of the community matrix (i.e., the Jacobian) with randomly varying magnitudes  
159 of the matrix elements while preserving the predator-prey sign structure (Allesina & Pascual,  
160 2008; Grilli et al., 2016; Saravia et al., 2022). The maximum eigenvalue describes the rate  
161 at which a small perturbation decays or amplifies over time near an equilibrium point. A more  
162 negative index indicates a more stable food web with a reduced probability of perturbation  
163 amplification. In predator-prey networks, system stability can be achieved by reducing  
164 network size, connectivity, or increasing self-regulation (Allesina & Tang, 2012). In our  
165 analysis, in the Jacobian the self-regulation terms are zero (the diagonal), this implies that  
166 the maximum eigenvalue values obtainable are mostly positive, indicating system instability.

167 This could be interpreted as the degree of self-regulation required for the food web to  
168 achieve stability (Grilli et al., 2016). Species whose removal results in a sharp decrease in  
169 the maximum eigenvalue and, consequently, an important increase in stability may be  
170 recognized as key species within the network. Their presence indicates a higher level of  
171 self-regulation necessary for network stability thus they may have an impact on the whole  
172 food web.

173 Food webs tend to naturally organize into modular patterns, where groups of species  
174 interact more strongly with each other than with species from other groups. Species can  
175 assume various roles within this modular organization based on the pattern of trophic links  
176 within their own module and/or across modules. Typically, a few key species, with high  
177 connectivity both between and within modules, play a crucial role in linking the entire food  
178 web. We measured the cohesion of the food web by calculating the number of connected  
179 components after the removal of a species. These connected components represent  
180 species or subgroups unconnected to others and can be considered an extreme form of  
181 modules. The number of components in ecological networks is important for the overall  
182 structure and resilience of the ecosystem. When an ecological network becomes separated  
183 into smaller components, it represents distinct channels of energy flow and species  
184 interactions. This characteristic could confer an advantage in scenarios where the network  
185 is subjected to perturbations, as it prevents the effects of perturbations from propagating  
186 to other components (Gilarranz et al., 2017; Stouffer & Bascompte, 2011). However, a higher  
187 number of components can be detrimental to the network. It can lead to fragmented energy  
188 pathways, reduced energy transfer, and limited species interactions. We considered the  
189 food web fragmented when there was more than one component, with the species  
190 responsible for the fragmentation considered a key species contributing to maintaining a  
191 cohesive food web structure.

192 We conducted 1000 simulations for the removal of each species, calculating the  
193 maximum eigenvalue for the food web in each case. We plotted the sequential species'  
194 extinction results, according to the different species properties, and their effect on food web  
195 stability and fragmentation.

## 196 VI. Data analysis and availability

197 All analyses, simulations and graphs were performed in R version 4.3.1 (R Core  
198 Team, 2023) using the R packages 'igraph' (Csardi & Nepusz, 2005), cheddar (Hudson  
199 et al., 2013) and the 'multiweb' R package to calculate all network metrics and food web  
200 simulations (Saravia, 2024).

## 201 **Results**

### 202 I. Interaction strength distribution

203 The interaction strength distribution analysis of the Potter Cove food web showed  
204 that the gamma model was the best fit, according to the AIC analysis, with a high proportion  
205 of weak interactions, and only a few strong interactions (Figure 2, Supporting Information  
206 Table S1).

### 207 II. Species interaction strength and topological properties

208 We found that species' total interaction strength was positively associated with both  
209 degree and trophic similarity in all three quantile regressions (Figure 3.b and d, Supporting  
210 Information Table S2). The species trophic level and omnivory showed a negative  
211 relationship with the total interaction strength for the quantile 75 regression (Figure 3.a and  
212 c, Supporting Information Table S2). However, no significant relationship was observed for  
213 regressions at quantiles 25 and 50 for both unweighted species properties (Supporting  
214 Information Table S2).

215 This suggests that species exhibiting the highest interaction strength tend to exhibit  
216 a higher degree and higher dietary and predator overlap, occupy lower trophic positions and  
217 display lower levels of omnivory. The identity of species that exert the most substantial  
218 influence on Potter Cove food web are basal species (detritus and some species of  
219 macroalgae) and grazers (mostly amphipods) (Supporting Information Table S2.a).

