

*Activity and space patterns of Pyrenean desman (*Galemys pyrenaicus*) suggest non-aggressive and non-territorial behaviour*

Article

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1 **Activity and space patterns of Pyrenean desman (*Galemys pyrenaicus*) suggest non-**
2 **aggressive and non-territorial behaviour**

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9

10 **Keywords** *Activity pattern; Galemys pyrenaicus; movement pattern; Pyrenean desman;*
11 *social organization*

12

13 **Abstract**

14 The Pyrenean desman is considered as a flag species of biodiversity and evolution. However,
15 its scientific knowledge is still under development and currently on debate, in special in
16 relation to the behavioural ecology and social organization. Based on the previous hypothesis
17 of individual desmans being solitary and territorial, activity and space patterns were
18 described as arranged to avoid conspecifics. However, recent new insights into the species
19 social behaviour revealed non-interspecific avoidance. With this study we provide novel
20 insights into their activity and space patterns and their relation to the social behaviour. A
21 total of 30 individuals were trapped of which 18 provided informative radiotracking data to
22 study (1) individuals activity behaviour, (2) proportion of home range utilised and movement
23 distances, and (3) movement directionality. Activity and space use patterns were affected by
24 daylight and seasonality but not by sex, age or number of other conspecifics sharing the home
25 range. In contrast to the previous observations, individuals did not show a pattern of
26 directionality in their movements. Noticeably, we observed encounters between individuals

27 without evidence of aggressive behaviour between them. Our results suggest that desmans do
28 not oppose their activity neither their spatial behaviour in order to avoid encounters with
29 conspecifics as previously suggested. These novel findings provide more evidences of a
30 social structure and organization with social interactions and non-aggressive behaviour. This
31 is of relevance for management actions and conservation purposes of this endemic mammal.

32

33

34 Authors declare no conflict of interest

35 **Introduction**

36 The Pyrenean desman (*Galemys pyrenaicus*; also known as Iberian desman) is a riparian
37 species considered as a flag species of biodiversity and evolution because of its relic and
38 narrow endemic character. Together with the Russian desman (*Desmansa moschata*) represent
39 the last two extant species of the Desmanini lineage of Soricomorpha (Nowak 1999) a
40 mammalian taxa of extremely high biodiversity value. However, the species has been quite
41 unknown to the general public due to its nocturnal elusive behaviour; and to the scientific
42 community because the difficulty of its study (due to e.g. the few approved capture
43 authorisations or the difficulty of scat identification using non-genetic methodologies since
44 desman and shrew scats can easily be misidentified)

45 The first published information on its social and ecological behaviour was thanks to
46 the novel studies carried by (Stone 1987b; Stone 1987a; Stone 1985; Stone and Gorman
47 1985), Stone (1987b; 1987a; 1985) in wild watercourses, and Richard and Michaud (1975)
48 and Richard (1986; 1985) in captivity. Since then a few seminal studies have talked about its
49 distribution, morphology and general biology (Aymerich and Gosàlbez 2013; Aymerich and
50 Gosàlbez 2002; Bertrand 1993; Palomo et al. 2007; Queiroz and Almada 1993; Williams-
51 Tripp et al. 2012) and most of them are grey literature and/or have low international
52 repercussion. Nonetheless, in the recent years the interest on the species has increased
53 notably by both the general public and the scientific community. Indeed, the Pyrenean
54 desman recently became strictly protected under the Bern Convention (Appendix II) and the
55 EU Habitats and Species Directive (Annexes II and IV). Notwithstanding, the scientific
56 knowledge on its behaviour and ecology is still poorly developed.

57 One of the most unknown aspects of the species biology is its behavioural ecology
58 and the reliability of little available information is currently on debate. The species was first
59 observed as largely territorial and solitary or organised in couples in the wild (Stone 1987a;

60 Stone and Gorman 1985) and solitary in captivity (Richard and Viallard 1969). This
61 hypothesis was supported by observations that described the individuals as highly aggressive
62 with conspecifics independently of the sex even between couples, except for temporal mating
63 and transient individuals (Stone 1987a). Since these first studies, there has been no more
64 research on its social organization or behaviour, and these observations have been the
65 foundation for the knowledge on the species behavioural ecology. Consequently, many
66 studies were based on the aegis of desmans being aggressive with resident male and female
67 couples occupying an exclusive range in which the male's range encloses that of the female,
68 and individuals hold exclusive shelters (Richard and Valette Viallard 1969; Stone 1987b;
69 Stone 1987a; Stone 1985). Controversially, we recently observed a different social behaviour
70 with non-territoriality nor conspecific avoidance (Melero et al. 2012). More in detail, we
71 found that socio-spatial organization was community based with non-exclusive or permanent
72 territories and shared home ranges and resting sites (shelters used for more than 1h) between
73 two or more resident non-couple individuals of different and/or same sex. Our new findings
74 thus, recalled for a re-evaluation of the behavioural ecology of the species and the subsequent
75 related research and management actions.

76 Under the observations of Stone (1985; 1987a;b) individual behaviour was observed
77 to be arranged to avoid conspecifics. It was described as a bimodal activity rhythm with one
78 diurnal and one nocturnal activity bout during which the whole riparian territory was seen to
79 be patrolled on a 48h basis if solitary and 24h basis in the case of mating couples sharing the
80 territory. In this patrolling, males were more frequently found in the border areas of the river
81 sections included in their territories to protect the territory and mating couples avoiding
82 encounters between them. In addition, individuals had fixed directional up or downstream
83 movements that were organised between individuals to avoid encounters, including couples
84 except for mating encounters. However, under the novel recent observations of the species

85 not being territorial or aggressive (Melero et al. 2012), individual activity and space use
86 might not follow the previously postulated objective of avoidance.

