

1 **Predator identification methods in diet studies: Uncertain assignment produces**  
2 **biased results?**

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11 **Abstract**

12 Knowledge on the diet is critical to understand the ecology of animal species, and also  
13 to design management and conservation strategies. Nonetheless, diet studies of many  
14 mammalian carnivores are usually based on indirect analyses (mostly through their  
15 faeces) rather than on direct observations of their feeding behavior, which could  
16 produce uncertain assignments of the predator species. Here, we tested the hypothesis  
17 that differences in the diet between studies are not associated with the predator  
18 identification method used by comparing results obtained in studies that used either  
19 *high confidence identification* (HCI; i.e. stomach or colon content, or genetic or  
20 chemical analyses of faeces) or *low confidence identification* methods (LCI; i.e. faeces  
21 appearance) for jaguars and cougars. We reviewed the literature on diet of these  
22 species and 1) assessed if similarity of the diet was related to the method used to  
23 identify the species, and 2) the possible consequences that potential misidentification  
24 of faeces could have on diet spectrums. Furthermore, we briefly summarized the most  
25 reliable knowledge currently available about the diets of both species. Our analyses  
26 indicated that the method used for predator identification significantly influences diet  
27 similarity, with HCI studies being more similar among them than LCI studies or HCI-LCI  
28 studies. Studies based on LCI methods apparently overemphasized the importance of  
29 certain prey for both species, whereas other significant prey items were not detected.  
30 Although approaches for a reliable identification of predators are expensive and require  
31 specialized technicians and equipment, we highlight the need to invest on them in order  
32 to accomplish a better ecological understanding of the feeding ecology of carnivore  
33 species, which is a key factor to consider in conservation and management plans.

34 **Introduction**

35 Knowledge on the diet of mammalian carnivores is critical to understand predator-prey  
36 relationships and species interactions (e. g. Gittleman and Harvey 1982, Bekoff et al.  
37 1984, Sunquist and Sunquist 1989). However, obtaining data for diet studies through  
38 direct observations is difficult for many carnivore species due to their elusive behavior,  
39 and most studies are based on the use of indirect methods for the identification of prey  
40 consumed, including the analysis of stomach and colon content and, most frequently,  
41 the examination of prey remains in carnivore faeces (Mills 1996).

42 Diet analyses based on faeces requires the previous identification of the producer  
43 species, which is often achieved by two general different methods: (1) the inspection of  
44 morphology and appearance of faeces in the field and, eventually, other associated  
45 evidences such as tracks, photo captures, scrapes, hairs and radio locations; and (2)  
46 laboratory genetic or chemical analyses. The identification of the species in the field  
47 often implies a high degree of uncertainty and subjectivity since it relies on the  
48 experience of the observer, the degree of preservation of the faeces, the quantity and  
49 quality of associated evidences and the presence of other carnivore species that may  
50 deposit similar faeces (Farrell et al. 2000, Davison et al. 2002, Chame 2003). On the  
51 contrary, it is generally accepted that laboratory techniques yield more accurate results  
52 (e. g. Fernández et al. 1997, Kohn and Wayne 1997, Hansen and Jacobsen 1999,  
53 Davison et al. 2002, Harrington et al. 2010), although it is known that they are not  
54 exempt of misidentifications due to some uncertainty or variability of the processes  
55 involved or to human error (Major et al. 1980, Quinn and Jackman 1994, Nauta and  
56 Weissing 1996, Waits and Paetkau 2005, Witt et al. 2006, Chaves et al. 2012). Thus,  
57 hereinafter traditional field methods for species identification based on appearance and  
58 associated evidences will be referred as "*low confidence identification (LCI)*", and  
59 laboratory faecal analyses or stomach and colon content as "*high confidence*  
60 *identification (HCI)*".

61 Despite of its potential pitfalls, most information on mammalian carnivore diet  
62 currently available comes from studies exclusively based on low confidence  
63 identification methods (e. g. Harveson et al. 2000, Núñez et al. 2000, Pessino et al.  
64 2001, Kuroiwa and Ascorra 2002, Bustamante-Ho 2008, Martins et al. 2008, McBride  
65 et al. 2010), yet, there is a lack of knowledge about how the associated uncertainty  
66 may bias results, since none study has explored the effect of predator identification  
67 reliability on available diet descriptions.

68 In this study we analyzed the potential biases that may result from using low  
69 confidence methods for the identification of carnivore faeces in diet studies. For this  
70 purpose we reviewed the literature available on the diet of two large carnivore species,  
71 the jaguar (*Panthera onca*) and the cougar (*Puma concolor*). Cougars and jaguars are  
72 similar in body size, coexist over much of their range (basically along the jaguar  
73 distribution), they are both generalist predators (see Seymour 1989, López-González  
74 and González-Romero 1998, Laundré and Hernández 2010 for a review) and the  
75 distinction of their faeces in the field is not straightforward. Furthermore, there is also  
76 potential to misclassify faeces from both jaguars and cougars with several other  
77 medium-large generalist carnivores with which they share distribution range, such as  
78 coyotes (*Canis latrans*), bobcats (*Lynx rufus*), wolves (*Canis lupus*), ocelots  
79 (*Leopardus pardalis*), jaguarundis (*Puma yagouaroundi*), and several fox species (e. g.  
80 Farrell et al. 2000). To achieve our main objective we outlined two specific aims:

