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Harpacticoida (Copepoda) in the plankton of Ushuaia and Golondrina Bays, Beagle Channel, Argentina

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1 **HARPACTICOIDA (COPEPODA) IN THE PLANKTON OF USHUAIA AND**
2 **GOLONDRINA BAYS, BEAGLE CHANNEL, ARGENTINA**

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40 **Abstract:** Harpacticoid copepods form a diverse and abundant group of the meiofauna
41 in marine benthic habitats. Moreover, harpacticoids are frequently found in planktonic
42 samples particularly in shallow and algae-covered coastal waters. Despite their high
43 abundance, little is known about their taxonomy and importance as a component of the
44 food web in the Southern bays of Argentina. Mesozooplankton samples and
45 environmental data were obtained seasonally from Ushuaia and Golondrina Bays
46 (August 2004 to June 2005) and analyzed for the composition and abundance of
47 harpacticoid copepods. Remarkable seasonal changes in the harpacticoid communities
48 were observed. In Ushuaia Bay, **nitrogenated** nutrients, chlorophyll *a*, salinity, and
49 temperature were the prevailing environmental parameters **that influenced** the
50 **harpacticoid community, giving rise to** different harpacticoid assemblages. The results
51 highlight the importance of the community of Harpacticoida in both bays and provide
52 background data for further studies on zooplankton communities and monitoring
53 programs in marine systems.

54 **Key words:** Harpacticoida, Copepoda, Subantarctic bay, Ushuaia Bay, Golondrina Bay.

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68 1. Introduction

69
70 Harpacticoid copepods form the second most abundant and diverse group of marine
71 meiofauna after Nematoda (Hicks and Coull, 1983). They inhabit environments with
72 salinities ranging from 18 to 30 and withstand temperature regimes of all climatic zones
73 (i.e. polar to tropical) (Folkers and George, 2011). Both, soft and hard bottom substrates
74 as well as algae fronds offer a great number of micro-habitats to harpacticoid copepods
75 and other crustaceans such as amphipods and isopods (Adami and Gordillo, 1999;
76 Arroyo et al., 2006). Harpacticoida are commonly found in seagrass beds and associated
77 with macroalgal thalli (Decho et al., 1985; Hicks, 1985) occupying several phytic sub-
78 habitats: interstices of finely divided epiphytes, the surfaces of the fronds themselves
79 and the sediment accumulated at the bases of fronds (Moore, 1973; Pallares and Hall,
80 1974). Consequently, a strong relationship exists between the presence of harpacticoids
81 in the shallow water column and the macroalgal cover. Many harpacticoids are good
82 swimmers, especially the phytal taxa (e.g. Hicks and Coull, 1983; Hicks, 1985; Palmer,
83 1988). In addition, individuals are easily transferred into the water column by the
84 mechanical effect of waves, tides, wind or human activities (maritime traffic, net and
85 dredge sampling). In this way, harpacticoid copepods as well as other benthic organisms
86 (e.g. amphipods and isopods) often use the planktonic habitat and thus provide food and
87 nutrition to different planktonic and demersal invertebrate and vertebrate predators
88 (Ozcan et al., 2012; Sakthivel and Fernando, 2012; Trivedi et al., 2012).

89 Harpacticoids can be used as suitable indicators for environmental pollution (Coull and
90 Chandler, 1992) because of their high sensitivity towards pollutants such as heavy
91 metals and hydrocarbons and their low tolerance to anaerobic conditions (van Daname
92 et al., 1984; Kotwicki, 2002; Veit-Köhler et al., 2009). Several studies have shown that
93 harpacticoid copepod communities are suitable for ecological monitoring of polluted

94 areas in marine systems (Warwick, 1981; Folkers and George, 2011; Ansari et al.,
95 2013).

96 Only a few studies on the meiobenthic copepod communities from the Strait of
97 Magellan and the Beagle Channel have been published (Chen et al., 1999; George and
98 Schminke, 1999; George, 2005). Although sediment samples were examined in these
99 benthic studies, several families and genera of harpacticoids encountered by these
100 authors were also found in the analyzed mesozooplankton samples from Ushuaia and
101 Golondrina Bay (Biancalana et al., 2014). The observed high abundances of
102 harpacticoids as components of the plankton suggest their ecological importance in
103 these two bays. The aims of the present study were: i) to determine the harpacticoid
104 copepod diversity and community composition within the two bays, ii) to study their
105 seasonal variability in relation with environmental and biological variables, and iii) to
106 consider their potential to be used as indicators for environmental changes, which are
107 predicted to severely impact the polar regions.

108 2. Materials and Methods

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110 2.1 Study area

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112 Ushuaia Bay (UB) and Golondrina Bay (GB) are located on the northern coast of the
113 Beagle Channel (54°79'S-68°22'W and 54°85'S-68°36'W, respectively) in southern
114 Argentina (Fig. 1). Ushuaia Bay has a total area of 21.7 km² (Luchini and Wicki, 2002).
115 It is characterized by asymmetric depths, which vary from 6 to 30 m in some sectors
116 towards the West and 100 to 170 m towards the East near the North coast of the Beagle
117 Channel. The seafloor is characterized by sandy-muddy, consolidated sediments with
118 the presence of shells and stones (Biancalana et al., 2007). The residual current in open
119 waters of the Beagle Channel reaches speeds between 7.9 and 13.7 cm Sec⁻¹ flowing
120 from the west to the east (Balestrini et al., 1990). This bay, particularly the northern

121 zone of it, is subjected to various anthropogenic pressures such as untreated sewage,
122 industrial effluents from the Industrial Park, and hydrocarbons from the port of Ushuaia
123 (Amin et al., 2011; Commendatore et al., 2012; Gil et al., 2011; Torres et al., 2009; a
124 detailed map of exposed stations is found in Biancalana et al., 2014).

