

1 **Effects of productive management of an agroforestry system on the associated diversity**
2 **of parasitoids (Hymenoptera: Braconidae)**

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9 **Summary**

10 Tropical agroecosystems have emerged from the continuous modification of natural
11 environments, as a sustainability alternative for food production and biodiversity
12 conservation. This work explores how the diversity of parasitoids is modified in
13 environments where plant diversity is limited e.g. crops and when these are adjacent to
14 secondary vegetation, i.e. a scenario fragmented continuously in a limited space. It was found
15 that there is no direct effect of plant diversity in the group of parasitoids studied; but the
16 number of specialist species is high, which indicates that in diversified agroecosystems these
17 probably function as remnants of natural habitat or as a refuge for parasitoids that disperse
18 to different types of management within the agroecosystem. Therefore, it is necessary to
19 consider in future studies the controls exerted by the plant diversity effects bottom-up and
20 consumer top-down. Adding to this the context of the interactions that occur in
21 agroecosystems.

22 **Key words:** agroecosystems, biodiversity, Braconidae, conservation, specialists

23 **Introduction**

24 Agroecosystems arise in the tropics derived from the loss of vegetation cover, the conversion
25 and fragmentation of natural areas in ecosystems. These activities modify the species that
26 inhabit and depend on vegetation, with effects that depend on the range of the species and its
27 habitat requirements (Scolozzi & Geneletti, 2012; Campos-Navarrete et al 2015a). On the
28 other hand, the speed in the loss of species has increased the interest in the study of
29 biological diversity in agroecosystems, mainly insects, because they constitute the most
30 important fraction of the diversity of a territory since they provide multiple ecological
31 services to ecosystems (Klein et al 2002).

32 Parasitoids are known for their high number of species and their habits that result in the
33 provision of regulatory services for the populations of their hosts (Lepidoptera, Coleoptera
34 and Diptera) (Shaw & Huddleston, 1991; Abdala-Roberts et al 2016a). In agroecosystems,
35 the study of these organisms is interesting from the anthropogenic point of view (integrated
36 pest control) and even little known in terms of the mechanisms that regulate it (Nicholls,
37 2008; Schmidt et al 2003; Thies et al 2005). Also in agroecosystems, plant species diversity
38 has effects on secondary productivity comparable to natural systems. In this sense, it has been
39 observed that environments with greater diversity of plant species promote increases in
40 richness and abundance in trophic levels (Abdala-Roberts et al 2016 b; Castillo-Sánchez et
41 al 2019).

42 The effect of land use, in conjunction with the associated plant diversity at higher trophic
43 levels, has been explained primarily because greater diversity, by generating a more complex
44 environment, consequently offers a greater number of shelters and prey (Russell, 1989;
45 Obermaier, et al 2008; Moreira et al 2016), which in turn generates increases in predation

46 rates, causing a reduction in the abundance of parasitoid prey ("up-down" effects). Evidently,
47 this type of effects are highly relevant to be considered in the design of productive systems
48 such as forestcrops, due to their potential in pest control (Russell, 1989; Abdala-Roberts et
49 al 2015; 2016a). This last factor can reduce or increase the abundance of prey (herbivores)
50 depending on characteristics such as the specialization of their diet (generalists vs.
51 specialists) and their interactions (Campos-Navarrete et al 2015b). For example, there is
52 evidence that for specialists the effects of an increase in diversity can be negative, due to the
53 low density of their priority resource (Hambäck et al 2014).

54 In contrast, for generalists the effects of increased diversity can vary and, in some cases, can
55 be positive due to their mixed diet and increased availability of places of refuge (Unsicker et
56 al 2008; Castagneyrol et al 2013). In this sense, the presence of herbivores can mediate their
57 interaction with the next trophic level of consumers where parasitoids are included (Abdala-
58 Roberts et al 2016b).

59 The present work explores the effect of four productive areas in an agroecosystem of multiple
60 production in relation to the diversity of parasitoids (Braconidae) associated. Particularly
61 changes in richness, abundance, similarity in areas and in parasitism strategies represented
62 by the proportion of koinobiont (specialist) and idiobiont (generalist) species. Trying to infer
63 how the diversity of parasitoids is modified in environments where plant diversity is limited
64 e.g. crops and when these are adjacent to secondary vegetation, i.e. a scenario with
65 continuously fragmented in a limited space.

66 **Materials and Methods**

67 **Study area.** The present work was carried out in the east of Yucatán in the municipality of
68 Tizimin, Yucatán, Mexico. This area is characterized by the conversion of land use from
69 native jungle to grasslands for the production of pasture for cattle feed. Livestock represents
70 30% of the economic activity of this area (INEGI 2015). The agroecosystem of study is
71 located in the area of agricultural and livestock production of the TecNM Campus Tizimin,
72 located at the end of the airport Cupul s/n C.P. 97700 with the coordinates 21°09'29" N
73 88°10'21"W.

74 The agroecosystem has three areas of crops: a plantation of *Cocos nucifera* "PC"
75 (monoculture), a plantation of *Citrus lemon* "PL" (monoculture), in the livestock production
76 area is located the grassland area with star grass *Cynodon sp.* named grassland "PT" and the
77 fourth type is the matrix of secondary vegetation with more than 30 years of recovery "VS".
78 This contrast in a limited space provides a frequent scenario today, originated by the
79 processes of fragmentation, originating contrasting sites.

80 **Fieldwork.** For the capture of insects were used malaise traps, which capture large numbers
81 of organisms, widely recommended and used to capture parasitic Hymenoptera (Noyes,
82 1982) (Nieves-Aldrey & Castillo., 1991). The orientation of the trap was from north to south,
83 because it is more effective if the openings are placed in the position where the wind comes
84 from. For the placement of the trap it was considered that it was far from the edges of each
85 area, in order to reduce the edge effect and between traps there was a distance of 500 m, to
86 ensure the independence of the samples. The traps remained active every day during the
87 period from October 2015 to March 2016, were checked every fortnight and the specimens
88 placed in jars with 70% alcohol.

89 **Identification of the** specimens: The samples were identified in the Laboratory of
90 Parasitology of the TecNM Campus Tizimín, before the identification the braconids were
91 separated from the rest of the insects, later they were counted and labeled with the
92 corresponding data, for their identification the specimens were assembled according to the
93 technique traditionally used for these organisms. Identification was carried out using the
94 taxonomic key for Braconidae (Wharton et al 1998).

95 The assembly was carried out using entomological pins correctly placing each insect, which
96 were also labeled for a systematic control of these. The reason for mounting is that in this
97 way it is easier to observe insects when they are dry, since when they are wet it is difficult to
98 observe certain characteristics.