81 (1) We assessed if the similarity of the diet reported for jaguars and cougars  
82 between the different studies was related or not to the method used to identify  
83 these species. If the identification method had no effect, diet similarity between  
84 studies would not differ significantly with the kind of pair compared, whether  
85 they were HCI-HCI, LCI-LCI, or HCI-LCI. Since jaguars and cougars are  
86 generalist predators with broad geographic distributions (see Seymour 1989,  
87 Laundré and Hernández 2010 for a review) we also accounted for the effects of  
88 geographic distances between the different studies.

89 (2) We evaluated the possible consequences of potential faeces misidentification  
90 on the estimated diet spectrum. Misidentification of faeces would lead to omit  
91 prey items that are actually consumed by the focal species (i.e. a potential  
92 omission error), or to include prey items that are not actually consumed (i.e. a  
93 potential inclusion error). We expected that the number of prey included in LCI  
94 studies would be higher than the number of prey omitted due to a higher  
95 probability of including prey not actually consumed by the focal predator of  
96 interest (e. g. Fernández et al. 1997, Farrell et al. 2000, Davison et al. 2002). As  
97 for the previous aim, we took into consideration in the analyses the potential  
98 geographic differences in prey availability.

## 99 **Methods**

### 100 **Data compilation and standardization**

101 We reviewed diet studies of jaguars and cougars searching in the bibliographic  
102 databases “Scopus”, “Google Scholar” and “Web of Science”, for the terms cougar,  
103 diet, food habits, jaguar, *Panthera onca*, and *Puma concolor*. We discarded those  
104 studies focusing on a single prey species or with poor discrimination and quantification  
105 of the different food items. We included diet studies based on analyses of faeces,  
106 stomachs and colon contents. The geographical location of each study was digitized  
107 using a Geographic Information System (ARC/INFO v10.0, ESRI 2011).

108 In order to compare results from different studies, and attending to the most  
109 frequent methodological approaches in publications, we considered those studies that:  
110 (1) allowed calculation of the percentage of occurrence (PO) of each prey (with regard  
111 to the sum of all prey items in all samples); and (2) provided information about the  
112 method used for the identification of the predator.

113 We established two categories of confidence in predator identification method:  
114 high confidence identification (HCI) and low confidence identification (LCI). HCI  
115 methods included studies based on stomach and colon contents and on faeces

116 identified through genetic or biliary acids analyses. LCI methods included studies  
117 based on faeces identified visually, using or no other associated evidences such as  
118 tracks, scrapes, photo captures, radiolocations, etc.

119 Studies performed in the same study site and under the same category of  
120 confidence identification were averaged. We also averaged data for those studies  
121 informing on results for stomachs and colon content separately, and pooled data for  
122 items of the same prey species differing in size (e.g. “small” vs. “large”).

123 Whenever possible we standardized the taxonomic resolution for the  
124 identification of prey at the genus level. Food items for which the taxonomic level of  
125 resolution was Class or Order were discarded unless they represented  $\geq 10\%$  of the  
126 diet in at least one study or if they were present in the majority of the studies.

## 127 **Data analysis**

### 128 **Effect of predator identification method on diet similarity**

129 We tested whether differences in diet similarity between pairs of studies were  
130 associated to the predator identification method using linear mixed models (LMM)  
131 through the function lmer of the R package lme4 (Bates et. al. 2012, R Development  
132 Core Team 2012). Trophic similarity between pairs of studies was modeled as a  
133 function of the type of method used in each study of the pair, including also the  
134 distance between study sites as a covariate. This covariate was included to account for  
135 the fact that prey availability vary with distance between study areas. Similarity for each  
136 pair was calculated using the Simplified Morisita index (Horn 1966) with the function  
137 niche.overlap of the R package spaa (Zhang et al. 2010, R Development Core Team  
138 2012). The resulting index ranges from 0 (completely distinct diets) to 1 (identical  
139 diets). We removed data with similarity = 0 and then applied an arcsin-transformation  
140 to the remaining data in order to comply with normality assumptions of LMM. The effect  
141 of the difference in the predator identification method was included as a categorical  
142 predictor with three factor levels: HCI-HCI, HCI-LCI and LCI-LCI. The geographical

143 distance was measured in km from the centroid of each study polygon using the  
144 function `spT.geo.dist` of the R package `spTimer` (Bakar and Sahu 2012, R  
145 Development Core Team 2012). In order to account for the effects of geographical  
146 distance on trophic similarity (e. g. associated to differences in prey communities) we  
147 also tested the distance effects and its interaction with the identification method.  
148 Besides, we controlled for the use of the same study in the calculation of many  
149 similarity pairs including the identity of each study of the pair as random intercepts in  
150 LMM analyses. In order to test for the specific contribution of the predator identification  
151 methods we compared the saturated model including all effects against a null model  
152 including only the fixed effect of the geographic distance and the random effects of  
153 study sites. Comparisons between these two models were performed using the  
154 likelihood ratio test (Bolker et al. 2008) and the significance of each fixed effect in the  
155 saturated model was assessed based on Markov Chain Monte Carlo sampling (Bolker  
156 et al. 2008) using the R package `languageR` (Baayen 2011, R Development Core  
157 Team 2012).