125 Golondrina Bay has a total area of 3.9 km², approximately one-fifth the size of Ushuaia
126 Bay. Its average depth is 6.3 m (Luchini and Wicki, 2002) with a maximum depth of 20
127 m in the area closest to the Beagle Channel. Its flat bottom is characterized by the
128 presence of mud or sand in which stones of different sizes, remains of bivalve shells,
129 snails and cirripeds were observed (Biancalana et al., 2007). Also, several isolated
130 sectors with large rocks were distinguished that give an irregular aspect to the bottom
131 (Biancalana et al., 2007). The speed of the permanent water current is 0.6 cm Sec⁻¹,
132 flowing from the south to the west (Fernandez-Severini and Hoffmeyer, 2005;
133 Biancalana et al., 2007). The two main sources of organic pollution in Golondrina Bay
134 are the Pipo River discharge, which is the major tributary characterized by a low
135 amount of land-use and heavy urbanization, and the maximum sewage collector of the
136 city that discharges at West Point of the Ushuaia Peninsula (Amin et al., 2011).

137 Both bays are characterized by the presence of dense macroalgae forests with a
138 predominance of the giant kelp *Macrocystis pyrifera*. In UB the macroalgae
139 predominate in the coastal zone where the conditions of depth, substrate, light intensity,
140 and nutrients are more propitious for their development (Adami and Gordillo, 1999).
141 Nevertheless, recent observations have registered an expansion of the macroalgae
142 population towards the deepest zones, its percentage of coverage fluctuating according
143 to the seasons of the year (e.g., higher growth rates of the population in spring-summer
144 and lower growth rates in autumn-winter). In GB, these kelp forests are distributed
145 almost everywhere (the first author surveyed the area by visual observation).

2.2 Sampling and laboratory work

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148 Four sampling campaigns were performed in Ushuaia and Golondrina Bays in late
149 winter (26 August 2004), late spring (09 December 2004), late summer (03–04 March
150 2005) and late autumn (15 June 2005). Seven stations were sampled in GB, 22 in UB.
151 However, only 15 stations were sampled in UB (1 to 16, except 15) in late winter due to
152 difficult sailing conditions (Fig. 1). Aboard a motor boat mesozooplankton samples
153 were collected using a 200- μm mesh net. At a speed of 2 knots during 5 minutes
154 sampling was carried out by means of oblique hauls from close to the bottom up to the
155 surface. The same effort of sampling was made in the presence of macroalgae kelp. A
156 General Oceanics® digital flowmeter was used to estimate the seawater volume filtered.
157 Samples were preserved in 4% formalin (Boltovskoy, 1981).
158 The harpacticoid community was qualitatively and quantitatively analyzed. Species
159 determination of Harpacticoida was performed at the German Centre for Marine
160 Biodiversity Research (DZMB, Senckenberg am Meer, Wilhelmshaven) using a Leica
161 MZ 9.5 stereomicroscope and a Leica DMLS 2M microscope equipped with a drawing
162 tube. The identification of harpacticoids was performed using Lang (1948), original
163 descriptions and redescriptions, and specific literature (Pallares 1968a, b). Total
164 individuals per sample were counted and harpacticoid abundance was expressed as
165 individuals per m^3 (ind. m^{-3}).
166 Surface water temperature and salinity were measured *in situ* at the time of each tow
167 using a multiparameter probe sensor (HORIBA® U-10). Salinity is defined as a unitless
168 conductivity ratio (practical salinity scale PSS-78: UNESCO, 1985). Additionally,
169 surface water samples were obtained using a Van Dorn bottle to determine inorganic
170 nutrients (nitrate and nitrite -N+N-, phosphate -SRP- and silicate), and chlorophyll *a*.
171 Chemical analyses were carried out by the Chemical Oceanography and Water Pollution

172 Laboratory at CENPAT-CONICET (Puerto Madryn, Chubut, Argentina) following
173 internationally validated methods (APHA, 1980).

174 2.3 Statistical analyses

175
176 Non-parametric statistical procedures were used because the results of the present study
177 did not meet the assumptions of normality and equality of variance. The Kruskal-Wallis
178 test was applied to detect differences in harpacticoid copepod mean abundances
179 between Ushuaia and Golondrina bays. The Mann-Whitney U-test with Bonferroni
180 correction was employed to detect statistical differences among abundances of
181 harpacticoids measured in different seasons. Spearman's rank correlation coefficients
182 were calculated to determine the relationship among environmental and biological
183 (Harpacticoida abundance) variables. Due to limitations caused by the small number of
184 samples obtained in Golondrina Bay ($n = 5-7$) the Spearman's rank correlation
185 coefficients analysis was not applied on data from this bay (Sokal and Rohlf, 1979).

186 Similarities among harpacticoid copepod assemblages were visualized by Cluster
187 analysis after transforming abundance values by means of $\log(X+1)$. Clusters were
188 built using Bray-Curtis similarities and the average linkage technique. Analysis of
189 similarities (ANOSIM) was applied to detect significant differences among assemblage
190 groups in each bay (Clarke and Warwick, 1994). All analyses were performed using the
191 PRIMER® 5 package and SPSS®.

192 2. Results

193 3.1. Environmental variables

194 The water temperature (Fig. 2) showed a seasonal trend with low values in late winter
195 (UB: $5.25^{\circ}\text{C} \pm 0.09$; GB: $5.28^{\circ}\text{C} \pm 0.14$) and late autumn (UB: $5.64^{\circ}\text{C} \pm 0.12$; GB:
196 $4.36^{\circ}\text{C} \pm 0.70$) and high values in late spring (UB: $10.73^{\circ}\text{C} \pm 0.34$; GB: $10.02^{\circ}\text{C} \pm$
197 $0.0,22$) and summer (UB: $9.73^{\circ}\text{C} \pm 0.04$; GB: $9.79^{\circ}\text{C} \pm 0.10$). Salinity values ranged