99 The material was determined up to the taxonomic level of genus subsequently the concept of
100 morphospecie was used in which (Simpson, 1961; Mayr & Ashlock., 1991; Delfín & Burgos
101 2000) mention that due to the existing difficulty in determining parasitoids at a specific level
102 it is advisable to use this concept to identify and separate individuals who present different
103 morphological characteristics. In addition, morphospecies were classified according to their
104 parasitism strategies as koinobiont species (specialists) and idiobionts (generalists), with the
105 help of specialized literature (Goulet & Huber, 1993). All the collected material is sheltered
106 in the TecNM Campus Tizimín.

107 **Data analysis.** We performed a classical diversity analysis in the braconid community in all
108 four areas using the Shannon-Wiener diversity index. This index expresses the uniformity of
109 the values of importance across all species in the sample; assumes that all individuals are

110 randomly selected, and that all species are represented in the sample (Ludwing and Reynolds,
111 1988; Magurran, 1988).

112 The similarity between the braconid communities was estimated using the Sorensen index
113 (Krebs, 1989) which is based on the presence/absence of species and the number of species
114 whether common or rare (Spellerberg, 1991). It relates the number of species in common to
115 the arithmetic mean of the species at the sites (Magurran, 1988).

116 To estimate the representativeness of the species richness of the samples in each type of
117 vegetation, the EstimateS version 9 program was used, which presents specialized estimators
118 for different types and sizes of data. We used ice wealth estimators based on the number of
119 rare species (those observed in less than 10 sampling units) and jackknife first order which is
120 based on the number of unique species (Colwell and Coddington, 1994).

121 With the data of the morphospecies recorded by area, using relative abundance, as the
122 response variable, the change between the four areas was evaluated. This is through a model
123 that explores the quantitative response of braconids to areas. This model used as the main
124 factor the area with four levels (PC, PL, PT, VS). The second model explored the parasitism
125 strategies of braconist species, using as the main factor parasitism strategy with two levels
126 (Idiobionts "I" and Koinobiontes, "K"), in relation to abundance. The third model explored
127 the interaction between the two main factors mentioned above in the relative abundance of
128 braconids. We fitted all models using the Penalized Quasi-Likelihood method (Crawley
129 2007). We conducted GLMM analyses using the R statistical package v. 3.01. (R Core Team
130 2020). We used a posteriori contrasts to test for differences among pairs of means for a given
131 factor within each level of the other factor (Crawley 2007).

132 **results**

133 **Collected specimens.** A total of 2031 specimens of braconids belonging to 20 subfamilies,
134 47 genera and 140 morphospecies (Appendice 1) were collected. In general, the subfamily
135 Microgastrinae was the most abundant representing 49% of the total number of individuals
136 captured, other abundant subfamilies were Doryctinae and Hormiinae with 8% and 6%
137 individuals respectively, the least abundant subfamilies were Ichneutinae and
138 Macrocentrinae which are represented by an individual equivalent to 0.05% (Table 1).

139 **Richness and abundance of species by typearea.** Wealth in each area of the agroecosystem
140 was distributed as follows from highest to lowest. PL with the largest number of subfamilies,
141 followed by PC, VS and PT (Table 1). As for gender from highest to lowest PL, PC, VS
142 and PT (Table 1). The morphospecies were distributed from highest to lowest in the areas
143 in the following order first PL, second PC and with the same number PT and VS (Table 1).
144 Finally, for the number of individuals the largest was concentrated in PL, followed by PC,
145 PT and finally VS (Table 1). For wealth in general it was observed that the PL and
146 PC, considered monocultures concentrated the largest number of individuals and
147 taxonomic wealth, while VS occupied the third site and with the least wealth and abundance
148 the PT with the simplest vegetation structure composed solely of grass.

149 The general pattern for the number of rare and unique morphospecies, as well as species
150 diversity according to the Shannon Index by area is described below. For rare species the
151 order of greatest number was in PT, PL, PC and VS (Table 2). As for unique species from
152 highest to lowest these were found in PC, PT, PL and finally VS (Table 2). In general, it is
153 observed that the VS considered a polyculture and with greater complexity was the one with

154 the lowest number of rare and unique species present. This contrasts with what was found
155 for the Shannon-Wiener diversity index, where the highest diversity was observed in PL,
156 followed by VS, finally PC and PT (Table 2).

157 **Specific wealth estimation:** The wealth estimators used were ICE and Jackknife of the first
158 order. According to the ICE, 60% of the species were captured on average for the
159 agroecosystem, while for the jackknife of the first order 70% were captured according to the
160 estimate for the agroecosystem. Table 3 shows in particular the percentage of wealth
161 estimators by area.

162 **Similarity of communities:** The Sorensen index indicated that the sites that presented the
163 greatest similarity were PC with VS, followed by PT with VS, in third place, PL with VS
164 and those that presented the least similarity were PC with PT (Table 4). The above highlights
165 the importance of conserving remnants of secondary vegetation in agroecosystems, since it
166 was observed that VS is similar to crop areas.

167 **Effect of the areas on the abundance.** As for the quantitative response in the abundance
168 relative to the area of cultivation and the functional role of the braconist in this system, it was
169 observed that the Area has a statistically significant effect on abundance ($F_{1,3} = 2.8125$ $p =$
170 0.000). Higher values of relative abundance were observed in PC, PT and VS with respect
171 to PL (Figure 1). As for the parasitism strategy, a significant effect was found on abundance
172 ($F_{1,2} = 8.5947$ $p = 0.000$), being greater in koinobionts (specialists) compared to idiobionts
173 (generalists) (Figure 2). However, no interaction effect was found between the Area and
174 parasitism strategies ($F_{1,1} = 0.6097$ $p = 0.65$) in this agroecosystem.

175 **Proportion of the estrategia of parasitism.** The distribution was as **follows**, in general
176 the Koinobionte (specialist) represented 63% on average, while 36% on average is classified
177 as Idiobiont (generalists) and only 1% that corresponds to the registrar a species of the genus
178 Epsilogaster (Mendesellinae) of which its biology is unknown (Table 5). The percentage
179 from highest to lowest in the areas of koinobiont species was higher percentage was
180 presented in PT, followed by PC, VS and finally PL (Table 5). As for Idiobionts with
181 the highest and equal percentages PL and VS, followed by PC and finally PT (Table 5).
182 This result suggests that in a diversified agroecosystem, species of braconide specialist
183 nests are more abundant, mainly in complex areas such as monocultures; and generalists
184 concentrate on areas of greater complexity such as secondary vegetation.

185 **Discussion**

186 Braconids are generally considered to be of great importance for their participation in the
187 natural control of other insects and for their use in biological control programs for forest
188 pests, fruit trees, vegetables and extensive crops worldwide (Coronado et al 2010). But the
189 mechanisms of this possible regulation in management systems are little explored,
190 particularly in agroecosystems that expect high levels of plant diversity and maintain high
191 levels of biodiversity, with abiotic and abiotic changes that can affect insect communities
192 (Klein et al 2002).

