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Field studies need to report essential information on social organisation – independent of the study focus

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1 **Field studies need to report essential information on**
2 **social organization – independent of the study focus**

3

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16

17 **Abstract**

18 Comparative studies on social evolution are ideally based on large datasets to ensure high
19 statistical power, but their scientific validity also relies on the quality of the data. However,
20 even though social organization, i.e., the composition of social units, is measured in many
21 field studies testing specific hypotheses, these data are often not adequately reported. Here,

22 we summarise which data on social organization should always be reported regardless of the
23 study focus to make them available for comparative studies. As an example, we report data
24 from a literature survey on one of the four superorders of placental mammals, the Xenarthra
25 from South America (armadillos, anteaters and sloths), of which all 30 species are generally
26 assumed to be solitary living. In total we found 4510 articles. The titles and abstracts of 61
27 publications indicated that data on social organization were collected, but only 12
28 publications contained sufficient information for us to determine the social organization. We
29 found reliable information on nine species, of which seven were strictly solitary. Two species
30 showed a combination of solitary-living and pair-living with one including female groups. This
31 review therefore indicates that Xenarthra may not be exclusively solitary. Our literature
32 survey further shows that valuable data are often not reported even though it can be assumed
33 that these data had been collected. We report examples from 23 additional studies on
34 monotremes, marsupials, and two other placental superorders showing similar issues in
35 reporting data. It is important to make authors aware that this information would be valuable
36 for comparative studies. In sum, we recommend including data on the composition of social
37 units, sex of individuals, occupancy of sleeping sites, frequency of observations and trapping
38 events, home range overlap, and the proportion of the individuals in the study area,
39 independent of the study question in all publications.

40

41 **Keywords:** Comparative study; Field data; Intraspecific variation; Social organization; Social
42 system; Social structure

43

44

45 **Introduction**

46 Comparative studies yield significant insight into the evolution of social systems (Chak et al.,
47 2017; Cornwallis et al., 2017; Firman et al., 2020; Griesser et al., 2017; Lukas & Clutton-Brock,
48 2013). The quality of such comparisons has increased over the last decades due to significant
49 improvements in statistical methods that correct for phylogeny and enable us to include
50 ecological and life-history factors (Garamszegi, 2014). However, the quality of comparative
51 studies also depends on the quality of the used database (Schradin, 2017). Many researchers
52 focused on getting a large, instead of an accurate, database, for example by using
53 phylogenetic inferences to add species that had not been studied (birds: Cockburn, 2006;
54 used also by Gonzalez et al., 2013; Jetz & Rubenstein, 2011; mammals: Lukas & Clutton-Brock,
55 2013). There are now statistically sound methods to infer missing phylogenetic data points
56 (for example see Callaghan et al. (2021)), which are useful when the important life-history
57 and ecological data for a few species are known, so that one can include these species.
58 However, such inference should only be done if the social data are missing from just a few
59 but not the majority of species (Schradin, 2017). Furthermore, information assuming the
60 social system from anecdotal observations or expert opinion published in secondary and
61 tertiary sources has often been included for species that have never been studied in the field
62 (Schradin, 2017). This has been criticised and a more careful approach has been
63 recommended (Griesser & Suzuki, 2016; Huck et al., 2020), i.e. to only use data from studies
64 where animals have been studied in their natural environment (Schradin, 2017). However,
65 while the number of field studies has increased over the last decades (Schradin & Hayes,
66 2017), basic data on social systems are often not reported in a way that makes them useable
67 for comparative studies.

68 In the field of Behavioural Ecology, the focus on field studies is on theory-driven
69 research and not on describing the social system of species (Clutton-Brock & Janson, 2012).
70 Social organization, which means the sex and the composition of social units, is one of the
71 four key components of social systems (Kappeler & van Schaik, 2002). Social organization is
72 easier to observe and to record than the three other components of the social system
73 (Schradin et al., 2018), which are the mating system (who reproduces with whom), the social
74 structure (social interactions; social networks) and the parental care system (who takes care
75 of the offspring) (Kappeler, 2019). While field researchers often record the composition of
76 study groups, details of such basic data are often not reported in the arising publications that
77 test specific hypotheses.