198 between 26.53 ± 0.91 (late spring) and 31.23 ± 0.05 (late winter) in UB, and between
199 29.34 ± 0.11 (late spring) and 31.34 ± 0.51 (late autumn) in GB (Fig. 2). Chlorophyll *a*
200 (Fig. 2) presented low values in late winter (UB: $0.71 \pm 0.14 \mu\text{g L}^{-1}$; GB: $0.31 \pm 0.08 \mu\text{g}$
201 L^{-1}) and late autumn (UB: $0.31 \pm 0.02 \mu\text{g L}^{-1}$; GB: $0.27 \pm 0.02 \mu\text{g L}^{-1}$) and high values
202 in late spring (UB: $3.39 \pm 0.25 \mu\text{g L}^{-1}$; GB: $2.73 \pm 0.25 \mu\text{g L}^{-1}$) and late summer (UB:
203 $11.13 \pm 0.89, \mu\text{g L}^{-1}$; GB: $2.43 \pm 0.27 \mu\text{g L}^{-1}$). Silicate values ranged between $5.07 \pm$
204 0.71 and $8.15 \pm 0.79 \mu\text{M}$ in late summer and late autumn, respectively in UB and
205 between 2.26 ± 0.44 and $9.53 \pm 1.29 \mu\text{M}$ in late spring and late autumn, respectively in
206 GB (Fig. 2). The N+N and phosphate concentration followed the same temporal trend
207 with low values during warm seasons and high values during cold seasons. In UB, N+N
208 varied between 0.66 ± 2.97 and $13.36 \pm 0.27 \mu\text{M}$ during late spring and late winter,
209 respectively, and phosphate ranged from 0.33 ± 0.02 to $1.40 \pm 0.05 \mu\text{M}$ in late spring
210 and late winter, respectively (Fig. 2). In GB, N+N varied between 1.66 ± 0.24 and 12.35
211 $\pm 4.67 \mu\text{M}$ during late spring and late autumn, respectively, and phosphate ranged from
212 0.41 ± 0.03 to $1.12 \pm 0.05 \mu\text{M}$ in late spring and late autumn, respectively (Fig. 2).

213 2.2. *Harpacticoid copepod composition and abundances*

214 The copepods identified for this study belonged to 15 families and 13 genera of the
215 copepod order Harpacticoida (Table 1). Only 18 taxa were found in both bays and the
216 total number of taxa in UB (n=26) was clearly higher than in GB (n=20).
217 Dactylopusiidae sp. 1, *Diarthrodes* spp., *Idyanthe* sp., *Mesochra* sp., *Paralaophonte*
218 *gracilipes*, and members of the families Ancorabolidae and Cletodidae were present in
219 UB but not in GB. Three new species belonging to the genera *Mesochra*, *Idyanthe*, and
220 *Scutellidium* were registered for the first time in these bays. The maximum number of
221 co-occurring taxa was 23 in UB (64%) and 16 in GB (42%) during late summer and late
222 spring, respectively (Fig. 3).

223 In UB, the mean total abundance was noticeably higher than in GB, with a great
224 variation among the seasons (Fig. 3). In UB, the mean abundance varied from $1.27 \pm$
225 0.94 to 85.15 ± 40.95 ind. m^{-3} (late winter and late summer, respectively) while in GB,
226 the mean abundance varied from 0.4 ± 0.21 to 9.57 ± 1.48 ind. m^{-3} (late winter and late
227 spring, respectively) (Fig. 3). Spatially, in both bays maximum values of mean
228 abundances were found at coastal stations in all seasons. The maximum abundance of
229 harpacticoids encountered in UB was 654.86 ind. m^{-3} at station 15 (late summer). In GB
230 the highest value was 30.75 ind. m^{-3} at station 1 in late autumn (Fig. 4).

231 Significant seasonal differences in harpacticoid abundances were only detected in UB
232 (K-W test=21.67; $p < 0.01$) but not in GB (K-W test=7.08; $p = 0.069$). Highly significant
233 differences were detected between late winter and late summer (M-W test, $U = 68$;
234 $p = 0.003$), and late spring and late summer (M-W test, $U = 76$; $p = 0.00007$). Significant
235 differences were found between late autumn and late spring (M-W test, $U = 125.50$;
236 $p = 0.005$).

237 2.3. Assemblages of harpacticoid copepods

238 In UB, Cluster analysis found four groups of taxa of Harpacticoida with similar co-
239 occurrence throughout the year (GI, GII, GIII and GIV; 43% similarity) (Fig. 5). Highly
240 significant differences among these groups were detected by ANOSIM (Global $R = 0.85$,
241 $p = 0.001$) (Fig. 5). Group I was represented by three taxa, *Diarthrodes* spp. and the
242 families Cletodidae and Ancorabolidae, which only appeared in late autumn. Group II
243 was formed by two taxa, *Paralaophonte gracilipes* and *Mesochra* sp., which appeared
244 in late spring and late summer. Group III was represented by taxa with high abundances
245 in late spring and late summer but no presence or low abundances during late winter and
246 late autumn. *Tisbe varians* was the most abundant harpacticoid copepod (3.25 ind. m^{-3})
247 in late spring (Fig. 5). *Harpacticus pacificus*, other members of the family

248 Harpacticidae and *T. varians* were present in high numbers in late summer (26.47,
249 19.12, 12.26 ind. m⁻³, respectively, Fig. 5). Group IV was represented by taxa which had
250 low abundances in late spring and late summer and were not present or only rarely
251 found during late winter and late autumn. *Tisbe* sp. (*gracilipes*-group) and *Scutellidium*
252 spp. appeared in all four seasons and contributed in abundance to late spring and late
253 summer communities in this group (Fig. 5).

254 In GB, groups were determined with a similarity of 42.9% (Fig. 6). Group I was
255 represented by the families Dactylopusiidae and Ameiridae, which only appeared in late
256 autumn. Group II was represented by taxa which were highly abundant in late spring
257 and late summer and were not present or had only low abundances during late winter
258 and late autumn. *Tisbe varians* was the most abundant copepod in late spring, late
259 summer and late autumn (3.25, 1.86 and 4.77 ind. m⁻³, respectively), followed by
260 members of the family Tisbidae (Fig. 6). Group III was formed by two taxa, the families
261 Tegastidae and Laophontidae, which appeared only in late autumn. Group IV was
262 represented by taxa which were present in low abundances in late spring and were not
263 present or had only low abundances in late winter, summer and late autumn, namely
264 *Parathalestris* spp., *Xanthous intermedia*, *Dactylopoidea paratisboides*, *Diarthrodes*
265 *lillacium*, *Tisbe* sp. (*gracilipes*-group), and the families Miraciidae and Thalestridae
266 (Fig. 6). Significant differences in the community structure of Harpacticoida were
267 detected between groups III and IV, and III and II (ANOSIM global R=0.61, p=0.001).