193 In the study of this diversified agroecosystem, it was found that the areas contain high levels
194 of diversity of braconid nests, with the presence of high percentages of specialists in the crops
195 and communities of these organisms very similar to the remaining secondary vegetation.
196 This supports the benefit of agroecosystems as conservation strategies, as some insects (e.g.

197 eumenid wasp and solitary bees) do not decline significantly to the modification of the
198 environment (Klein et al 2002), which apparently happens in the case of braconests.

199 According to the data obtained in this work it was observed that Microgastrinae was the most
200 abundant subfamily, which is expected. For this subfamily it has been estimated between
201 4000 to 10 000 species in the world (Jones et al 2009). The high abundance of microgastrinae
202 may be due to the fact that they are braconids with a wide range of hosts, which attack almost
203 all families of Lepidoptera, except the family Hepialidae (Shaw, 1994). And it includes
204 species of small size and with dark colors that possibly help them not to be seen by their
205 predators (Rathcke and Price, 1976; Hawkins et al 1992). The subfamilies Ichneutinae and
206 Macrocentrinae were the least abundant, this is in line with the predicted for these subfamilies
207 which estimate there are between 100 -300 species worldwide (Jones et al 2009).

208 The study of braconids in Mexico is focused on three areas and they are, the knowledge of
209 their taxonomic richness, which includes both faunal studies and descriptions of new taxa;
210 research in ecology, mainly using these organisms as indicators of biodiversity; their use as
211 biological control agents of other insects, with potential applications in agriculture and
212 forestry activities (Coronado et al 2010; Coronado, 2011).

213 Recent studies have reported 318 genera of Braconidae for Mexico, 194 belonging to
214 Yucatán (Coronado and Zaldívar, 2014). In this work, 47 genera were registered, which
215 constitutes 24% of what was recorded for Yucatán. This family is well represented in the
216 peninsula as it is the state with the highest number of genera recorded so far. It should be
217 mentioned that the high number of genera found for this state is due to the fact that it is very
218 close to the Gulf of Mexico and because it is one of the states where national and foreign

219 specialists work and /or where more collections have been made (Coronado and Zaldívar,
220 2014).

221 With the data obtained in this agroecosystem it was possible to observe that the areas of
222 monocultures (e.g. PL), presented greater diversity of species, in terms of taxonomic
223 richness and abundance of individuals. However, for parasitoid hymenoptera considered
224 "specialised enemies" are not affected by the manipulation of plant diversity (Koricheva et
225 al 2000; Abdala-Roberts et al 2016a). This was observed in three of the four areas where
226 there were no significant differences in the abundance of braconid nests.

227 In this agroecosystem it was found that the largest number of individuals were classified as
228 specialists (koinobionts) and that the presence of these is independent of the area of
229 cultivation. One mechanism that could explain the patterns found in this agroecosystem may
230 be More specialization (sensu Obermair et al 2008) which indicates specialization prevents
231 competition, so productive communities support a greater number of species.

232 In this agroecosystem it remains to explore the role of the abundance of herbivores, which
233 has been pointed out in other cases, as a factor that suggests that the presence of herbivores
234 affects the number of parasitoids and the density of their population with respect to
235 landscape, climate and management (Koricheva et al 2000; Schmidt et al 2003). This
236 indicates that the presence of herbivores in crops, caused by the concentration of a single
237 resource would affect the incidence of certain pests, which result in an important source for
238 the attraction of certain parasitoids, increased consumer abundance as proposed by the More
239 Individuals Hypothesis (Srivastava & Lawton 1998).

240 On the other hand, polyculture (VS) can present greater plant diversity than other sites,
241 probably functioning as a remnant of natural habitat or as a refuge for parasitoids that disperse

242 to different types of management within the agroecosystem, depending closely on the
243 management (Thies and Tschardtke, 1999) which should be explored.

244 The results correspond to what was reported by Askew and Shaw (1986), Hawkins (1994),
245 Ruiz-Guerra et al (2014), Rodríguez-Solis et al (2016) where they indicate that the braconid
246 community is dominated by koinobiont parasitoids, mentions that the specialty of the host is
247 not related to the degree of disturbance and therefore koinobiont parasitoids can occur both
248 in the early stage and in the late succession phase of vegetation.

249 Finally, the controls exerted by the plant diversity bottom-up and consumer top-down effects
250 should be considered in future experimental work. Adding to this the context of the
251 interactions that occur in agroecosystems must be studied with respect to the communities
252 (e.g. insects, animals) associated with the different trophic levels and the functional role they
253 take in these systems.

254

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257 **Declaration of interest statement**

258 The authors declare that there is no conflict of interest

259 **References**

260 Scolozzi, R., & Geneletti, D. (2012). A multi-scale qualitative approach to assess the impact
261 of urbanization on natural
262 habitats and their connectivity. *Environmental Impact Assessment Review*, 36: 9-22.
263 [https://doi.org/10.1016/j.](https://doi.org/10.1016/j.eiar.2012.03.001)
264 [eiar.2012.03.001](https://doi.org/10.1016/j.eiar.2012.03.001)

- 265 Campos-Navarrete, M. J., Munguía-Rosas, M. A., Abdala-Roberts, L., Quinto, J. and
266 Parra-Tabla, V. (2015a). Effects of Tree Genotypic Diversity and Species Diversity on the
267 Arthropod Community Associated with Big-leaf Mahogany. *Biotropica*, 47(5): 579-5.
- 268 Klein, A.M., Steffan-Dewenter, I., Buchori, D., & Tschardtke, T. (2002). Effects of land-use
269 intensity in tropical agroforestry systems on coffee flower-visiting and trap-nesting bees and
270 wasps. *Conservation biology*, 16(4), 1003-1014.
- 271 Abdala-Roberts, L., González-Moreno, A., Mooney, K. A., Moreira, X.,
272 González-Hernández, A. and Parra-Tabla, V. (2016a). Effects of tree species diversity and
273 genotypic diversity on leafminers and parasitoids in a tropical forestplantation. *Agricultural
274 and Forest Entomology*, 18(1): 43-51
- 275 Nicholls, C. I. (2008). Biological control of insects: an agroecological approach (Vol. 2).
276 University of Antioquia.
- 277 Schmidt, M. H., Lauer, A., Purtauf, T., Thies, C., Schaefer, M., & Tschardtke, T. (2003).
278 Relative importance of predators and parasitoids for cereal aphid control. *Proceedings of the
279 Royal Society of London. Series B: Biological Sciences*, 270(1527), 1905-1909.
- 280 Thies, C., Roschewitz, I., & Tschardtke, T. (2005). The landscape context of cereal aphid–
281 parasitoid interactions. *Proceedings of the Royal Society B: Biological Sciences*, 272(1559),
282 203-210.
- 283 Abdala-Roberts, L., Hernández-Cumplido, J., Chel-Guerrero, L., Betancur-Ancona, D.,
284 Benrey, B., & Moreira, X. (2016b). Effects of plant intraspecific diversity across three trophic
285 levels: Underlying mechanisms and plant traits. *American Journal of Botany*, 103(10), 1810-
286 1818.
- 287 Castillo-Sánchez, L. E., Jiménez-Osornio, J. J., Delfín-González, H., Ramírez Pech, J.,
288 Canul-Solís, J. R., Gonzalez-Moreno, A., & Campos-Navarrete, M. J. (2019). Diversity of
289 Ichneumonoidea (Hymenoptera) in three types of land use in a multiple production
290 agroecosystem in Xmatkuil, Yucatan, Mexico. *Revista Bio Ciencias*, 6.
- 291 Russell, E. P. (1989). Enemies hypothesis: a review of the effect of vegetational diversity on
292 predatory insects and parasitoids. *Environmental entomology*, 18(4), 590-599.
- 293 Obermaier, E., Heisswolf, A., Poethke, H. J., Randlkofer, B., & Meiners, T. (2008). Plant
294 architecture and vegetation structure: two ways for insect herbivores to escape
295 parasitism. *European Journal of Entomology*, 105(2).
- 296 Moreira, X., Abdala-Roberts, L., Rasmann, S., Castagneyrol, B., & Mooney, K. A. (2016).
297 Plant diversity effects on insect herbivores and their natural enemies: current thinking, recent
298 findings, and future directions. *Current opinion in insect science*, 14, 1-7.
- 299 Abdala-Roberts, L., Mooney, K. A., Quijano-Medina, T., Campos-Navarrete, M. J.,
300 González-Moreno, A. and Parra-Tabla, V. (2015). Comparison of tree genotypic diversity
301 and species diversity effects on different guilds of insect herbivores. *Oikos*, 124(11): 1527-
302 1535.