### 158 **Prey mismatches between predator identification methods**

159 We compared the prey items obtained in LCI with those obtained in HCI studies to  
160 evaluate the possible inclusion and omission of prey as a consequence of potential  
161 faeces misidentification using LCI methods. For that purpose, we compared each LCI  
162 study with all available HCI studies, obtaining the percentages of prey items that  
163 resulted from potential inclusion (i. e. exclusively found in LCI) and omission (i. e.  
164 exclusively found in HCI) errors. The same was undertaken with all pairs of HCI studies  
165 in order to compare the former results with the only difference that we obtained two  
166 values per pair (equivalent to non-matching prey, rather than inclusion or omission)  
167 since figures may be different depending of what element of the pair is used as  
168 reference. If there were no errors in the identification of the predator by LCI methods,  
169 we expected to find no significant difference between results obtained in HCI-LCI  
170 comparisons from those obtain in HCI-HCI comparisons, which was examined by the

171 Mann-Whitney U test (Sokal and Rohlf 1981). To minimize the effect of differences in  
172 prey availability between study sites we analyzed the data by ecoregions (Nearctic  
173 and Neotropic) where large-scale patterns in prey availability are expected to be  
174 more similar. In addition, we tested whether differences in percentages of exclusive  
175 prey between pairs of studies were associated to distance using linear models through  
176 the function `lm` of the R package Stats (R Development Core Team 2012). For jaguars  
177 we only had one study in the Nearctic, so analyses were only undertaken for the  
178 Neotropic. We assigned the ecoregions corresponded to each study site in a  
179 Geographic Information System (ARC/INFO v10.0, ESRI 2011) using the digital map  
180 of Terrestrial Ecoregions of the World (Olson et al. 2001).

181 In order to further control for the possible effect of differences in prey, we also  
182 analyzed differences between diet studies undertaken within the distributional areas of  
183 each prey item considered representative of the diet of jaguars and cougars. Thus, for  
184 these analyses we first identified the set of representative prey items ( $PO \geq 10\%$  of the  
185 total diet in any study excluding domestic prey and vegetable matter) for each predator  
186 and delineated their distributions using the IUCN digital distribution maps (IUCN 2012).  
187 Prey taken as potentially included in LCI studies were those recorded with  $PO \geq 10\%$  in  
188 at least one LCI study and no recorded in any HCI study performed inside the  
189 distributional area of the respective prey, and *vice versa* for prey potentially omitted.  
190 The number of LCI and HCI studies overlapping the distribution of each representative  
191 prey was obtained using a Geographic Information System (ARC/INFO v10.0, ESRI  
192 2011). Differences between percentages of potential inclusion and omission of  
193 representative prey for each predator were tested by the Z test (Sokal and Rohlf 1981).

194 Finally, we obtained a broad picture of the diet composition of jaguar and  
195 cougar throughout their distribution ranges by analyzing which prey items were found in  
196 HCI studies with  $PO \geq 10\%$ . Results were reported at the taxonomic identification level  
197 originally achieved in those studies.

## 198 **Results**

### 199 **Data compilation and standardization**

200 We found a total of 61 studies on diet composition of jaguars and cougars published  
201 between 1959 and 2013. From these studies we obtained 32 diet descriptions for  
202 jaguars (with 54 food items identified) and 61 for cougars (with 79 food items  
203 identified), from which only 9 descriptions (28.1% of the total) corresponded to studies  
204 that used HCI methods to identify the predator for jaguars, all of them from the  
205 Neotropic; and 16 for cougars (26.2% of the total), 8 in each ecoregion (Fig. 1). In most  
206 cases prey items were identified to the genus level. See supplementary material  
207 Appendix 1, Table A1 for a list of the studies used, and Appendix 2 for their complete  
208 references.

### 209 **Effect of the predator identification method on diet similarity**

210 Full models (main effects and their interaction) were significant for both cougar and  
211 jaguar (likelihood ratio test:  $\chi^2 = 22.82$ , DF = 4,  $p < 0.001$ ; and  $\chi^2 = 21.11$ , DF = 4,  $p <$   
212  $0.001$ , respectively), and each factor separately, i.e. predator identification method and  
213 distance, also significantly affected the similarity between diet studies (Table 1). As  
214 predicted, trophic similarity was higher between pairs of HCI studies and lower at  
215 longer distances (Fig. 2, Table 1).