268 2.4. Correlation analysis

269 Harpacticoid abundance showed a high negative significant association with N+N in
270 late spring, and a high positive significant association with Chlorophyll *a* in late
271 summer (Spearman's rank correlation, Table 2). Positive significant associations were

272 found **between harpacticoid abundance and temperature** in late summer, N+N in late
273 **autumn, and chlorophyll *a* and phosphate in late winter** (Table 2).

274 **4. Discussion**

275 *4.1 Seasonal changes in environmental variables*

276 **Observations on seasonal changes** in temperature in both bays are in agreement with
277 previous studies (Amin et al., 2011; Fernández-Severini and Hoffmeyer, 2005; Gil et
278 al., 2011). According to previous research, the decreasing trend in salinity **during the**
279 **warm season is due to increased freshwater input** to the bay **sourced from ice- and**
280 **snowmelt** (Amin et al., 2011; Gil et al., 2011; Torres et al., 2009).

281 Input of inorganic nutrients, especially nitrate, phosphate, and silicate produced during
282 thawing periods and rainy seasons, can be extremely high in UB and GB (Amin et al.,
283 2011; Gil et al., 2011). Natural tributaries such as Olivia River and Grande Stream
284 located in the northeast area of the UB, as well as Pipo River in GB discharge large
285 amounts of nutrients **into the bays. Particularly silicates and phosphates are** derived
286 from storm water and thaw outfall coupled with **urban runoff and waste** (Amin et al.,
287 2011). **Our results showed that** nutrients **had** the highest values in late winter and late
288 autumn and the lowest values in late spring and late summer. **High** concentrations are
289 the result of freshwater input to the coastal system after running across **dense woods** and
290 large peatlands, along with inputs **from Ushuaia City**, and a low biological activity **in**
291 **the cold seasons.**

292 **A decrease of chlorophyll *a*** was observed during the cold season **when the temperature**
293 **decreased**, while an increase of this pigment was found during the warm season. This
294 seasonal pattern of chlorophyll *a* **in the bay has already been** observed by Amin et al.
295 (2011), Aguirre et al. (2011), and Gil et al. (2011). **The enhanced chlorophyll *a* values**
296 **during the warm season are due to an increased phytoplankton growth which is favored**

297 by optimum temperature and light conditions. At the same time high amounts of
298 nutrients are consumed.

299 4.2 Harpacticoida community and their relationship with environmental variables

300 Studies of Antarctic meiofauna and in particular of Harpacticoida have been intensified
301 (e.g. Dahms *et al.*, 1990; Veit-Köhler, 2005) and new species of phytal harpacticoids
302 with planktonic phases described (e.g. Veit-Köhler and Fuentes, 2007). But only a few
303 studies deal with the composition of harpacticoid communities in the Strait of Magellan
304 and the Beagle Channel (George and Schminke, 1999; George, 2005). Although these
305 studies addressed benthic communities, members of several harpacticoid families were
306 found in the mesozooplankton samples of the present study, composing the plankton of
307 Ushuaia and Golondrina Bays (Biancalana *et al.*, 2007; Biancalana *et al.*, 2014). The
308 families Ameiridae, Ancorabolidae, Canthocamptidae, Cletodidae, Harpacticidae,
309 Laophontidae, Thalestridae, and Tisbidae which were found in this study, were also
310 observed in samples of benthic meiofauna in the Strait of Magellan and the Chilean
311 sector of the Beagle Channel (George and Schminke, 1999). In UB and GB these
312 groups were closely associated with dense kelp beds dominated by *Macrocystis*
313 *pyrifera*. These kelps were particularly located in the shallowest areas of both bays
314 down to approximately 15 m depth. The latter is in agreement with the findings by
315 Pallares (1968b) for Deseado Port (Santa Cruz, Argentina) and Fernández-Severini and
316 Hoffmeyer (2005) for the same bays during January 2001. Interestingly, this shallow
317 zone is most affected by organic and nutrient loadings (Amin *et al.*, 2011b; Gil *et al.*,
318 2010; Torres *et al.*, 2009).

319 During warm seasons harpacticoids contribute in UB with $\approx 20\%$ and in GB with $\approx 30\%$
320 to the total mesozooplankton abundance (see complementary data). In our study the
321 remarkable differences in harpacticoid mean abundances and taxa number, may be

322 explained by differences in physical and hydrological features, the action of winds,
323 different depths and water circulation (Balestrini et al., 1990), the anthropogenic
324 influence in the coastal area (Torres et al., 2009; Amin et al., 2011b; Duarte et al., 2011;
325 Gil et al., 2011) as well as the distribution of the *Macrocystis* forests (Adami and
326 Gordillo, 1999). Several studies report highest abundances of Harpacticoida from the
327 eastern Beagle Channel and lowest in the northern Magellan Straits, suggesting that the
328 differences in distribution and diversity patterns were dependant on small-scale and
329 local conditions (George and Schminke, 1999; George, 2005). Furthermore, high
330 densities of Copepoda Harpacticoida were found in Southern Magellan meiofauna
331 communities (Chen et al, 1999). These authors considered that hydrodynamic features
332 (tidal currents with strong winds), geographical characteristics, together with sediment
333 composition were the key parameters structuring the meiofauna communities in the
334 Straits of Magellan and in the Beagle Channel (Chen et al, 1999).

335 The favorable environmental conditions during later spring and later summer, especially
336 the availability of light and nutrients accumulated during cold seasons, promoted the
337 development of macroalgae forests. Mainly composed of *M. pyrifera*, they provide
338 many convenient microhabitats for harpacticoid copepods. As mentioned before,
339 inorganic nutrients showed the highest concentrations during cold seasons and the
340 lowest values during warm seasons. Nutrient concentrations are reduced in spring and
341 summer due to (micro) algal growth which is favored by optimum temperature and light
342 conditions. Microalgae form great part of the diet of copepods. Conclusively,
343 harpacticoids not only found favorable microhabitats but also abounding food during
344 warm seasons.