- 303 Campos-Navarrete, M. J., Abdala-Roberts, L., Munguia-Rosas, M. A., & Parra-Tabla, V.
304 (2015b). Are tree species diversity and genotypic diversity effects on insect herbivores
305 mediated by ants?. *PloS one*, 10(8), e0132671.
- 306 Hambäck, P. A., Inouye, B. D., Andersson, P. and Underwood, N. (2014). Effects of plant
307 neighborhoods on plant–herbivore interactions: resource dilution and associational effects.
308 *Ecological society America*. 95: 1370-1383.
- 309 Unsicker, S.B., Oswald, A., Köhler, G. and Weisser, W. W. (2008). Complementarity effects
310 through dietary mixing enhance the performance of a generalist insect herbivore. *Oecologia*,
311 156: 313-324.
- 312 Castagneyrol, B., Giffard, B., Péré, C., & Jactel, H. (2013). Plant apparency, an overlooked
313 driver of associational resistance to insect herbivory. *Journal of Ecology*, 101(2), 418-429.
- 314 Inegi 2015. Intercensal Survey. <https://www.inegi.org.mx/programas/intercensal/2015/>
- 315 Noyes, J. S., 1982. Collecting and preserving chalcid wasps (Hymenoptera: Chalcidoidea)..
316 *Journal of Natural History*., Volume 16, pp. 315-334.
- 317 Nieves-Aldrey, J. L. & Castillo., C. R. d., 1991. Preliminary Essay on the Capture of Insects
318 by Means of a Trap "Malaise" in the Sierra de Guadarrama (Spain) with Special. *Ecology*,
319 Volume 5, pp. 383-403.
- 320 Wharton, R. A., Marsh, P.M. & Sharkey, M. J., 1998. *Manual of the New World genera of*
321 *the family Braconidae (Hymenoptera)*. 1 ed. Washington: International Society of
322 Hymenopterists .
- 323 Simpson, G. G., 1961. *Principles of animal taxonomy*. New York: s.n.
- 324 Mayr, E. & Ashlock., P. D., 1991. *Principles of systematic zoology*. New York: McGraw
325 Hill.
- 326 Delfín, G. H. and D. Burgos R. (2000). The braconids (Hymenoptera: Braconidae) as a
327 parameter group of diversity in the deciduous forests of the tropics: a discussion about their
328 possible use. *Acta Zool. Mex.* (n.s.) 79: 1-14.
- 329 Goulet, H., & Huber, J. T. (1993). *Hymenoptera of the world: and identification guide to*
330 *families* (No. 595.79 G8).
- 331 Ludwing, J. A. and J. F. Reynolds. (1988). *Statistical ecology. A primer on methods and*
332 *computing*. Canada. Ed. John Wiley and Sons. Inc. p. 337.
- 333 Magurran, A. (1988). *Ecological diversity and its measurement*. Princeton University Press.
334 New Jersey, USA. p. 179.
- 335 Krebs, C. J. 1989. *Ecological Methodology*. Harper Collins Publishers. New York, USA.
- 336 Spellerberg, I. F. (1991). A Biological and ecological basis for monitoring. *Elements of*
337 *ecology and ecological methods*. Spellerberg, I. F. (Ed.). *Monitoring Ecological Changes*.
338 Cambridge University Press. Cambridge. 4: 61-90

- 339 Colwell, R. K. and J. A. Coddington. (1994). Estimating terrestrial biodiversity through
340 extrapolation. *Philosophical Transactions of the Royal Society of London*. 345: 101-118.
- 341 Crawley MJ. The R book. Chichester: John Wiley & Sons Ltd.2007.
- 342 R Core Team (2020). A: A language and environment for statistical computing. R Foundation
343 for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.
- 344 Rodríguez-Solís, B. A., J. A. Trejo-Rivero., R. J. Nava-Guizar and A. González-Moreno.
345 (2016). Spatial variation of braconid subfamilies (Hymenoptera: Ichneumonoidea) in a
346 private reserve in the state of Yucatán, Mexico. *Entomología Mexicana*, 3: 555-559.
- 347 Coronado B. J. M., E. Ruíz, C., V. López M., J. A. Sánchez G., J. I. Figueroa. R. & H. Delfín,
348 G. (2010). Braconidae (Hymenoptera) in Mexico. *In memory*. II International Workshop on
349 Natural Resources. V. H. Toledo-Hernández, A.M. Corona-López, A. Flores-Palacios, E.
350 Tovar-Sánchez, J.M. Coronado-Blanco and E. Ruíz-Cancino (eds.). Cuernavaca, Morelos,
351 Mexico. p. 80-87.
- 352 Jones, O. R., Purvis, A., Baumgart, E., & Quicke, D. L. (2009). Using taxonomic revision
353 data to estimate the geographic and taxonomic distribution of undescribed species richness
354 in the Braconidae (Hymenoptera: Ichneumonoidea). *Insect Conservation and Diversity*,
355 2(3), 204-212.
- 356 Shaw, M. R. & Huddleston, T. (1991). *Classification and biology of braconid wasps*.
357 (*Hymenoptera: Braconidae*). Handbooks for the identification of British insects. London.
358 Royal entomological society of London. 126 pp.
- 359 Rathcke, B. J. and P. W. Price. (1976). Anomalous diversity of tropical Ichneumonid
360 parasitoids: a predation hypothesis. *American Naturalist*. 110: 889-893.
- 361 Hawkins, B. A., M. R. Shaw and R. R. Askew. (1992). Relations among assemblage size,
362 host specialization, and climatic variability in North American parasitoid communities. *Tom*.
363 *Nat*. 139: 58-79.
- 364 Coronado, B., J.M. (2011). Braconidae (Hymenoptera) from Tamaulipas, Mexico. Editorial
365 Plan. Mexico. 203 p.
- 366 Coronado, B. J.M. & A. Zaldívar, R. (2014). Biodiversity of Braconidae (Hymenoptera:
367 Ichneumonoidea) in Mexico. *magazine Mexican biodiversity*, 85: S372-S378.
- 368 Koricheva, J., Mulder, C. P., Schmid, B., Joshi, J., & Huss-Danell, K. (2000). Numerical
369 responses of different trophic groups of invertebrates to manipulations of plant diversity in
370 grasslands. *Oecologia*, 125(2), 271-282.