78 The conclusions from hypothesis-driven research are important to test and develop
79 theory; however; conclusions can change and the main values of each study are the data that
80 were recorded. It is as important to include these data and the conclusions drawn from them.
81 The availability of published data has been recognised as being of crucial importance
82 (Ramachandran et al., 2021; Reichman et al., 2011). For comparative studies and for meta-
83 analyses data are more valuable than interpretations. This is demonstrated by the example
84 of intra-specific variation in social systems (Lott, 1984; Schradin et al., 2018). For example, if
85 a study population is reported to be pair-living because most animals live in pairs but some
86 populations or individuals also live solitarily or in groups, then biologically meaningful
87 variation might be missed. We have been building a database on mammalian social evolution
88 since 2015 (Agnani et al., 2018; Valomy et al., 2015). For this, we have searched more than
89 ten thousand peer-reviewed articles for information about the composition of social units,
90 focusing on data reported in the methods and results sections. We noticed that many field
91 studies that presumably collected such data did not report them, but instead assigned a

92 general form of social organization to the study population in the introduction and / or
93 discussion.

94 The aim of the current paper was to identify which data are often missing from
95 publications even though they probably had been collected and could have been used to
96 accurately assign social organization, including its variation. For this, we surveyed the
97 literature on one mammalian superorder as an example, the Xenarthra (armadillos, sloths and
98 ant-eaters), and added more examples from other mammalian taxa. We chose this
99 superorder as it is small, containing only 30 species, all of which had been assumed to live
100 solitary (Lukas & Clutton-Brock, 2013). Our aims were to (1) provide an overview of what is
101 known regarding the social organization of Xenarthra, (2) identify which information is
102 missing in published field studies on Xenarthra to correctly characterise their social
103 organization, (3) report additional examples from other mammalian taxa, and finally (4)
104 provide a template for field researchers on which data to provide in every published paper so
105 that they are available for comparative studies of social evolution.

106

107

108 **Methods**

109 *Xenarthra social organization*

110 The Xenarthra (armadillos, sloths and anteaters) is one of four superorders within the
111 placentals; with the other three being Afrotheria (elephants, sea cows and elephant-shrews),
112 Euarchontaglires (primates and rodents) and Laurasiatheria (bats, carnivores and ungulates)
113 (Wildman et al., 2007). Xenarthra mainly occur in South America, with one species ranging to

114 North America. They consist of 30 species of which 20 belong to the order Cingulata
115 (armadillos) and 10 to the order Pilosa (six species of sloths and four species of anteaters).
116 Xenarthra are typically considered to be solitary living (Lukas & Clutton-Brock (2013)
117 categorised all 24 Xenarthrans in their database as solitary living), though it has been
118 acknowledged that small groups might occur (Nowak & Wilson, 1999; Wilson & Mittermeier,
119 2018). Determining the social organization of species in this superorder is important for
120 comparative studies regarding mammalian social evolution.

121

122 *Data collection and literature review Xenarthra*

123 Literature research was done from the 27th July 2020 until the 30th June 2021. During this
124 period a species list of the extant members of the superorder Xenarthra was compiled using
125 the IUCN Red List of Threatened Species (www.iucnredlist.org). Using this list, a search was
126 conducted on the primary literature on social organization in Web of Science and Google
127 Scholar. The search string used to assemble this information consisted initially of the term
128 social in conjunction with the species scientific name or common name. For example, the
129 search string used for the Northern long-nosed armadillo *Dasypos sabanicola* was ("*Dasypos*
130 *sabanicola*" OR "Northern long-nosed armadillo" AND "*social*"). If no records were found with
131 the initial search string, then a second search string was used that consisted only of the
132 scientific species name (e.g., "*Dasypos sabanicola*"). If the second search string still yielded
133 no results, then the final search string used was just the genus name and the term social (e.g.,
134 "*Dasypos*" AND social). Within the search results from Web of Science, the following research
135 areas were selected to refine the results – "*zoology*", "*behavioural science*" and
136 "*environmental science/ecology*" – and the document type - "*article*". All publication titles

137 that were not applicable to the topic were removed from the generated database. From the
138 remaining articles the abstracts were read and reviews not reporting primary data or studies
139 done on captive animals were excluded from the database. The PDFs of the remaining
140 publications were then obtained and searched for the following terms related to social
141 organization: “social,” “group,” “territorial,” “solitary,” “bachelor,” “plural,” “aggregation,”
142 “gregarious”, “pair” and “singular.” The figures, tables and supplementary materials were also
143 checked for information that may not have been recorded in the main text. The same process
144 was applied in Google scholar to search for additional articles.

145 The social organization described in the primary literature for each of the species was
146 recorded according to the following categories (for details see (Agnani et al., 2018; Valomy et
147 al., 2015): “solitary,” “pair,” “one male multiple females,” “one female multiple males,”
148 “multiple males and multiple females.”