345 Since harpacticoids were negatively correlated with nitrate + nitrite concentrations
346 during late spring and positively correlated with chlorophyll *a* during late summer the

347 plankton may be directly associated with the forests of *Macrocystis*. Contributions of
348 freshwater (= sewage water) cause a decrease of salinity and an increase of nitrate +
349 nitrite, which are consumed during the development of macroalgae and phytoplankton.
350 These conditions were met in the coastal zones of both bays.
351 Torres et al. (2009) mention an important development of macroalgae in the coastal area
352 of Ushuaia Bay, very close to Encerrada Bay, which coincides with the high individual
353 numbers of plankton at station 2 (167.94 ind. m⁻³ in late spring). The maximum nutrient
354 concentrations, particularly ammonium and phosphate, were mostly observed at stations
355 located on the northwest coast of the UB. Especially stations 1 and 2 were affected by
356 untreated urban discharge from Encerrada Bay (not currently existing; Biancalana et al.,
357 2014). In this sense, harpacticoid copepods were successfully used as indicators of
358 polluted estuarine and coastal zones (Coull and Chandler, 1992; van Damme et al.,
359 1984).
360 During the warm seasons the dominant harpacticoids were *Tisbe varians*, *Harpacticus*
361 *pacificus*, and other members of the family Harpacticidae. While most of the
362 harpacticoids lead benthic, sediment-bound life styles, some taxa are good swimmers.
363 However, they usually stay close to a substrate being it phytal (algae) or aphytal, such
364 as substrates covered with organic detritus or inorganic elements (Pallares and Hall,
365 1974). So, these three taxa present phytophilous habits. They are mainly associated
366 with algae substrates where they find the best conditions for their development (Lang,
367 1948; Pallares, 1975).
368 The number of Harpacticoida in the plankton communities of the two investigated bays
369 decreased significantly in the colder seasons because they present unfavorable
370 conditions for the growth and development of macroalgae, especially *M. pyrifera*
371 (Kühnemann, 1970). Additionally, low temperatures and the decrease in the hours of

372 daylight reduce primary production, which **intensifies**, by trophic effect, the decrease of
373 the Harpacticoida.

374 **5. Conclusions**

375 This study is the first conducted on Copepoda Harpacticoida in the Ushuaia and
376 Golondrina Bays. It shows the great diversity and occurrence of harpacticoid copepods
377 in mesozooplankton samples obtained from both bays. Also, this study highlights the
378 seasonal dynamics in the abundance and frequency of the harpacticoid communities. As
379 an important contribution, we highlight the significant role of this group of copepods for
380 their function within the planktonic trophic web and as pollution indicators, even more
381 in those coastal areas where macroalgae forests predominate.

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526 **Figures**

527 Figure 1. Map of the study area showing the sampling stations in Ushuaia and
528 Golondrina Bays.

529 Figure 2. Environmental variables: temperature [°C], salinity, Chlorophyll *a* [$\mu\text{g L}^{-1}$]
530 Silicate [μM], Nitrite+Nitrate [μM] and Phosphate [μM] in Ushuaia and Golondrina
531 Bays in each season (2004–2005).

532 Figure 3. Taxa number (TN, %) and total mean abundance of Harpacticoida (TMA, ind.
533 m^{-3}) in each season (2004–2005) in Ushuaia and Golondrina Bays.

534 Figure 4. Harpacticoida abundance distribution in Ushuaia and Golondrina Bays in late
535 winter, late spring, late summer and late autumn (2004–2005).

536 Figure 5. Graphic showing the clustering of the harpacticoid taxa and the assemblages
537 of Harpacticoida (GI, GII, GIII and GIV) depending on the mean abundance, relative
538 abundance (RA%) and frequency of occurrence (FO%) of each taxon in Ushuaia Bay in
539 late winter, late spring, late summer and late autumn (2004–2005).

540 Figure 6. Graphic showing the clustering of the harpacticoid taxa and the assemblages
541 of Harpacticoida (GI, GII, GIII and GIV) depending on the mean abundance, relative
542 abundance (RA%) and frequency of occurrence (FO%) of each taxon in Golondrina Bay
543 in late winter, late spring, late summer and late autumn (2004–2005).

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558 Table 1. Total taxa list of Copepoda Harpacticoida found in mesozooplankton samples
 559 from Ushuaia and Golindrina Bays in 2004 and 2005.

560

PHYLUM ARTHROPODA
 SUBPHYLUM CRUSTACEA
 CLASS MAXILLOPODA
 SUBCLASS COPEPODA
 ORDER HARPACTICOIDA
 FAMILY AMEIRIDAE
 FAMILY ANCORABOLIDAE
 FAMILY CANTHOCAMPTIDAE
 GENUS *Mesochra* (Boeck, 1865), *Mesochra* sp
 FAMILY CLETODIDAE
 FAMILY DACTYLOPUSIIDAE
 GENUS *Dactylopusia*, *Dactylopusia paratisboides* (Lang, 1965)
 GENUS *Diarthrodes*, *Diarthrodes lilacinus* (Pallares, 1977)
 GENUS *Paradactylopodia*, *Paradactylopodia brevicornis* (Claus, 1866).
 FAMILY HARPACTICIDAE
 GENUS *Harpacticus*, *Harpacticus pacificus* (Lang, 1965)
 FAMILY IDYANTHIDAE
 GENUS *Idyanthe* (Sars, 1909), *Idyanthe* sp.
 FAMILY LAOPHONTIDAE
 GENUS *Paralaophonte*, *Paralaophonte gracilipes* (Brady, 1910)
 FAMILY MIRACIIDAE
 FAMILY PELTIDIIDAE
 GENUS *Eupelte*, *Eupelte simile* (Monk, 1941)
 FAMILY PORCELLIDIIDAE
 GENUS *Porcellidium*, *Porcellidium rubrum* (Pallares, 1966)
 FAMILY PSEUDOTACHIDIIDAE
 GENUS *Xauthous*, *Xauthous intermedia* (= *Idomene intermedia* Lang, 1934)
 FAMILY TEGASTIDAE
 FAMILY THALESTRIDAE
 GENUS *Parathalestris* (Brady & Robertson, 1873), *Parathalestris* spp.
 FAMILY TISBIDAE
 GENUS *Scutellidium* (Claus, 1866), *Scutellidium* sp.,
 Scutellidium spp.
 GENUS *Tisbe*, *Tisbe varians* (T. Scott, 1914)
 Tisbe sp. (*gracilipes*-group)

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564 Table 2. Spearman's rank correlations among environmental variables and harpacticoid
 565 copepods in Ushuaia Bay in late winter, late spring, late summer and late autumn
 566 (2004–2005).