### 216 **Prey mismatches between predator identification methods**

217 For all cases, i. e. jaguar in the Neotropic and cougar in both ecoregions, the average  
218 percentage of exclusive prey (i. e. mismatches between studies) was always lower  
219 when comparing HCI-HCI studies than when comparing HCI-LCI studies (Table 2).  
220 However, such differences were significant only for potential inclusion of prey items in  
221 LCI studies for jaguars in the Neotropic ( $U = 5569.5$ ,  $p = 0.006$ ), and for both potential  
222 inclusion ( $U = 3402$ ,  $p = 0$ ) and omission ( $U = 5826.5$ ,  $p = 0.005$ ) of prey for cougars in  
223 the Neotropical region. Furthermore, when we represented the percentage of exclusive  
224 prey as a function of distance between study areas, we observed a significant positive

225 trend in all HCI-HCI comparisons excepting for cougar's studies in the Nearctic (Fig. 3,  
226 Table 3). Nonetheless, in HCI-LCI comparisons such a response was significant for  
227 inclusion of prey in LCI cougar's studies of both ecoregions, and for omission of prey in  
228 the Nearctic (Fig. 3, Table 3). The inclusion and omission of prey for jaguars did not  
229 show a significant trend, and neither did the percentage of omission for cougar's LCI  
230 studies in the Neotropic (Fig. 3, Table 3).

231         When we analyzed the prey mismatches between predator identification  
232 methods taking into account the distributional ranges of the representative prey rather  
233 than the ecoregion, we found that for both predators almost half (42.1%,  $n = 19$  for  
234 jaguars; and 44.8%,  $n = 29$  for cougars) of the items considered representative of the  
235 diet in LCI studies might be potentially included, since were not representative in HCI  
236 studies. Whereas for potential omission, we found that 15.8% ( $n = 19$ ) of the items  
237 considered representative for cougar's diet in HCI studies were not in LCI studies, but  
238 no omission of prey was found for jaguar ( $n = 11$ ). Percentage of potential inclusion of  
239 representative prey was significantly greater than potential omission for jaguars ( $Z =$   
240  $2.085$ ,  $p = 0.037$ ) but did not for cougars ( $Z = 1.771$ ,  $p = 0.076$ ). See supplementary  
241 material Appendix 1, Table A2 for detailed data of representative prey and number of  
242 HCI and LCI studies where they appeared.

#### 243 **Brief overview of the main prey consumed by jaguars and cougars according to** 244 **HCI studies**

245 In the Neotropical region, mammal prey such as anteaters, sloths, pacas, agoutis,  
246 peccaries, brocket deer, armadillos, and lagomorphs were frequent in the diet of both  
247 predators. Coatis were a representative prey only in jaguar's diet, whereas deers,  
248 opossums, and monkeys were representative only in cougar's diet (Table 4). For  
249 cougars in the Nearctic, the most important prey were deer, peccaries, moose,  
250 lagomorphs, porcupines, and skunks, but also domestic prey as sheep, cattle, and  
251 carrion (Table 4).

252 According to the total number of studies that used HCI methods, armadillos  
253 were the prey most widely consumed by jaguars (7 of 9 studies; representing up to  
254 46% of occurrence in some studies), while pacas (6 of 8 studies; up to 58% of  
255 occurrence) and deers (5 of 8 studies; up to 21% of occurrence) were the most  
256 important prey for cougars in the Neotropic. In the Nearctic, deers were present in all  
257 eight studies of cougars with an occurrence in the diet up to 69% (Table 4).

258 Taking into account only items identified to species level, 9 were representative  
259 prey species in the diet of Neotropical jaguars, being *Myrmecophaga tridactyla*  
260 (although only in one study) and *Dasypus novemcinctus* the ones which reached  
261 higher percentages of occurrence (Table 4). Regarding cougars, *Choloepus didactylus*  
262 and *Cuniculus paca* were the most important of the 8 prey species with PO  $\geq$  10%;  
263 while in the Nearctic, *Odocoileus hemionus* and *Pecari tajacu* (although appeared in a  
264 single study) presented the higher values of the 9 representative prey species (Table  
265 4).

## 266 **Discussion**

### 267 **Possible effects of predator identification reliability on diet studies**

268 The determination of the diet of carnivores through faeces analyses is associated to a  
269 level of uncertainty in the predator identification process, which may produce a bias in  
270 the results. For cougars and jaguars, Fernandez et al. (1997) shown that only 38% of  
271 jaguar and 30% of cougar faeces were identified correctly using subjective criteria as  
272 compared with identification through bile acid analyses. Moreover, they found that  
273 diameters of cougar and jaguar faeces overlapped at almost all sizes from 20 to 39  
274 mm, making it difficult a morphological differentiation. In another study, Farrel et al.  
275 (2000) found that 83% of faeces classified as jaguar or cougar on the basis of size  
276 thresholds were actually produced by ocelots (*Leopardus pardalis*) or crab-eating foxes  
277 (*Cerdocyon thous*). They concluded that using faeces size thresholds instead of DNA  
278 analysis to identify a carnivore species is likely to result in misinterpretation of dietary  
279 behavior. Studies in other carnivores support that high misclassification rates can be a