371 Srivastava, D. S., & Lawton, J. H. (1998). Why more productive sites have more species: an
 372 experimental test of theory using tree-hole communities. *The American Naturalist*, 152(4),
 373 510-529.

374 Thies, C. and T. Tschardtke. (1999). Landscape Structure and Biological Control in
 375 Agroecosystems. Science. Vol. 285: 893-895.

376 Ruiz-Guerra, B., J.C. López-Acosta, A. Zaldivar-Riverón, and N. Velázquez-Rosas, (2014).
 377 Braconidae (Hymenoptera: Ichneumonoidea) abundance and richness in four types of land
 378 use and preserved rain forest in southern Mexico. *Revista Mexicana de Biodiversidad*, 86
 379 (2015) 164-171.

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382 Appendices

383 Appendix 1

384 List of subfamilies, morphospecies, abundances and biology of braconids in four sites:
 385 PS=Parasitism strategy, K=Koinobionte, I=Idiobionte, ?= Unknow, PC = Coconut
 386 Plantation, PL = Lemon Plantation, PT = P astizal, VS = *Secondary Vegetation* and TL =
 387 Total *in the* agroecosystem.

subfamily	species	B	PC	pl	Pt	vs	Tl
Agathidinae	<i>Alabagrus</i> sp1	K	8	7	1	2	18
Agathidinae	<i>Alabagrus</i> sp2	K	0	2	0	0	2
Agathidinae	<i>Bassus</i> sp1	K	7	2	1	0	10
Agathidinae	<i>Bassus</i> sp2	K	4	0	0	0	4
Agathidinae	<i>Bassus</i> sp3	K	10	13	2	0	25
Agathidinae	<i>Bassus</i> sp4	K	3	0	1	0	4
Agathidinae	<i>Pharpa</i> sp1	K	0	0	0	2	2
Agathidinae	<i>Plesiocoelus</i> sp1	K	0	0	1	0	1
Alysiinae	<i>Aphaereta</i> sp1	K	3	7	1	3	14
Alysiinae	<i>Asobara</i> sp1	K	0	23	0	0	23
Alysiinae	<i>Aspilota</i> sp1	K	0	0	1	2	3
Alysiinae	<i>Aspilota</i> sp2	K	0	1	0	0	1

Alysiinae	<i>Microcrasis</i> sp1	K	0	2	0	0	2
Aphidiinae	<i>Aphidiinae</i> sp1	K	0	78	0	0	78
Blacinae	<i>Blacus</i> sp1	K	0	0	0	5	5
Blacinae	<i>Blacus</i> sp2	K	0	0	0	2	2
Braconinae	<i>Bracon</i> sp1	I	25	5	1	0	31
Braconinae	<i>Bracon</i> sp2	I	16	26	2	0	44
Braconinae	<i>Bracon</i> sp3	I	1	2	1	0	4
Braconinae	<i>Compsobraconoides</i> sp1	I	1	1	0	0	2
Braconinae	<i>Habrobracon</i> sp1	I	0	3	1	0	4
Braconinae	<i>Lapicida</i> sp1?	I	0	2	0	3	5
Braconinae	<i>Vipio</i> sp1	I	1	0	2	0	3
Cardiochilinae	<i>Schoenlandella</i> sp1	K	0	17	0	0	17
Cardiochilinae	sp1	K	0	1	1	1	3
Cheloninae	<i>Chelonus</i> sp1	K	1	17	0	0	18
Cheloninae	<i>Chelonus</i> sp2	K	0	10	4	3	17
Cheloninae	<i>Chelonus</i> sp3	K	0	0	0	1	1
Cheloninae	<i>Chelonus</i> sp4	K	2	9	0	0	11
Cheloninae	<i>Chelonus</i> sp5	K	0	4	0	0	4
Cheloninae	<i>Chelonus</i> sp6	K	0	4	0	0	4
Cheloninae	<i>Chelonus</i> sp7	K	1	0	0	0	1
Cheloninae	<i>Chelonus</i> sp8	K	3	0	0	0	3
Cheloninae	<i>Chelonus</i> sp9	K	0	0	1	0	1
Cheloninae	<i>Chelonus</i> sp10	K	0	0	1	0	1
Cheloninae	<i>Chelonus</i> sp11	K	0	2	0	0	2
Cheloninae	<i>Phanerotoma</i> sp1	K	3	12	0	0	15
Cheloninae	<i>Phanerotoma</i> sp2	K	1	3	2	0	6
Cheloninae	<i>Phanerotoma</i> sp3	K	0	0	0	1	1
Cheloninae	<i>Phanerotoma</i> sp4	K	0	0	1	0	1
Cheloninae	<i>Pseudophanerotoma</i> sp1	K	0	2	0	0	2
Doryctinae	<i>Acrophasmus</i> sp1	I	7	1	1	0	9
Doryctinae	<i>Curtisella</i> sp1	I	0	1	0	0	1