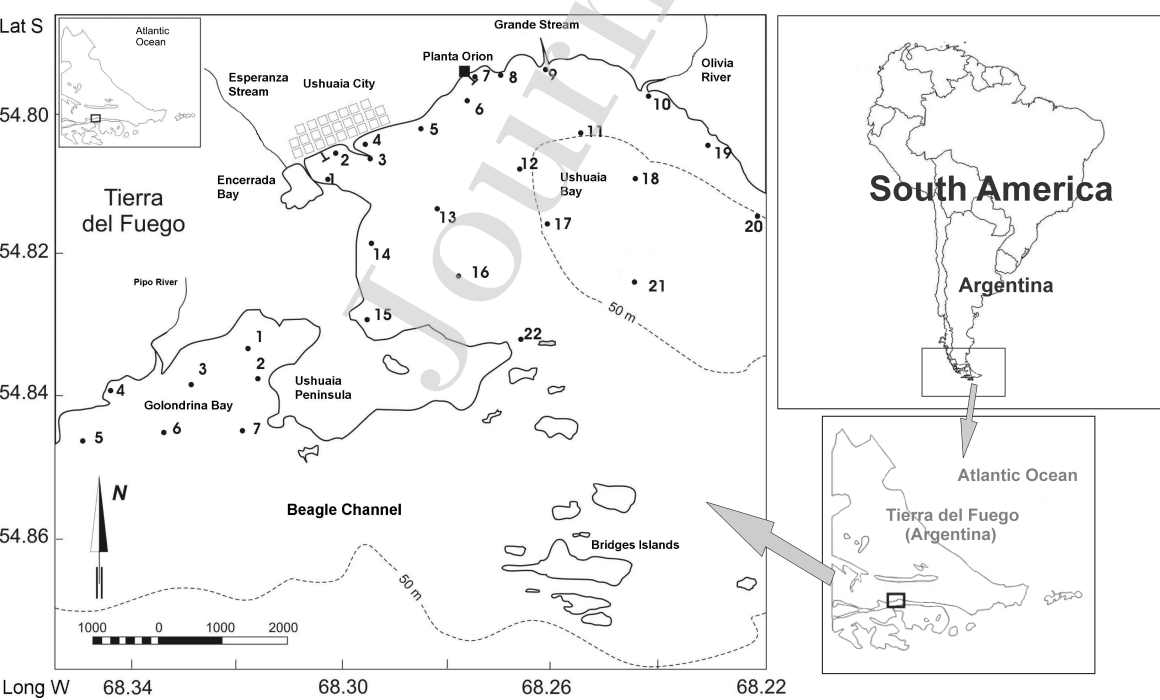
Spearman Correlations		
Late winter		
Variables		Rho de Spearman
TMA	Chlorophyll a	0.58*
	Phosphate	0.64*
Temperature	Phosphate	0.66**
Salinity	Phosphate	0.53*
Later Spring		
TMA	N+N	0.71**
Temperature	Chlorophyll a	0.43*
	Phosphate	0.50*
Salinity	Chlorophyll a	0.47*
	Silicate	0.68**
Silicate	Chlorophyll a	0.47*
Late Summer		
TMA	Temperature	0.43*
	Chlorophyll a	0.56*
Temperature	Chlorophyll a	0.52*
	Salinity	0.50*
	N+N	0.63**
Salinity	N+N	0.51*
	Silicate	0.45*
N+N	Phosphate	0.61**
	Chlorophyll a	0.47*
Chlorophyll a	Silicate	0.42*
Late Autumn		
TMA	N+N	0.48*
Temperature	Salinity	0.60**
	Phosphate	0.48*

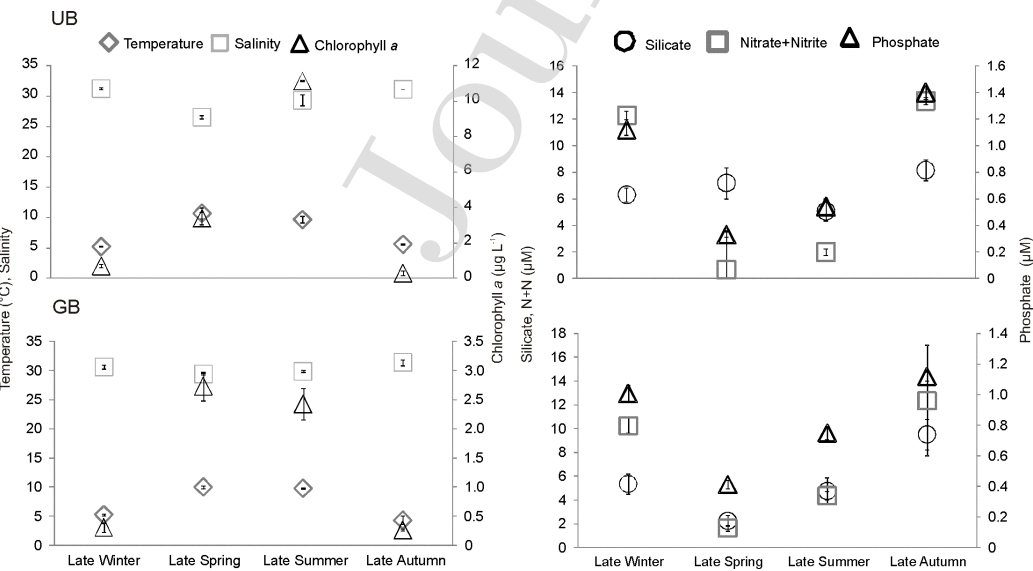
*p<0.05 significant difference, ** p<0.01 high significant difference. Late Winter n=15, Late Spring, Late Summer and Late Autumn n=22