### 220 III. Species impact on food web stability and fragmentation

221 The extinction analyses revealed that removal performed by different species  
222 properties has distinct effects on food web stability (Figure 4). While no clear pattern  
223 emerged in stability when removing species by decreasing trophic level and omnivory  
224 (Figure 4.b and d), we observed that network stability increased after the removal of species  
225 with higher interaction strength, degree, and trophic similarity (Figure 4.a, c and e).

226 When extinctions were performed by decreasing interaction strength, we found that  
227 the removal of the amphipods *Prostebbingia sp.* and *P. gracilis*, the 3rd and 4th species with  
228 higher interaction strength, substantially increased food web stability (Figure 4.a, Supporting  
229 Information Table S2.a). In sequential removals of high-degree species, the amphipods  
230 *Gondogenia antarctica* and *Prostebbingia gracilis* caused a major increase in food web  
231 stability (Figure 4.c, Supporting Information Table S2.c).

232 Regarding food web fragmentation, we observed that the removal of the fish  
233 *Notothenia coriiceps*, in extinctions by trophic level, degree, and omnivory (Figure 4.b-d,  
234 Supporting Information Table S2.b-d), was responsible for the fragmentation of the food web  
235 into 9 compartments. For extinctions performed by interaction strength, the amphipod  
236 *Paradexamine fissicauda* caused the fragmentation of the food web into 2 compartments,  
237 which remained unchanged until *N. coriiceps* was removed, dividing the food web into 14  
238 compartments (Figure 4.a, Supporting Information Table S2.a). In the simulations run by

239 decreasing trophic similarity *N. coriiceps* did not contribute to the fragmentation of the food  
240 web. Instead, *Nacella concinna* was responsible for the fragmentation of the network (Figure  
241 4.e, Supporting Information Table S2.e). Notably, network fragmentation does not seem  
242 related to stability as fragmentation points do not align with significant stability changes.

## 243 **Discussion**

244 The estimation of the species interaction strength for the Potter Cove food web  
245 allowed us a better understanding of species' role in food web stability. We found that the  
246 distribution of interaction strength was skewed toward a few strong and many weak links, as  
247 observed in extensive theoretical and empirical studies (Drossel et al., 2004; Kortsch et al.,  
248 2021; Marina et al., 2024; J. T. Wootton & Emmerson, 2005). This asymmetrical pattern has  
249 been proposed to promote ecosystem persistence and stability (Bascompte et al., 2005;  
250 Drossel et al., 2004; Emmerson & Yearsley, 2004; McCann et al., 1998).

251 We employed a range of descriptors, including unweighted and weighted metrics, to  
252 elucidate what makes a species important in the Potter Cove food web. Our findings  
253 revealed a positive correlation between a species' interaction strength and its degree, as  
254 well as trophic similarity. Conversely, trophic level and omnivory exhibited a negative  
255 correlation with the highest levels of interaction strength. The species that exert the most  
256 substantial influence on Potter Cove food web are basal species (detritus and some species  
257 of macroalgae) and grazers (mostly amphipods), with a high number of interactions and  
258 trophic redundancy. This theoretical framework aligns with empirical evidence that the large  
259 biomass macroalgae dominating shallow benthic communities, along with the detritus  
260 derived from them, play a fundamental role as the energetic base of the Potter Cove food  
261 web (Gómez & Huovinen, 2020) and support a high-density assemblage of invertebrates,  
262 especially amphipods (Huang et al., 2007). While macroalgae have a great influence in  
263 shaping the structure of the Potter Cove food web, their direct impact on its stability appears

264 to be less important. Local losses of macroalgae species do not immediately destabilize the  
265 food web; rather, they exhibit relative robustness until a high critical stress threshold is  
266 surpassed. Beyond this point, negative effects propagate rapidly throughout the entire food  
267 web, leading to its collapse (Cordone et al., 2018, 2020).