149

150 *Data from other mammalian taxa*

151 We are in the process of building a database on mammalian social organization reported from
152 field studies using the same methods as described above. In addition to the detailed case
153 study on Xenarthra, we also reported examples from several other mammalian taxa, but
154 without the claim to cover all species in these taxa.

155

156 **Data analysis**

157 The following variables were calculated from the information provided from the literature.
158 The total number of social units observed per population and per species was summed up.

159 Then the main social organization was determined by the most commonly observed social
160 organization. Following this, the percentage of main social organization was calculated by
161 dividing the number of social units of the main social organization by the total number of
162 social units multiplied by 100. Finally, intra-specific variation in social organization (IVSO) was
163 determined as within population when variation occurred only within a population, among
164 populations when variation occurred among populations only, both if variation occurred
165 within and among populations, and none if there was no variation reported.

166

167 **Results**

168 *Xenarthra*

169 We found 4510 articles (1801 for Pilosa and 2709 for Cingulata). The titles from 61 articles (30
170 for Pilosa and 31 for Cingulata) indicated that information on social organization was
171 collected. These articles were searched in detail for information. Twelve publications
172 provided information on social organization for 15 populations of nine of the 30 Xenarthran
173 species. From these nine species, the following seven species were reported to be exclusively
174 solitary: southern naked-tailed armadillo, *Cabassous unicinctus* (Desbiez et al., 2018), giant
175 armadillo, *Priodontes maximus* (Desbiez et al., 2019), nine-banded armadillo, *Dasypus*
176 *novemcinctus*, (McDonough, 2000), maned three-toed sloth, *Bradypus torquatus* (Falconi et
177 al., 2015), Hoffmann's two-toed sloth, *Choloepus hoffmanni* (Vaughan et al., 2007), southern
178 tamandua, *Tamandua tetradactyla* (Rodrigues et al., 2001) and giant anteater,
179 *Myrmecophaga tridactyla* (Di Blanco et al., 2017; Medri & Mourão, 2005; Shaw et al., 1987).
180 Two Pilosa species showed intra-specific variation in social organization. In the pale-throated
181 three-toed sloth, *Bradypus tridactylus* (Taube et al., 1999), solitary living (of both sexes), pair-

182 living, and multi-female groups were reported. In the brown-throated sloth, *Bradypus*
183 *variegatus*, solitary living (of both sexes) and pair-living was reported (Garcés-Restrepo et al.,
184 2017; Pauli & Perry, 2012).

185 While the title and abstract of 61 publications indicated that data on social
186 organization was collected, only 12 publications contained useable information. Most of the
187 49 remaining studies focussed on population dynamics (N=14), habitat use (N=12), or other
188 ecological aspects such as conservation, spatial ecology, or monitoring via camera traps (see
189 ESM 1). Most studies could not be used to correctly determine social organization because
190 they either did not report the sex of individuals or state the composition of the social units
191 they observed (for example they observed / trapped / tracked individuals but did not present
192 data whether they were solitary or not; Table 1). Studies using radio-tracking often failed to
193 report whether or not individuals shared home ranges and sleeping sites (Table 1). One study
194 had information we could use for our database for one species (*Bradypus tridactylus*) and
195 missing information for the other species (*Choloepus didactylus*) (Taube et al., 1999).

196

197 *Other mammalian taxa*

198 Examples from other mammalian taxa show that the same information to determine social
199 organization is often missing, just as for Xenarthra (Table 1; ESM 2). For example, in
200 Perissodactyla, groups have been observed in onagers (*Equus hemionus*) and kiangs (*E. kiang*)
201 without the sex of the individuals being reported (ESM2), which would be essential to
202 determine the sex composition of the social units, i.e., whether it is one male with several
203 females, multi-male multi-female groups, or all male and all female groups. The same
204 problem occurred in several species of kangaroos (ESM2). In platypus (*Ornithorhynchus*

205 *anatinus*), which are typically regarded to be solitary living (Wilson & Mittermeier, 2015), den
206 sharing has been reported repeatedly, but not whether the same individuals permanently
207 share one den and home range, or whether such associations were short lived, representing
208 random aggregations at preferred resting sites (ESM 2).

209

210

211 **Discussion**

212 It is mandatory to have access to reliable field data of animal social systems if one wants to
213 do comparative studies on social evolution (Schradin, 2017). Conducting field studies is costly
214 in time and funding (Clutton-Brock & Sheldon, 2010; Schradin & Hayes, 2017). It is, therefore,
215 both surprising and frustrating when such valuable data are collected but not reported. Here
216 we report in detail for one superorder of placentals, the Xenarthra, that most conducted field
217 studies do not report data essential to accurately determine social organization. We further
218 add examples from other mammalian taxa indicating similar problems. Data on social
219 organization are valuable and difficult to collect; therefore, we give advice on how to report
220 such data in the future, independent of the study focus.