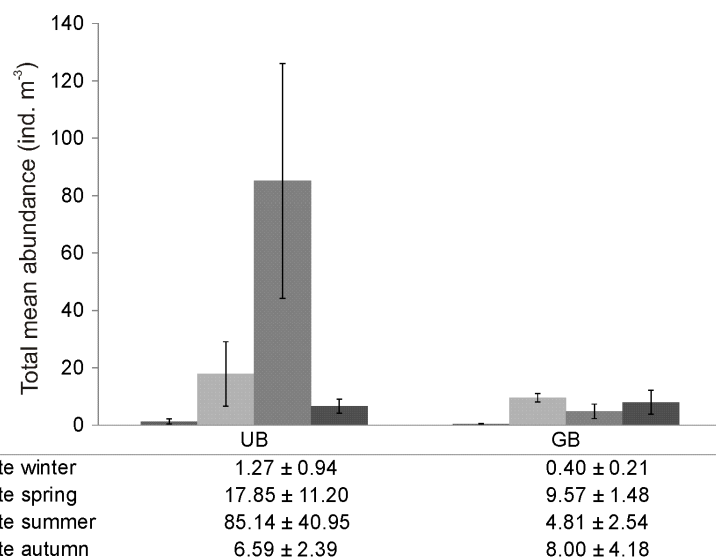
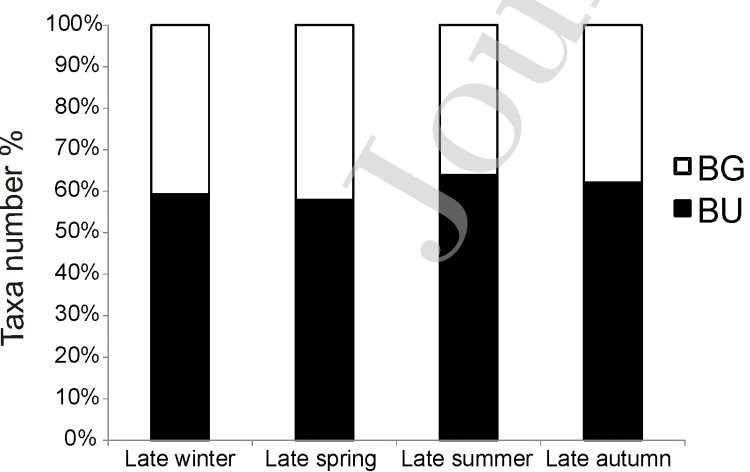
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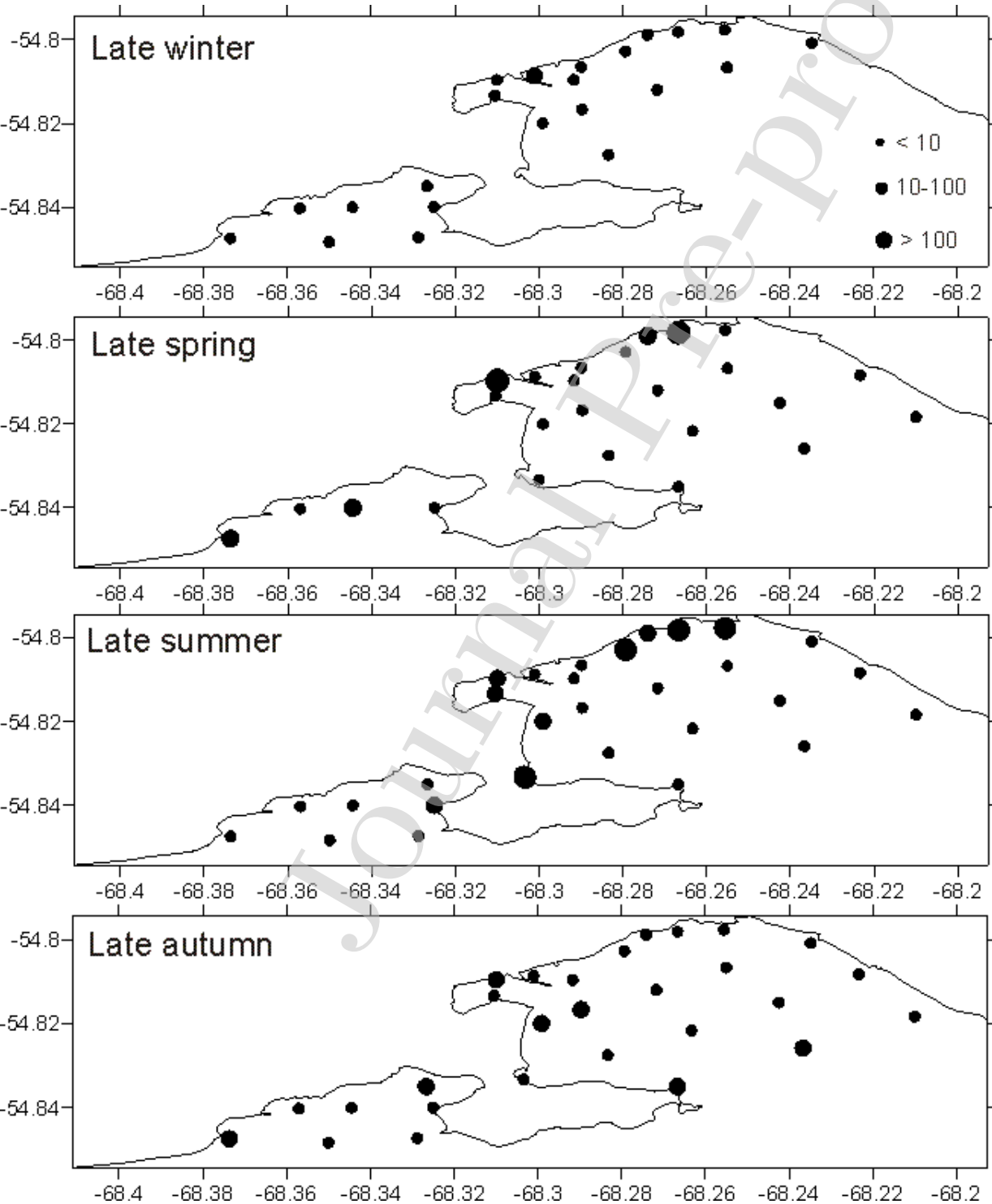
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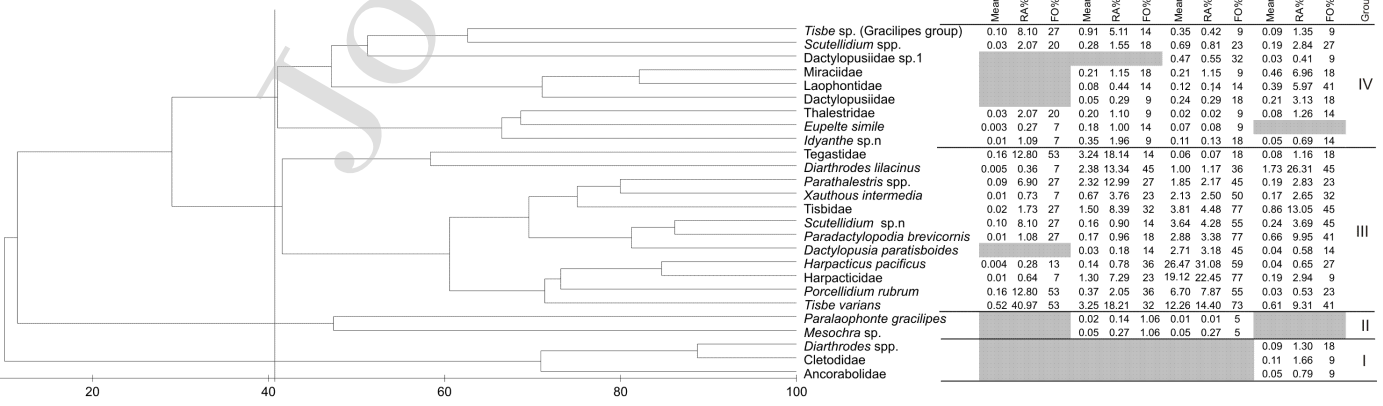