268         The Potter Cove food web tends to be more stable and less connected upon the  
269 removal of species, as expected. Our study underscores that species exhibiting high total  
270 interaction strength, degree, and trophic similarity need to be considered with particular  
271 attention when trying to predict the effects of perturbations on the Potter Cove ecosystem.  
272 The extinction simulations reveal a threshold behavior in stability—meaning it does not  
273 increase gradually—when species are removed by interaction strength, degree, and to a  
274 lesser extent by trophic similarity. This is significant as it suggests non-linear effects and  
275 confirms the existence of key species that produce these thresholds. This pattern is not  
276 observed with omnivory or trophic level. Contrary to expectations, species with the highest  
277 degree or interaction strength are not necessarily the most important. Instead, our analysis  
278 suggests that interaction strength and degree predominantly shape network structure,  
279 influencing the stability of the Potter Cove food web.

280         Stability appears to be unrelated to the fragmentation of the network, as extinctions  
281 causing fragmentation do not correspond to shifts in stability. Fragmentation is linked to  
282 modularity as species causing fragmentation are responsible for connecting different  
283 modules (Melián & Bascompte, 2004). If these connecting species go extinct, the modules  
284 become disconnected. Previous studies, such as Grilli et al. (2016), have demonstrated that  
285 the modular structure in food webs can yield varied effects, including no effect, contingent  
286 on the distribution of interaction strengths and the degree of self-regulation. Therefore, our  
287 observed results align with these expectations.

288 Our findings show some discrepancies with those of Marina et al. (2024), who  
289 applied the same method to calculate interaction strength for the Weddell Sea (Antarctica)  
290 food web, without incorporating empirical density/biomass values. They found a positive  
291 relationship between species interaction strength, trophic level, and degree. They identified  
292 that species that possess key positions in terms of food web stability are characterized by  
293 high interaction strength, a middle to high trophic level, a high number of interactions, and  
294 middle to low trophic similarity. The discrepancies between their results and those of our  
295 study underscore the intricate nature of the relationship between topological unweighted  
296 indices and interaction strength. This highlights the inadequacy of relying solely on  
297 unweighted indices as reliable indicators of interaction strength. Conversely, utilizing  
298 interaction strength estimations applied to the study of food web stability appears to be a  
299 valuable tool for identifying key species within ecosystems, considering the unique  
300 characteristics and structure of individual food webs.

301 Our findings revealed that the black rockcod, *Notothenia coriiceps*, a generalist,  
302 omnivorous, top predator fish with the highest degree, consistently contributes to the  
303 fragmentation of the Potter Cove food web in most extinction simulations (by decreasing  
304 interaction strength, trophic level, degree and omnivory). This further supports its potential  
305 status as a keystone species in this ecosystem. Previous research examining topological  
306 characteristics of the Potter Cove food web has highlighted the central role of *N. coriiceps*  
307 in enhancing overall network connectivity (Marina, Salinas, et al., 2018; Rodriguez et al.,  
308 2022). Salinas et al. (2024) observed that the removal of *N. coriiceps* resulted in cascading  
309 effects on metrics such as connectance, modularity, and stability.

310 Furthermore, our different analysis consistently points at grazers, like the limpet  
311 *Nacella conncina* and the amphipods *Paradexamine fissicauda*, *Gondogenia antarctica* and  
312 species of the genus *Prostebbingia*, as another group of key species influencing the

313 structure and stability of the Potter Cove food web. Amphipods constitute an important and  
314 abundant component of antarctic benthic communities and, alongside macroalgae,  
315 represent the primary food sources for antarctic fish, such as *N. coriiceps* (Barrera-Oro et al.,  
316 2019).

317         Climate change-induced warming in Potter Cove is substantially changing the  
318 community composition, species distribution, and abundance. This warming has led to  
319 glacier retreat, creating new habitats for macroalgal colonization, and increased glacier  
320 sediment runoff, impacting the photosynthetic rates of primary producers and intensifying  
321 competition among species (Deregibus et al., 2016). Simultaneously, Barrera-Oro et al.  
322 (2019) observed changes in the feeding selectivity of *N. coriiceps* on amphipods, correlating  
323 with shifts in the macroalgae-associated amphipod community. These shifts are linked to  
324 alterations in salinity and changes in water column mixing processes, which regulate  
325 phytoplankton biomass accumulation (Schloss et al., 2002, 2012). However, the net effects  
326 of climate change on macroalgae and other key species, such as amphipods and fish,  
327 remain uncertain and represent a challenge to elucidate.