221 So far, Xenarthrans, which represents sloths, anteaters and armadillos, have been
222 believed to live solitarily (Wilson & Mittermeier, 2018). This might be the reason why most
223 field studies on Xenarthrans did not report the composition of social units: possibly the
224 authors were assuming that it is clear that they are solitary. However, in our literature survey
225 we found some indication that some species of Xenarthrans show intra-specific variation in
226 social organization, including pair-living and female groups. The Xenarthra represent one of
227 four mammalian superorders, such that the social organization of these species might have a

228 significant impact on comparative studies regarding mammalian social evolution. From our
229 point of view, while solitary living is the most common form of social organization in
230 Xenarthra, ignoring other possible forms of social organization in this taxon could lead to
231 mistakes in comparative studies of mammals. To prevent such mistakes from occurring, field
232 data from long-term monitoring of natural populations is essential; however, this data is often
233 missing.

234 In another database, all Xenarthra were classified as solitary living (Lukas & Clutton-
235 Brock, 2013). It is important to note that there is agreement that comparative studies need
236 clear definitions (Lukas & Clutton-Brock, 2017; Schradin, 2017). For example, Lukas & Clutton-
237 Brock (2013) had a more stringent definition to classify species as pair-living than we had:
238 pairs had to be together for more than one breeding season (Lukas & Clutton-Brock, 2013).
239 Whereas we recorded pairs in pale-throated three-toed sloths (*Bradypus tridactylus*; Taube
240 et al. (1999)) even though it was unknown for which time they stayed together. In contrast,
241 using radio-tracking in brown-throated sloths (*Bradypus variegatus*), the authors indicate
242 mate fidelity of one female remaining in the home range of one male for 3 years (Fig 3a in
243 Garcés-Restrepo et al. (2017)), and the female mated only with this male, such that it can be
244 regarded as a pair (Garcés-Restrepo et al., 2017). We did not consider observed pairs in nine-
245 banded armadillos (*Dasypus novemcinctus*) as indication for pair-living, because pairs were
246 only present during courtship and mating, indicating a solitary form of social organization
247 (McDonough, 2000). The secondary literature also reports some degree of sociality for some
248 Xenarthra, for example female groups in Hoffmann's two-toed sloth (*Choloepus hoffmanni*;
249 Nowak & Wilson (1999)), groups in pale-throated three-toed sloths (*Bradypus tridactylus*,
250 Wilson & Mittermeier (2018)), and groups of adult offspring staying together in nine-banded
251 armadillos (*Dasypus novemcinctus*, Nowak & Wilson (1999)). In sum, some data from the

252 primary literature (Garcés-Restrepo et al., 2017; McDonough, 2000; Taube et al., 1999) and
253 reports from secondary literature (Nowak & Wilson, 1999; Wilson & Mittermeier, 2018)
254 indicate that *Xenarthra* might be less asocial than generally assumed. Whether to score these
255 species as solitary, variable in their social organization, or excluding them due to uncertainties
256 from further comparative analysis will have to depend on the specific study objective.

257 A similar problem as in *Xenarthra* exists for monotremes, which are all generally
258 believed to be solitary living (Wilson & Mittermeier, 2015). However, numerous reports of
259 den sharing in the platypus (*Ornithorhynchus anatinus*), covering decades of studies (Grant et
260 al. 1992; Serena 1994; Serena et al. 1998 and older reports cited within), indicate that this
261 general assumption might not cover the full range of social organization occurring in this
262 species.

263 While in *Xenarthra* and monotremes, the general assumption that they live solitarily
264 might explain why researchers are reluctant to report data on social organization.
265 Alternatively, in group-living species we found that the correct group composition could often
266 not be determined as no information about the sexes was given such as in Perissodactyla,
267 Carnivora, Rodentia, and Marsupialia. However, whether the social organization consists of
268 one male with multiple females or multiple males and multiple females, has a significant
269 influences on other aspects of the social system, for example the mating system and the social
270 structure (Kappeler, 2019). In sum, we found throughout the mammalian taxa, examples of
271 field studies that likely collected data on social organization without reporting it. This can lead
272 to the misclassification and ignorance of important variation (Schradin et al., 2018), therefore
273 affecting the outcome of comparative studies (Schradin, 2017).