280 general source of bias in many other species. Davison et al. (2002) found that expert  
281 naturalists failed to distinguish pine marten (*Martes martes*) and red fox (*Vulpes*  
282 *vulpes*) faeces. Harrington et al. (2010), shown that none of 45 American mink  
283 (*Neovison vison*) faeces identified by experienced surveyors in 31 study sites were  
284 correctly identified, being confounded with a diversity of other species including pine  
285 marten, red fox, Eurasian otter (*Lutra lutra*), polecat (*Mustela putorius*) and stoat  
286 (*Mustela erminea*). Although these error rates are troubling, to our knowledge no  
287 previous work has analyzed the effects on the results of diet studies. Our results show  
288 that assuming equal confidence between the different identification methods  
289 significantly influences how similar are the diets between different studies.  
290 For both jaguars and cougars, similarity between diet studies that identified the  
291 predator through HCI methods was higher than those using LCI methods, once the  
292 effect of distance was controlled. This result supported our suspect that LCI methods  
293 are including prey from predators different to the target one. Furthermore, it is  
294 interesting to note that prey mismatch analyses indicated that LCI studies on both  
295 species in the Neotropical region included prey items that may actually have not been  
296 consumed by these predators. In the case of cougars the percentage of inclusion was  
297 also influenced by the distance among sites, which is indicator of changes in prey  
298 communities. We also found a significant omission of prey items in LCI studies for  
299 cougars in the Neotropic, but not for jaguars, despite that the trend obtained in relation  
300 to distance suggested a potential omission error. As expected, we found a significant  
301 effect of distance on the percentage of exclusive prey in HCI-HCI comparisons, except  
302 for cougar's studies in the Nearctic, which might be due to similarities on prey  
303 availability among sites.

304 On the other hand, we did not detect any significant difference in the inclusion-  
305 omission analysis for cougars in the Nearctic. Distance had a significant effect over the  
306 percentage of exclusive prey, thus in this case the predator identification method could  
307 not be biasing the trophic spectrum of cougars. Since cougars and jaguars overlap

308 their ranges mostly in the Neotropic (Seymour 1989, López-González and González-  
309 Romero 1998), this might be indicating that jaguar is the species which is most likely to  
310 confound cougar's faeces, as has been suggested by Fernandez et al. (1997) and  
311 Farrel et al. (2000). Additionally, it could also be indicating that the diet of cougars in  
312 the Nearctic is very similar to the diet of other carnivores with potentially similar faeces.  
313 In fact, wolves and cougars seem to have similar diets in some areas (Kunkel et al.  
314 1999, Kortello et al. 2007).

315 The results obtained in the evaluation of the potential inclusion and omission  
316 errors were supported by the independent analysis for each representative prey item  
317 identified (which comprised only the diet studies that were within the distribution areas  
318 of these prey): the error of including a prey as representative in LCI studies was more  
319 frequent than the error to omit it.

#### 320 **Diet of jaguars and cougars**

321 There are some reviews about jaguar and cougar diet studies along their  
322 distributional ranges (Iriarte et al. 1990, López-González and González-Romero 1998,  
323 Oliveira 2002, Laundré and Hernández 2010, Haemig 2012), however none of them  
324 have considered the confidence of the method employed to identify the predator and  
325 neither the result of mixing studies with different levels of uncertainty. Our results  
326 suggest that studies based on LCI methods might overestimate the importance of  
327 reptiles and rodents in the diet of both felids, since in the set of representative prey, we  
328 found that *Caiman*, *Iguana* and *Tupinambis* were overemphasized for both predators;  
329 and *Ctenosaura* and *Serpentes* for cougars. Whereas regarding rodents, *Hydrochoerus*  
330 and *Proechimys* were included for both felids; while *Cricetidae*, *Ctenomys*, *Dolichotis*  
331 and *Lagostomus* only for cougars. Mesocarnivores may have also been overestimated,  
332 *Procyon* for cougars, and *Cerdocyon* for jaguars. Also included in the set of  
333 representative prey of cougars were giant anteater (*Myrmecophaga*) and sheep (*Ovis*);  
334 and for jaguars were sloth (*Bradypus*), deer (*Odocoileus*), and Primates. On the

335 contrary, the importance of *Alces*, *Erethizon* and Mephitidae was underestimated for  
336 cougar's diet in LCI studies.

337 Furthermore, looking at two jaguar diet studies from the same site that differ in  
338 the confidence of the predator identification method (Silveira 2004 for LCI, and  
339 Sollmann et al. 2013 for HCI), we found that Tayassuidae was the most important prey  
340 item in the LCI study, while it was only represented 6% of the total diet in the HCI  
341 study. Besides, Aves and *Ozotoceros bezoarticus* represented 13% in the LCI study  
342 but they were not present at all in the HCI study. *Myrmecophaga tridactyla* was an  
343 important prey in both studies, but much more in the HCI one.