328         The methodology applied in this study shows great potential for guiding monitoring  
329 and conservation strategies, focused on key species, aimed at protecting the integrity of  
330 Antarctic marine ecosystems in times of rapid climate changes. Through the incorporation  
331 of species interaction strength into our analysis of the Potter Cove food web, we have  
332 identified characteristics and potential key species that exert significant influence over both  
333 the structure and stability of the ecosystem. The non-linear effects observed in the stability  
334 analysis stress the importance of protecting these key species to maintain ecosystem  
335 resilience.

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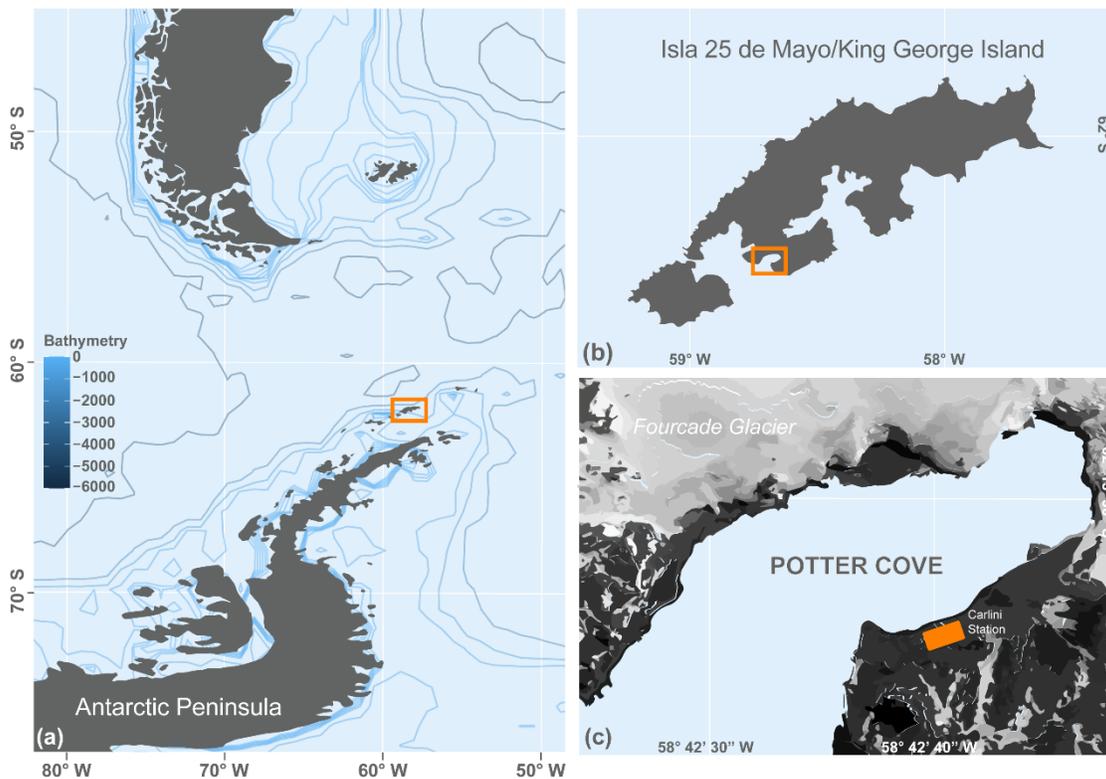
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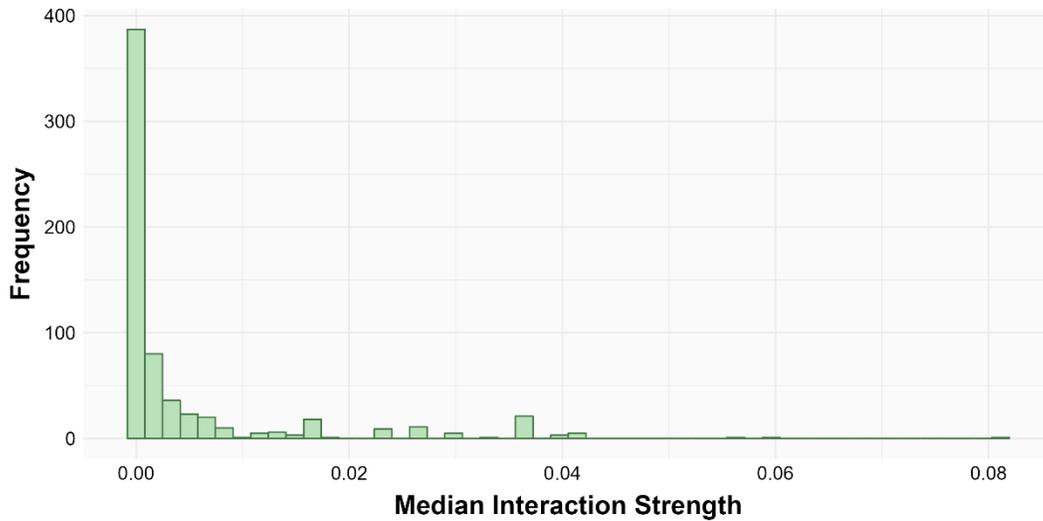
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## 510 Figures