274 To compensate for missing data, others solved this by using phylogenetic
275 interferences (assuming closely related species have the same social system), included data
276 from captive studies, and expert opinions, with the risk of coming to wrong conclusions
277 (Schradin et al., 2018). Here we argue for field researchers to report life-history data in a
278 precise way, making it possible to accurately determine the social organization and especially
279 the composition of social units, one of the key components of social systems (Kappeler, 2019).
280 Sometimes it is impossible for researchers to give the correct information about the sex
281 composition of social units, especially in species forming large herds (Moehlman 1998;
282 Rudman 1998) or when individuals are not captured, sexed, and individually marked.
283 However, when such information is routinely collected, it should also be reported. In
284 Xenarthra, this problem exists for studies published during the last 4 decades and was even
285 dominant during the last decade (ESM1); indicating that it is not a problem of research
286 methodology, but of publishing culture. We argue that in future, it is important to report such
287 data even if the study focus is on a different topic.

288 Kappeler (2019) defined the social organization as the composition of social units,
289 which was inferred by previous comparative studies from direct observations (Jaeggi et al.,
290 2020), trapping data (Valomy et al., 2015) and from sleeping sites (Agnani et al., 2018). Table
291 1 states the information which every study on wild living animals should report in their
292 methods and results section, to make information about the social organization of the study
293 population available for comparative studies, even when the study focus is on something else.
294 While Table 1 lists this information in the order of missing information, in any publication it
295 should typically be reported as: (1) proportion of individuals within the study area trapped,
296 marked, radio-tracked, and observed, (2) frequency of trapping / observation event, (3) sex
297 of individuals studied, (4) composition of social units, (5) in studies using radio-tracking the

298 home range overlap with all individuals should be stated, and (6) which individuals shared
299 nesting / sleeping / resting sites and how regularly. It is very important that all of this
300 information is also reported for species which are believed to live solitarily, because as
301 demonstrated here for *Xenarthra*, important deviation from this main form of social
302 organization might occur. Furthermore, it has been empirically demonstrated that many
303 species that were believed to be solitary living in fact live in pairs or groups (Agnani et al.,
304 2018; Valomy et al., 2015).

305 Similar considerations as for reporting data on social organization may also apply to
306 the three other components of the social system. For the mating system, it is now common
307 that the number of extra-pair paternities are reported, how many offspring each male sired
308 in a group, and the frequency of multiple paternities, which can then be used in comparative
309 studies (Dobson et al., 2018). For the social structure, different measures of the social
310 networks must be reported in a way that they can be used for comparative studies (see
311 <https://github.com/bansallab/asnr>). For the parental care system, it is important to report
312 not only whether maternal, paternal and allo-parental care by breeders and non-breeders
313 occurs, but also how commonly parental behaviour is shown by the different group members,
314 and how many social units show which category of parental care system (Griesser et al., 2017;
315 Griesser & Suzuki, 2016). Therefore, our demand to accurately report data on social
316 organization can be extended to the other components of the social system.

317

318 **CONCLUSIONS**

319 During the process of building a database on mammalian social organization we came
320 across several peer-reviewed publications that indicated that they had collected data we

321 could use for the database, but this information was not presented in a way that we could
322 reliably determine the composition of social units. Here we argue for field researchers to
323 always report life history data, making it possible to accurately determine the social
324 organization; especially to report the proportion of population studied, frequency of trapping
325 / observation events, sex of individuals studied, the composition of social units and sharing of
326 home ranges and sleeping sites. These recommendations are not only important for
327 mammals, but also for databases in other taxa, such as fish (Tanaka et al., 2018) and birds
328 (Griesser & Suzuki, 2016).

329

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336

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454 **Table 1** Reasons why field studies could not be used to determine the social organization of
 455 the study population. For Xenarthra, data from a detailed literature survey trying to identify
 456 all published field studies are reported. Additional examples from other mammalian taxa are
 457 also reported.

Missing information to determine social organization	Total number of field studies on Xenarthra (ESM1)	Examples from other mammalian taxa (ESM2)
Composition of social units not stated.	29	Carnivora: 1 Chiroptera: 2 Marsupialia: 1 Monotremes: 3
Sex of individuals not stated.	23	Perissodactyla: 6 Carnivora: 2 Chiroptera: 2 Rodents: 2 Marsupialia: 4 Monotremes: 1
Occupancy of sleeping sites.	6	Monotremes: 1
Home range overlap not stated.	3	Monotremes: 1
Frequency of trapping events not stated.	2	Monotremes: 1
Not stated what proportion of the population was studied.	1	

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