Doryctinae	<i>Ecphylus</i> sp1	I	0	4	0	0	4
Doryctinae	<i>Ecphylus</i> sp2	I	1	3	0	0	4
Doryctinae	<i>Heterospilus</i> sp1	I	0	3	0	1	4
Doryctinae	<i>Heterospilus</i> sp2	I	0	1	0	1	2
Doryctinae	<i>Heterospilus</i> sp3	I	0	17	4	4	25
Doryctinae	<i>Heterospilus</i> sp4	I	1	19	6	5	31
Doryctinae	<i>Heterospilus</i> sp5	I	1	8	2	1	12
Doryctinae	<i>Heterospilus</i> sp6	I	0	1	0	1	2
Doryctinae	<i>Heterospilus</i> sp7	I	0	3	0	0	3
Doryctinae	<i>Heterospilus</i> sp8	I	1	0	0	0	1
Doryctinae	<i>Heterospilus</i> sp9	I	3	0	1	1	5
Doryctinae	<i>Heterospilus</i> sp10	I	0	4	0	1	5
Doryctinae	<i>Heterospilus</i> sp11	I	0	1	0	0	1
Doryctinae	<i>Heterospilus</i> sp12	I	0	0	0	1	1
Doryctinae	<i>Heterospilus</i> sp13	I	0	0	0	2	2
Doryctinae	<i>Heterospilus</i> sp14	I	1	6	0	0	7
Doryctinae	<i>Heterospilus</i> sp15	I	0	6	0	2	8
Doryctinae	<i>Heterospilus</i> sp16	I	0	0	2	0	2
Doryctinae	<i>Heterospilus</i> sp17	I	0	0	4	1	5
Doryctinae	<i>Heterospilus</i> sp18	I	1	0	1	0	2
Doryctinae	<i>Heterospilus</i> sp19	I	0	1	0	0	1
Doryctinae	<i>Heterospilus</i> sp20	I	2	6	0	2	10
Doryctinae	<i>Heterospilus</i> sp21	I	0	1	0	0	1
Doryctinae	<i>Heterospilus</i> sp22	I	0	1	0	0	1
Doryctinae	<i>Heterospilus</i> sp23	I	0	1	0	0	1
Doryctinae	<i>Odontobracon</i> sp1	I	0	3	0	1	4
Doryctinae	<i>Rhaconotus</i> sp1	I	1	2	4	0	7
Doryctinae	<i>Rhaconotus</i> sp2	I	0	1	0	0	1
Doryctinae	Sp1	I	0	1	0	0	1
Euphorinae	<i>Aridelus</i> sp1	K	1	12	2	0	15
Euphorinae	<i>Leiophron</i> sp1	K	0	10	0	0	10

Euphorinae	<i>Leiophron</i> sp2	K	2	2	0	0	4
Euphorinae	<i>Microctonus</i> sp1	K	0	0	0	2	2
Euphorinae	<i>Microctonus</i> sp2	K	1	0	0	0	1
Euphorinae	<i>Peristenus</i> sp1	K	0	1	0	0	1
Homolobinae	<i>Exasticolus</i> sp1	K	0	1	1	0	2
Homolobinae	<i>Homolobus</i> sp1	K	0	5	0	0	5
Homolobinae	<i>Homolobus</i> sp2	K	0	0	1	0	1
Hormiinae	<i>Cantharoctonus</i> sp1	I	0	1	0	0	1
Hormiinae	<i>Hormius</i> sp1	I	1	1	1	0	3
Hormiinae	<i>Hormius</i> sp2	I	5	23	0	0	28
Hormiinae	<i>Hormius</i> sp3	I	0	1	0	1	2
Hormiinae	<i>Hormius</i> sp4	I	3	33	0	0	36
Hormiinae	<i>Oncophanes</i> sp1	I	0	1	0	0	1
Hormiinae	<i>Oncophanes</i> sp2	I	2	2	0	0	4
Hormiinae	<i>Oncophanes</i> sp3	I	1	5	0	1	7
Hormiinae	<i>Oncophanes</i> sp4	I	0	4	0	2	6
Hormiinae	<i>Pambolus</i> sp1	I	0	5	0	2	7
Hormiinae	<i>Parahormius</i> sp1	I	1	1	0	0	2
Hormiinae	<i>Rhysipolis</i> sp1	I	4	4	7	1	16
Hormiinae	<i>Rhysipolis</i> sp2	I	0	1	0	1	2
Hormiinae	<i>Rhysipolis</i> sp3	I	0	1	0	0	1
Hormiinae	<i>Xenarcha</i> sp1	I	0	0	0	3	3
Hormiinae	<i>Xenarcha</i> sp2	I	0	1	0	0	1
Ichneutinae	<i>Oligoneurus</i> sp1	K	0	1	0	0	1
Macrocentrinae	<i>Macrocentrus</i> sp1	K	1	0	0	0	1
Mendesellinae	<i>Epsilogaster</i> sp1	?	2	7	0	0	9
Meteorinae	<i>Meteorus</i> sp1	K	1	0	1	0	2
Microgastrinae	sp1	K	24	139	14	4	181
Microgastrinae	sp2	K	5	0	4	0	9
Microgastrinae	sp3	K	14	62	17	3	96
Microgastrinae	sp4	K	1	0	2	0	3

Microgastrinae	sp5	K	18	54	8	8	88
Microgastrinae	sp6	K	26	47	8	2	83
Microgastrinae	sp7	K	30	55	38	0	123
Microgastrinae	sp8	K	11	55	7	1	74
Microgastrinae	sp9	K	6	14	0	6	26
Microgastrinae	sp10	K	65	37	2	0	104
Microgastrinae	sp11	K	2	0	3	0	5
Microgastrinae	sp12	K	3	6	3	0	12
Microgastrinae	sp13	K	31	9	3	0	43
Microgastrinae	sp14	K	1	6	2	0	9
Microgastrinae	sp15	K	0	5	0	0	5
Microgastrinae	sp16	K	6	43	5	12	66
Microgastrinae	sp17	K	1	5	1	0	7
Microgastrinae	sp18	K	0	2	1	2	5
Microgastrinae	sp19	K	1	4	1	0	6
Microgastrinae	sp20	K	2	12	1	0	15
Microgastrinae	sp21	K	0	15	0	7	22
Microgastrinae	sp22	K	0	0	0	1	1
Microgastrinae	sp23	K	0	2	1	0	3
Miracinae	<i>Mirax</i> sp1	K	4	17	0	6	27
Opiinae	<i>Opius</i> sp1	K	30	81	2	27	140
Opiinae	<i>Opius</i> sp2	K	0	3	0	0	3
Opiinae	<i>Opius</i> sp3	K	0	2	0	0	2
Opiinae	<i>Opius</i> sp4	K	4	4	0	0	8
Opiinae	<i>Opius</i> sp5	K	1	10	1	8	20
Opiinae	<i>Opius</i> sp6	K	11	37	2	3	53
Opiinae	<i>Opius</i> sp7	K	1	6	1	1	9
Orgilinae	<i>Orgilus</i> sp1	K	0	0	0	2	2
Orgilinae	<i>Orgilus</i> sp2	K	4	0	0	0	4
Orgilinae	<i>Stantonia</i> sp1	K	1	0	1	0	2
Orgilinae	<i>Stantonia</i> sp2	K	0	4	3	2	9

Rogadinae	<i>Aleiodes</i> sp1	K	1	0	0	1	2
Rogadinae	<i>Aleiodes</i> sp2	K	0	4	0	0	4
Rogadinae	<i>Stiropius</i> sp1	K	9	12	0	0	21
Rogadinae	<i>Stiropius</i> sp2	K	0	7	0	0	7
			447	1232	194	158	2031

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391 **Table(s) with caption(s) (on individual pages)**