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	Late winter			Late spring			Late summer			Late autumn			Groups
	Mean Abundance (ind. m ³)	RA%	FO%	Mean Abundance (ind. m ³)	RA%	FO%	Mean Abundance (ind. m ³)	RA%	FO%	Mean Abundance (ind. m ³)	RA%	FO%	
<i>Tisbe</i> sp. (Gracilipes group)	0.10	8.10	27	0.91	5.11	14	0.35	0.42	9	0.09	1.35	9	IV
<i>Scutellidium</i> spp.	0.03	2.07	20	0.28	1.55	18	0.69	0.81	23	0.19	2.84	27	
Dactylopsiidae sp.1							0.47	0.55	32	0.03	0.41	9	
Miracidae				0.21	1.15	18	0.21	1.15	9	0.46	6.96	18	
Laophontidae				0.08	0.44	14	0.12	0.14	14	0.39	5.97	41	
Dactylopsiidae				0.05	0.29	9	0.24	0.29	18	0.21	3.13	18	
Thalestridae	0.03	2.07	20	0.20	1.10	9	0.02	0.02	9	0.08	1.26	14	
<i>Eupelte simile</i>	0.003	0.27	7	0.18	1.00	14	0.07	0.08	9				
<i>Idyanthe</i> sp.n	0.01	1.09	7	0.35	1.95	9	0.11	0.13	18	0.05	0.69	14	
Tegastidae	0.16	12.80	53	3.24	18.14	14	0.06	0.07	18	0.08	1.16	18	
<i>Diarthrodes lilacinus</i>	0.005	0.36	7	2.38	13.34	45	1.00	1.17	36	1.73	26.31	45	
<i>Parathalestris</i> spp.	0.09	6.90	27	2.32	12.99	27	1.85	2.17	45	0.19	2.83	23	
<i>Xauthous intermedia</i>	0.01	0.73	7	0.67	3.76	23	2.13	2.50	50	0.17	2.65	32	
Tisbidae	0.02	1.73	27	1.50	8.39	32	3.81	4.48	77	0.86	13.05	45	
<i>Scutellidium</i> sp.n	0.10	8.10	27	0.19	0.90	14	3.64	4.28	55	0.24	3.69	45	
<i>Paradactylopodia brevicornis</i>	0.01	1.08	27	0.17	0.95	18	2.68	3.36	77	0.68	9.95	41	
<i>Dactylopusia paratisboides</i>				0.03	0.18	14	2.71	3.18	45	0.04	0.58	14	
<i>Harpacticus pacificus</i>	0.004	0.28	13	0.14	0.78	36	26.47	31.08	59	0.04	0.65	27	
Harpacticidae	0.01	0.64	7	1.30	7.29	23	19.12	22.45	77	0.19	2.94	9	
<i>Porcellidium rubrum</i>	0.16	12.80	53	0.37	2.05	36	6.70	7.87	55	0.03	0.53	23	
<i>Tisbe varians</i>	0.52	40.97	53	3.25	18.21	32	12.26	14.40	73	0.61	9.31	41	
<i>Paralaophonte gracilipes</i>				0.02	0.14	1.06	0.01	0.01	5				
<i>Mesochira</i> sp.				0.05	0.27	1.06	0.05	0.27	5				
<i>Diarthrodes</i> spp.										0.09	1.30	18	
Cletodidae										0.11	1.66	9	
Ancorabolidae										0.05	0.79	9	