344 In another case like the exposed before where we had two jaguar studies in the  
345 same site (Rabinowitz and Nottingham 1986 for LCI, and Foster et al. 2010 for HCI),  
346 we found that both studies reported Dasypodidae as the main prey item, but it was  
347 more important in the LCI study. Additionally, Tayassuidae was the second most  
348 important item in the HCI study (PO = 15.40%) but it was not representative in the LCI  
349 one (PO = 5.40%), the same occurred with *Nasua narica* which represented 10.8% of  
350 the total diet in the HCI and only 1% in the LCI study. On the contrary, *Cuniculus paca*  
351 and *Tamandua mexicana* followed the most important prey in the diet (PO = 9.30%) in  
352 the LCI study but were barely consumed in the HCI one (4.5 and 0.8%, respectively).

353 There were no studies in the same area for cougars, but from two close study  
354 sites in the Neotropic (Silveira 2004 for LCI, and Taber et al. 1997 for HCI), we found  
355 that Dasypodidae and Tayassuidae were the most important prey items in the LCI  
356 study, while in the HCI study represented less than 6% of the total diet. The rest of the  
357 prey items between these two studies were completely different. In the Nearctic, again  
358 from two close study sites (Cunningham et al. 1999 for LCI, and McCain 2008 HCI),  
359 diet results were more similar, since all representative prey items found in the LCI  
360 study appeared in the HCI, and *Odocoileus* sp. was the most important prey in both  
361 studies. However, cattle and Tayassuidae were more important in the LCI study and

362 Lagomorpha in the HCI one; besides eight prey items were only reported in the HCI  
363 study.

364 Even though it was not our purpose to perform a detailed review of jaguar's and  
365 cougar's diets, but rather to call for attention about potential errors that might be  
366 committed in LCI studies, we can highlight some general findings about diets according  
367 to HCI studies. First of all, the variability of prey consumed by both felids support a  
368 generalist predation pattern, from which mammals comprised the bulk. We also found  
369 coincidence of some representative prey groups for cougars and jaguars in the  
370 Neotropic, however there was a difference in their relative importance. Thus, sloths and  
371 pacas were more important for cougars than for jaguars; while anteaters, armadillos,  
372 agoutis, peccaries, brocket deer, lagomorphs and birds were more important for  
373 jaguars than for cougars. In addition, armadillos were the most broadly consumed prey  
374 by jaguars; while for cougars they were pacas and brocket deer. Concerning to  
375 mammals that could be identified at a species level, we remark the importance of  
376 *Tamandua tetradactyla*, *Choloepus didactylus*, *Cuniculus paca* and *Mazama*  
377 *gouazoubira* for being relevant in the diet of both predators in the Neotropical region,  
378 which could derive into some level of niche overlap and exploitative competition where  
379 they are sympatric. In the Nearctic region, we found cervids (mainly *Odocoileus* sp.)  
380 was the most important prey group for cougars and the most broadly consumed.

381 Thus reliable information on diet composition for both predators is much scarcer  
382 than expected, particularly for jaguars, and only comprised a small fraction of the total  
383 distribution area of each species: 9 study sites distributed in 4 countries for jaguars,  
384 and 16 sites within 6 countries for cougars. Thus, in the area where their distributions  
385 overlap the information available reduces to 8 studies for jaguars and 7 for cougars (in  
386 both cases located in Belize, Guatemala, Brazil and Paraguay, 21% of the total  
387 countries where they can coexist), which represent 25% of total data found for jaguars  
388 and 11.47% for cougars.

389 **Final considerations**

390           Jaguars and cougars are considered to be declining; they are threatened by  
391 habitat loss, fragmentation, over-hunting by people of their prey and themselves  
392 (Sanderson et al. 2002, Negri and Quigley 2010). In this context, conservation and  
393 management programs based on accurate ecological knowledge on their habitats and  
394 feeding requirements are urgently required. Inaccurate results of diet assessments  
395 could have far reaching implications, especially if they are used to explain processes  
396 like coexistence, competition, conflict with humans, and resource partitioning (e. g.  
397 Facure and Giaretta 1996, Núñez et al. 2000, Leite and Galvao 2002, De Azevedo  
398 2008), since estimates like niche breadth and/or overlap, mean prey weight, biomass  
399 consumed, and issues of comparative ecology with other carnivores, or among sites,  
400 depend on the number, kind and proportion of the items in the diet (e. g. Levins 1968,  
401 Colwell and Futuyma 1971, Hurlbert 1978, Ackerman et al. 1984, Iriarte et al. 1990).  
402 Thus, even so approaches for a reliable identification of predators are expensive and  
403 require specialized technicians, materials, and equipment; we highlight the need to  
404 invest on them in order to accomplish a better ecological understanding for these  
405 species conservation.

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559 Appendix 1-2.

560 **Tables**

561 Table 1. Generalized Linear Mixed Models results for the effect of the method  
 562 employed to identify the predator, the distance between study areas, and their  
 563 interaction, on the trophic similarity (simplified Morisita index) found between pairs of  
 564 diet studies. Only pairs with similarity >0 were included in this analysis. Sample sizes  
 565 (pairs of studies): HCI-HCI = 36 and 98; HCI-LCI = 200 and 563; LCI-LCI = 245 and  
 566 847, for jaguars and cougars, respectively.