392 Table 1. Number of genera (G), morphospecies (S) and abundance (A) by subfamilies in
 393 each area PC= Coconut Plantation, PL= Lemon Plantation, PT= Pastizal, VS=Secondary
 394 Vegetation and the Total, in the agroecosystem.

subfamily	PC			pl			Pt			vs			total	
	G	s	to	G	s	to	G	s	to	G	s	to		
Number of individuals	447			1232			194			158				
Agathidinae	2	5	32	2	4	24	3	5	6	2	2	4	66	8
Alysiinae	1	1	3	4	4	33	2	2	2	2	2	5	43	5
Aphidiinae	-	-	-	-	1	78	-	-	-	-	-	-	78	1
Blacinae	-	-	-	-	-	-	-	-	-	1	2	7	7	2
Braconinae	3	5	44	4	6	39	3	5	7	1	1	3	93	7
Cardiochilinae	-	-	-	1	2	18	-	1	1	-	1	1	20	2
Cheloninae	2	6	11	3	9	63	2	5	9	2	3	5	88	16

Doryctinae	4	1 0	19	6	24	95	3	9	25	2	1 4	24	163	31
Euphorinae	3	3	4	3	4	25	1	1	2	1	1	2	33	6
Homolobinae	-	-	-	2	2	6	2	2	2	-	-	-	8	3
Hormiinae	4	7	17	7	15	84	2	2	8	5	7	11	120	16
Ichneutinae	-	-	-	1	1	1	-	-	-	-	-	-	1	1
Macrocentrin ae	1	1	1	-	-	-	-	-	-	-	-	-	1	1
Mendesellinae	1	1	2	1	1	7	-	-	-	-	-	-	9	1
Meteorinae	1	1	1	-	-	-	1	1	1	-	-	-	2	1
Microgastrina e	-	1 8	24 7	-	19	572	-	1 9	12 1	-	1 0	46	986	23
Miracinae	1	1	4	1	1	17	-	-		1	1	6	27	1
Opiinae	1	5	47	1	7	143	1	4	6	1	4	39	35	7
Orgilinae	2	2	5	1	1	4	1	2	4	2	2	4	17	4
Rogadinae	2	2	10	2	3	23	-	-	-	1	1	1	34	4
total	2	6	44	3	10	123	2	5	19	2	5	15	203	14
	8	8	7	9	4	2	1	8	4	1	1	8	1	0

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399 Table 2. Shannon-Wiener diversity index, Total number of morphospecies, Singletons,
400 Doubletons, Unique species and rare species in PC coconut plantation areas; PL lemon
401 plantation; PT grassland and VS secondary vegetation in the agroecosystem.

	<i>PC</i>	<i>pl</i>	<i>Pt</i>	<i>vs</i>
<i>Shannon-Wiener index</i>	3.43	3.77	3.41	3.45
<i>Total number of species</i>	68	104	58	51
<i>Singletons</i>	28	25	28	20
<i>Doubletons</i>	7	13	12	14
<i>Unique species</i>	35	31	32	30
<i>Rare species</i>	35	38	40	34

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415 Table 3. Ice and Jacknife wealth estimators of the first order (Jacknife 1), with respect to the
416 morphospecies captured, calculated in the areas of PC coconut plantation; PL lemon
417 plantation; PT grassland and VS secondary vegetation in the agroecosystem.

	PC	PL	PT	VS
MORPHOSPECIES	68	104	58	51
CAPTURED				
ICE	120	129	103	94
% CAPTURED FROM	57%	81%	56%	54%
ICE				
JACKNIFE 1	97	130	85	76
% CAPTURED FROM	70%	80%	68%	67%
JACKNIFE 1				

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431 Table 4. Similarity of the braconid community in the areas of PC coconut plantation; PL

432 lemon plantation; PT grassland and VS secondary vegetation in the agroecosystem.

	PC	PL	PT	VS
PC	-	0.41	0.33	0.65
PL	-	-	0.49	0.54
PT	-	-	-	0.58
VS	-	-	-	-

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449 Table 5. Strategies of parasitism and morphospecies in which it is not known (?=Unknow)
450 expressed in total and percentage for PC coconut plantation; PL lemon plantation; PT
451 grassland and VS secondary vegetation in the agroecosystem.

	PC	%	PL	%	PT	%	VS	%
KOINOBIO	45	66	58	56	42	72	29	57
NTS								
IDIOBIONTS	22	32	45	43	16	28	22	43
?	1	2	1	1	-	-	-	-
TOTAL	68	100	104	100	58	100	51	100

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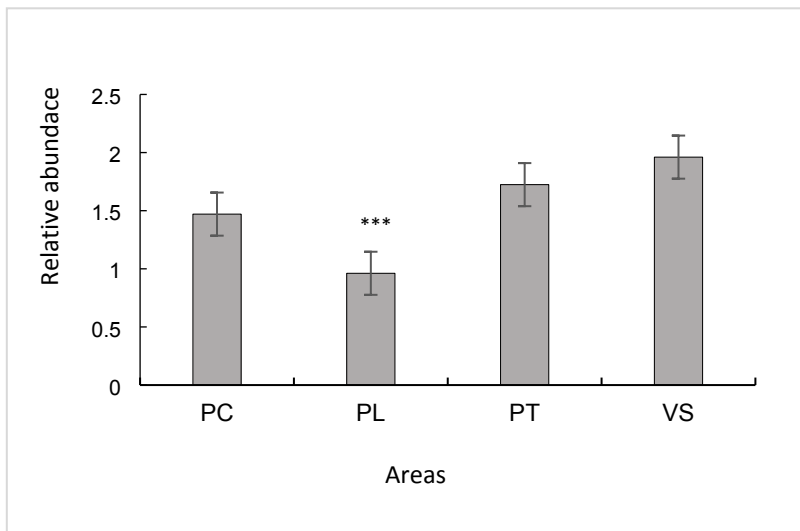
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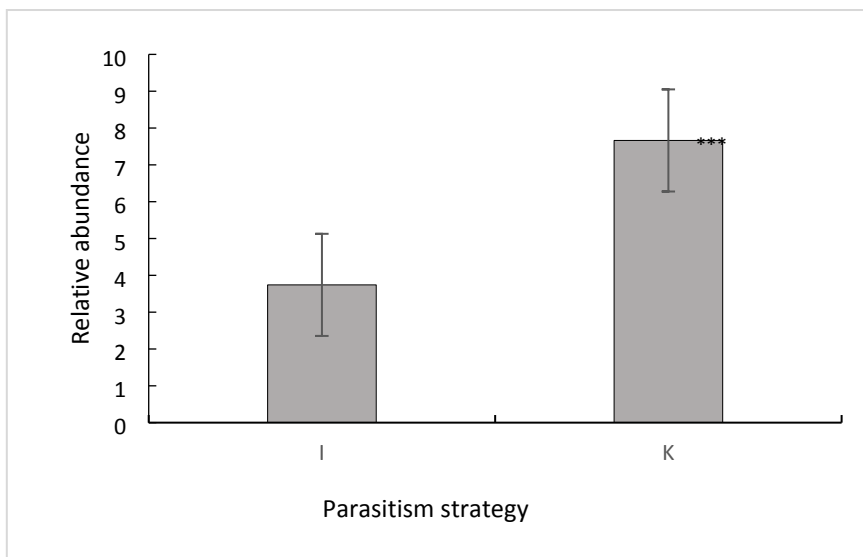
466 **Figures**