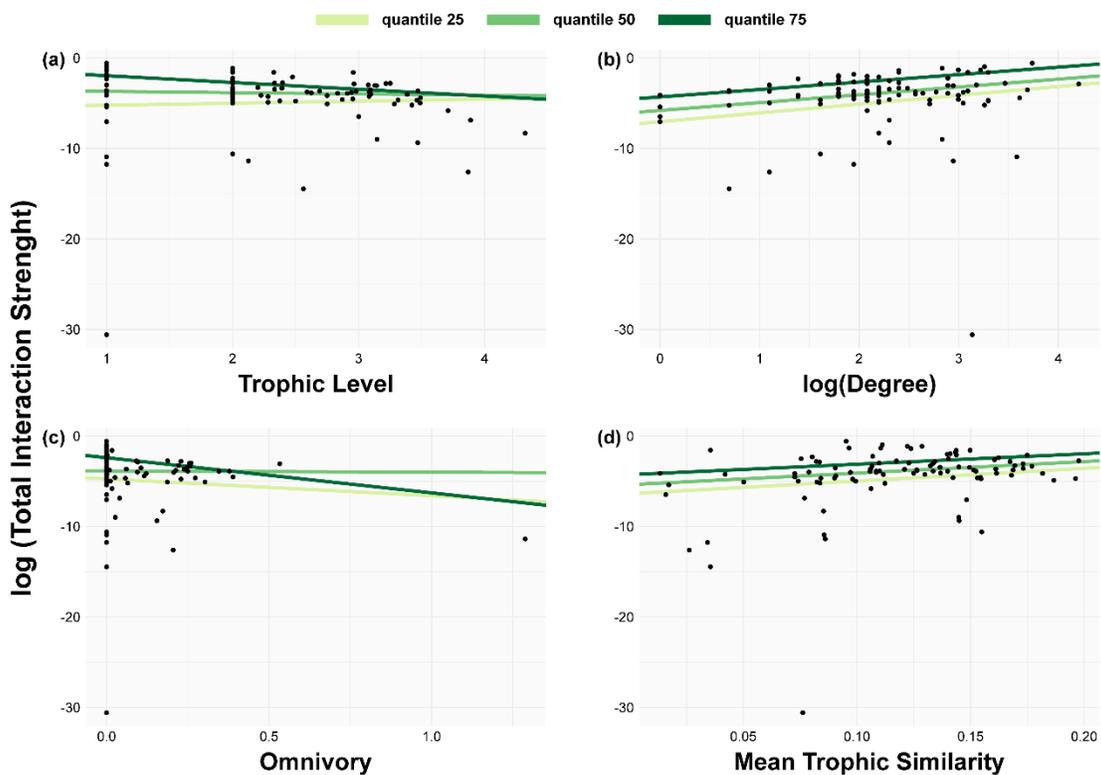
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512 **Figure 1.** Map of Potter Cove and its location at Isla 25 de Mayo/King George Island (South  
513 Shetland Islands, Antarctic Peninsula). The bicontinental map (a) was drawn using the  
514 ‘marmap’ R package (Pante et al., 2023). Contour shape file for Isla 25 de Mayo/King  
515 George Island (b) was obtained from [www.ign.gob.ar](http://www.ign.gob.ar), and Potter Cove’s (c) from (Neder  
516 et al., 2022).