567

Effect	Jaguar			Cougar		
	Estimate	SE	pMCMC	Estimate	SE	pMCMC
Intercept HCI-HCI	7.668e-01	7.530e-02	0.0001	8.994e-01	5.052e-02	0.0001
Distance	-5.844e-05	1.529e-05	0.0004	-6.936e-05	6.902e-06	0.0001
HCI-LCI	-2.456e-01	6.594e-02	0.0001	-1.790e-01	4.158e-02	0.0001
LCI-LCI	-1.975e-01	8.394e-02	0.0156	-2.436e-01	5.658e-02	0.0001
Interaction	4.571e-05	1.639e-05	0.0084	1.867e-05	7.418e-06	0.0086
Dist:Methods HCI-LCI						
Interaction	4.229e-05	1.614e-05	0.0128	2.169e-05	7.167e-06	0.0016
Dist:Methods LCI-LCI						

568

569 HCI: high confidence identification; LCI: low confidence identification; pMCMC, p value  
 570 based on Markov Chain Monte Carlo sampling.

571 Table 2. Mean percentage ( $\pm$ SE) of exclusive prey when comparing each two diet  
572 studies for jaguars and cougars in Neotropic and Nearctic regions regarding the levels  
573 of confidence in predator identification (i.e. HCI-HCI and HCI-LCH). For each pair of  
574 studies compared we obtained two values (one from each study of the pair). In the  
575 case of HCI-LCI comparisons, results are shown in different columns, indicating in bold  
576 what study is used as reference for the comparison. When HCI study is used as  
577 reference, the percentage of exclusive prey is informing about potential omission of  
578 prey, while when LCI study is used as reference, the percentage of exclusive prey is  
579 informing about potential inclusion of prey. Asterisks indicate when the Mann-Whitney  
580 U tests detected significant differences (i.e.  $p < 0.05$ ) for the comparison of **HCI-LCI**  
581 and **HCI-LCI** data with those obtained in HCI-HCI for jaguars and cougars separately.  
582

Percentage of exclusive prey						
	Jaguar			Cougar		
	HCI-HCI	<b>HCI-LCI</b>	<b>HCI-LCI</b>	HCI-HCI	<b>HCI-LCI</b>	<b>HCI-LCI</b>
Neotropic	55.6 $\pm$ 2.67	59.5 $\pm$ 1.60	65.1 $\pm$ 1.33*	50.4 $\pm$ 2.87	59.9 $\pm$ 1.98*	73.8 $\pm$ 1.28*
	n=72	n=198	n=198	n=56	n=272	n=272
Nearctic	-	-	-	52.7 $\pm$ 2.61	55.4 $\pm$ 2.01	56.1 $\pm$ 2.32
				n=56	n=88	n=88

583

584

585 Table 3. Linear Models results for the effect of distance (km) between study areas on  
 586 the percentages of exclusive prey obtained in HCI-LCI comparisons and those  
 587 obtained in HCI-HCI comparisons for cougars and jaguars by ecoregion. For HCI-LCI  
 588 pairs we indicated in bold what study is used as reference for the comparison. When  
 589 HCI studies are used as reference, the percentage of exclusive prey is informing about  
 590 potential omission of prey in LCI studies, while for the contrary the percentage of  
 591 exclusive prey is informing about potential inclusion.

592

Cougar								
Comparison	Neotropic				Nearctic			
	Estimate	SE	<i>t</i>	p	Estimate	SE	<i>t</i>	p
HCI- <b>LCI</b>	2.966e-03	6.121e-04	4.846	<0.001	5.36e-03	1.83e-03	3.559	<0.01
<b>HCI</b> -LCI	-7.802e-04	9.855e-04	-0.792	0.429	7.363e-03	2.069e-03	2.929	<0.01
HCI-HCI	5.628e-03	1.364e-03	4.126	<0.001	4.286e-03	3.505e-03	1.223	0.227
Jaguar								
HCI- <b>LCI</b>	-1.703e-04	6.716e-04	-0.254	0.8				
<b>HCI</b> -LCI	8.834e-06	8.981e-04	0.011	0.991				
HCI-HCI	3.206e-03	1.372e-03	2.337	<0.05				

593

594

595 Table 4. Prey items (taxonomic resolution as originally reported in the bibliography  
 596 sources) with percentage of occurrence (PO)  $\geq$  10% in diet studies of jaguars and  
 597 cougars that used high confidence identification methods, and the number of studies  
 598 (n) where these prey items were recorded (between brackets are shown the ranges of  
 599 PO reported in the studies).