467 **Figure 1**



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469 **Figure 2**



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474 **Figure captions (as a list).**

475 Figure 1. Average relative abundance ($EE \pm$) of braconid morphospecies per pc coconut
476 plantation area; PL lemon plantation; PT grassland and VS secondary vegetation in the
477 agroecosystem (** $p < 0.05$)

478

479 Figure 2. Relative average abundance by parasitism strategy ($EE \pm$) of braconid
480 morphospecies per area PC coconut plantation; PL lemon plantation; PT grassland and VS
481 secondary vegetation in the agroecosystem (** $p < 0.05$)

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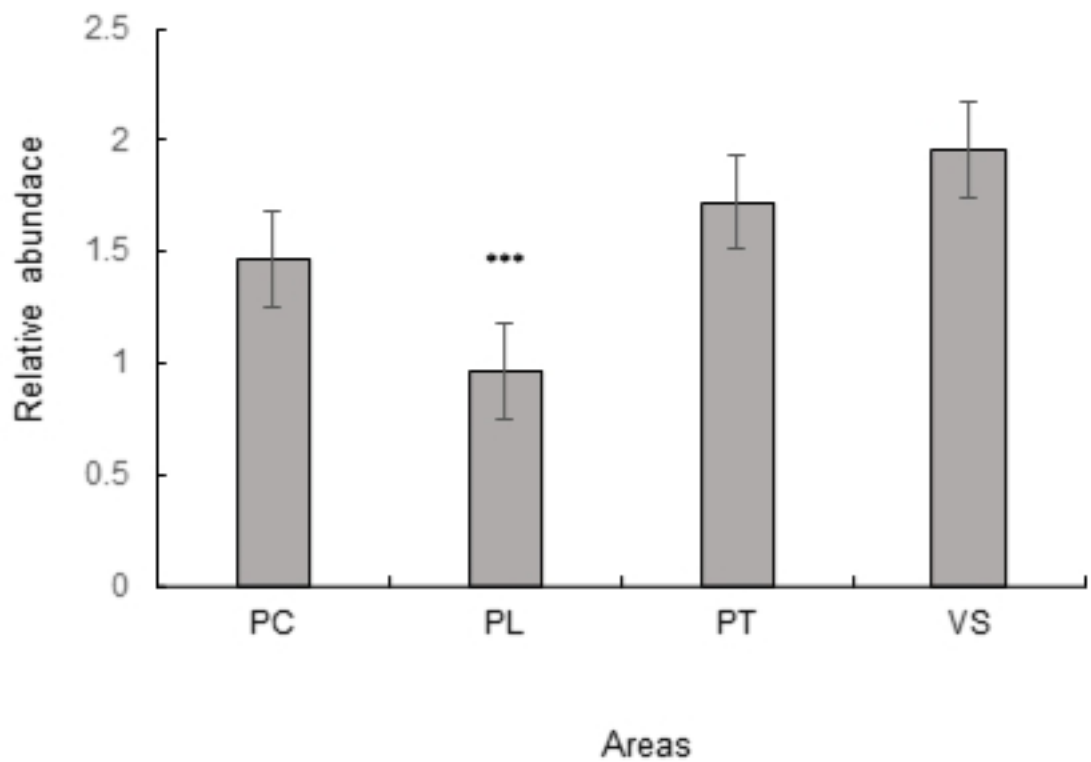


Figure 1

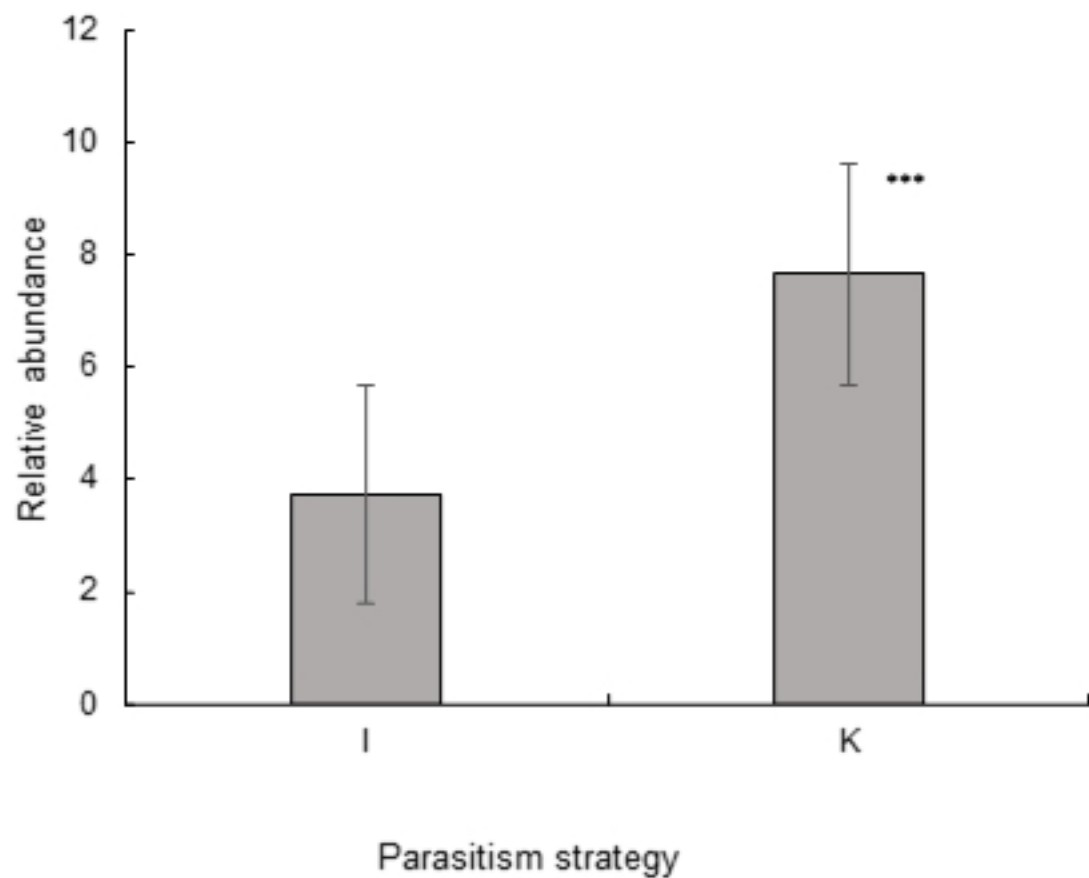


Figure 2