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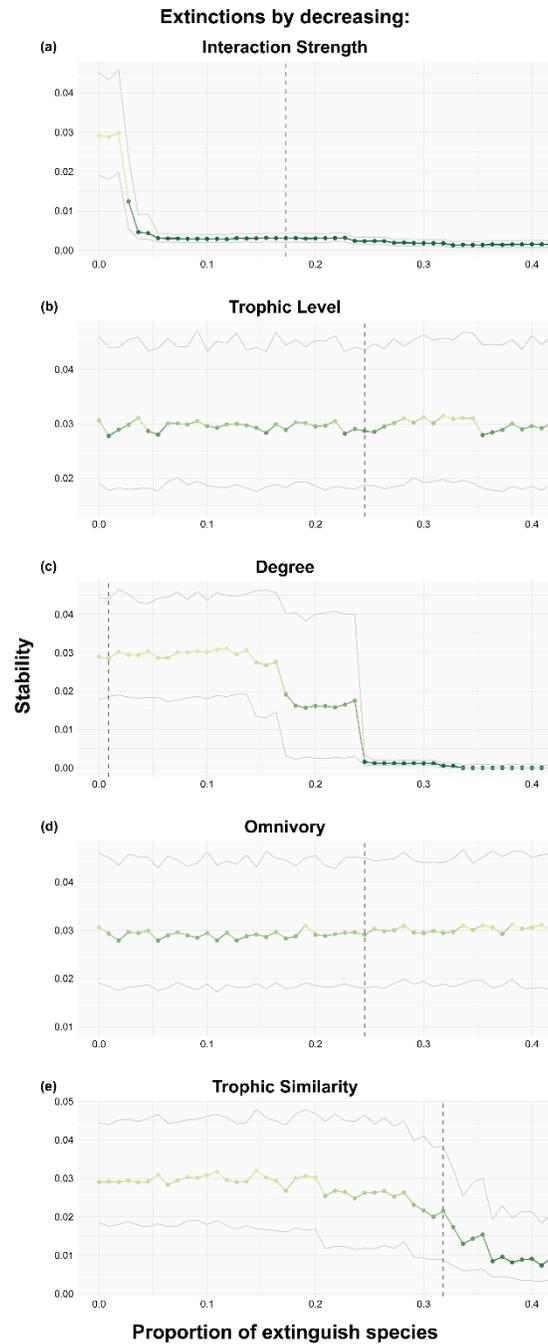
518 **Figure 2.** Frequency distribution of the median interaction strengths for the Potter Cove food  
 519 web. Total number of interactions = 649. The distribution was best fitted to a gamma model.



520

521 **Figure 3.** Relationships between weighted (total interaction strength) and unweighted food  
 522 web properties. We fitted quantile regressions (light green line = quantile 25, medium green

523 line = quantile 50, dark green line = quantile 75) to show the tendency between log total  
524 interaction strength and (a) trophic level, (b) degree, (c) omnivory, and (d) trophic similarity.



525

526 **Figure 4.** Effects on stability (median maximum eigenvalue) when removing species  
527 sequentially based on decreasing weighted and unweighted network properties: (a)

528 interaction strength, (b) trophic level, (c) degree, (d) omnivory, and (e) trophic similarity. Gray  
529 continuous lines represent interquartile stability values. Dark gray dotted vertical line  
530 represents the species whose extinction results in the fragmentation of the food web into  
531 more than one compartment.