600

Main prey	Jaguar		Cougar			
	Neotropic		Neotropic		Nearctic	
	(N=9)		(N=8)		(N=8)	
	n	(range)	n	(range)	n	(range)
MAMMALIA	9	(10.1-74)	8	(10.2-62.7)	8	(10.2-68.5)
Pilosa	3	(14.8-74)	3	(10.2-62.7)		
Megalonychidae	2	(20-26)	3	(11.1-62.7)		
<i>Choloepus didactylus</i>	2	(20-26)	3	(11.1-62.7)		
Myrmecophagidae	2	(14.8-74)	1	(11.1)		
<i>Tamandua tetradactyla</i>	1	(14.8)	1	(11.1)		
<i>Myrmecophaga tridactyla</i>	1	(74)				
Bradyrodidae			1	(10.2)		
<i>Bradypus</i>			1	(10.2)		
Rodentia	3	(10.1-20)	8	(10.2-57.9)	3	(10.2-13.5)
n.i.	1	(10.1)	2	(12.1-20)		
Cuniculidae	1	(20)	6	(10.2-57.9)		
<i>Cuniculus paca</i>	1	(20)	6	(10.2-57.9)		
Dasyproctidae	2	(20)	4	(11.1-22.4)		
<i>Dasyprocta</i>			4	(11.1-22.4)		
<i>D. punctata</i>			2	(17.7-22.4)		
<i>D. sp.</i>	2	(20)	2	(11.1-11.8)		
Caviidae			1	(14.3)		

<i>Galea musteloides</i>			1	(14.3)		
Erethizontidae					3	(10.2-13.5)
<i>Erethizon dorsatum</i>					3	(10.2-13.5)
Artiodactyla	4	(20-24.1)	5	(11.1-21.2)	8	(11-68.5)
Cervidae	2	(21.7-24.1)	5	(11.1-21.2)	8	(11-68.5)
<i>Mazama</i>	2	(21.7-24.1)	5	(11.1-21.2)		
<i>M. gouazoubira</i>	2	(21.7-24.2)	1	(21.2)		
<i>M. sp.</i>			4	(11.1-20.3)		
<i>Odocoileus</i>			1	(15.2)	8	(27-68.5)
<i>O. hemionus</i>					6	(28-68.5)
<i>O. virginianus</i>			1	(15.2)	1	(31.5)
<i>O. sp.</i>					1	(39.1)
<i>Cervus elaphus</i>					1	(18.6)
<i>Alces alces</i>					1	(11)
Tayassuidae	2	(20-20.6)	2	(11.1-12.1)	1	(39.1)
n.i.			1	(12.1)		
<i>Tayassu pecari</i>			1	(11.1)		
<i>Pecari tajacu</i>	2	(20-20.6)			1	(39.1)
Bovidae					1	(18.2)
<i>Ovis aries</i>					1	(18.2)
Cingulata	7	(11.1-46.4)	1	(21.2)		
Dasyopodidae	7	(11.1-46.4)	1	(21.2)		
n.i.	4	(11.1-40)	1	(21.2)		
<i>Dasyopus novemcinctus</i>	3	(26.5-46.4)				
Lagomorpha	2	(22.2-24.6)	1	(15.2)	2	(15.4-27)
n.i.	2	(22.2-24.6)	1	(15.2)		
Leporidae					2	(15.4-27)
<i>Lepus americanus</i>					1	(27)
<i>Sylvilagus floridanus</i>					1	(15.4)
Didelphimorphia			1	(12.9)		

Didelphidae			1	(12.9)		
<i>Didelphis albiventris</i>			1	(12.9)		
Primates			1	(11)		
n.i.			1	(11)		
Carnivora	3	(10.8-23.5)			1	(11.2)
Mephitidae					1	(11.2)
n.i.					1	(11.2)
Procyonidae	3	(10.8-23.5)				
<i>Nasua</i>	3	(10.8-23.5)				
<i>N. nasua</i>	2	(22.4-23.5)				
<i>N. narica</i>	1	(10.8)				
Carrion					1	(13)
Cattle					1	(11.9)
AVES	1	(20)	1	(12.1)		
PLANTAE					1	(17.1)

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601

602

603 **Figure Legends**

604 Figure 1. Geographical distribution of diet studies of jaguars (a) and cougars (b).  
605 Darkest areas are the current distribution ranges according to Zeller (2007) for jaguar  
606 and IUCN (2012) for cougar. White points represent location of predator high  
607 confidence identification studies, black triangles represent location of predator low  
608 confidence identification studies, and white squares represent sites with both high and  
609 low confidence identification studies.

610 Figure 2. Mean and standard error of diet similarity (simplified Morisita index)  
611 between pairs of studies with similarity  $>0$  according to the confidence of the method  
612 employed to identify the predator for jaguar and cougar. HCI: high confidence  
613 identification; LCI: low confidence identification. Sample sizes (pairs of studies): HCI-  
614 HCI= 36 and 98; HCI-LCI= 200 and 563; LCI-LCI= 245 and 847, for jaguar and cougar,  
615 respectively.

616 Figure 3. Percentage of prey items exclusive to the LCI study (gray points) and  
617 the HCI study (black points) for every pair of HCI-LCI studies compared in function of  
618 the distance between them for jaguars in the Neotropic, and cougars in the Neotropic  
619 and in the Nearctic (left panels). For comparison, the same information (i.e. percentage  
620 of prey items exclusive) is represented for all pairs of HCI-HCI studies compared (right  
621 panels). Tendency lines and their standard errors are also shown.