87 In this study, we investigated the activity and space use patterns of a local population
88 of Pyrenean desman. We hypothesised that individual activity and space use patterns were
89 not organised to avoid conspecific encounters. To test our hypothesis we studied (1)
90 individuals activity behaviour (active versus inactive), (2) proportion of home range utilised
91 and movement distances during the activity bouts, and (3) directionality of individual
92 desmans. We also state several observed spatiotemporal encounters between individuals. Our
93 overall aim was to increase the scarce research and knowledge on the behaviour of the
94 species. We believe that clarifying the scientific knowledge on the species behaviour is
95 crucial for the understanding of the species biology and its conservation. This will contribute
96 to the awareness of the species and, ultimately, to improve design of on-going and future
97 research, management and conservation actions.

98

99 **Material and methods**

100

101 The study area and the methodology for trapping and radiotracking was previously described
102 in the in Melero et al. (2012) because the data used in this study was a subset of the data used
103 in the preceding publication consisting of individuals captured between 2002 and 2004 in the
104 river Tor.

105

106 Study area

107

108 The study was conducted in the river Tor, located in the Eastern Pyrenees (UTM 31TCH61).
109 We selected 2 km of the river Tor which presented 4 m of mean width, 0.1-0.4 m of mean
110 depth, and 6.5% of mean slope, rocky river-bed and rocky shorelines covered by dense

111 vegetation. The river Tor is a well preserved river without anthropogenic pressures. Winter
112 snowfalls and their subsequent spring thaws maintain a constant high river flow with a peak
113 in April-May but without significant seasonal differences. Mean altitude of the area ranges
114 between 1200 and 1400 m and precipitation falls regularly along the year within a range of
115 800-1000 mm being the highest between May and September. Temperatures in the area range
116 from an average of 20 °C in summer to -2 °C in winter.

117 Other aquatic and semiaquatic vertebrates sharing the habitat with the Pyrenean
118 desman are the brown trout *Salmo trutta*, viperine snake *Natrix Maura*, White-throated
119 Dipper *Cinclus cinclus*, the Eurasian Water Shrew *Neomys fodiens*, the water vole *Arvicola*
120 *sapidus* and the Eurasian otter *Lutra lutra*. The river provides availability of a diverse
121 invertebrate fauna such as caddisflies (Trichoptera) and mayflies (ephemeroptera) among
122 others.

123

124 Trapping and radiotracking

125

126 Two trapping sessions of 5 to 7 days each were conducted annually with 28-35 trap nights per
127 session between 2002 and 2004. The sessions were set each year in April to June (spring-
128 summer, spring hereafter) and in September-October (autumn) to cover both the expected
129 reproductive and the non-reproductive seasons (Castién 1994). Animals were live trapped at
130 night in partially submerged unbaited mesh traps designed for trapping the species and based
131 on the designs of eel traps. Traps were located inside the rivers in adequate places for
132 trapping (i.e. narrow pathways) maintaining a separation of 30-300 m between them and
133 checked every 3 hours during the night every day (traps were open during daylight hours).

134 After immobilization with anaesthetic (isoflurane), animals were measured, weighted, sexed,
135 aged and classified as either a new capture or a recapture. Animals were classified by sex and
136 age based on the data of Peyre (1961), González-Esteban et al. (2003) and González-Esteban

137 et al. (2002) respectively. The captured animals were marked with a subcutaneous
138 transponder (PIT; ID K162 FDX-B; AEG ID; Trovan Ltd., Madrid, Spain) and
139 radiotransmitter (frequency 150-151, Pip model, BioTrack, Ltd., Wareham, Dorset, UK and
140 Tinyloc Ltd., Mataró, Spain). Transponders weighted approximately 0.95mg < 1.7% of the
141 lightest individuals (M16 and F11, weight = 54g). Radiotransmitters weighted approximately
142 2.5-3g < 5.5% of the weight of the lightest individuals and < 4.4% of the heaviest individual
143 (F8, weight = 70g). All manipulated animals were released in the capture area once fully
144 recovered. None of the captured individuals died during the procedures. Trapping was carried
145 out by three accredited biologist and one accredited veterinary, but animal manipulation was
146 carried out only by the accredited veterinary. Research permit and accreditations were
147 provided by the Scientific Ethical Committee of the Department of Environment and Housing
148 of the Catalonian Government (Spain). Our methods followed the “Guidelines for the Use of
149 Animals in Research” (Association for the Study of Animal Behaviour and Animal Behavior
150 Society 2012). All recaptured animals showed a good condition with no effects by the
151 manipulation, the transponder or the transmitter. Failed radiotransmitters of recaptured
152 individuals were removed following procedures explained above.

153 Radiotracking was done with a RX-8910HE (Televilt International AB) and three
154 multidirectional and bidirectional antennas (for long, medium and short distances) with a
155 mean precision of 0.2 and 0.1m respectively. Radiolocations were recorded by homing to the
156 animals without triangulation as desman movements follow the river course. The study area
157 did not have proper coverage for GPS systems. Therefore, animal position was recorded and
158 mapped following as reference the 100 m signals of the road that flows parallel to the river (1
159 – 10m distance, mean = 7m). This and the narrow width of the river facilitated the location of
160 the individuals with the precision of the bidirectional antennas being the limiting factor
161 (0.1m).

162

163 Radiotracking was started five-seven days after the animal was released to avoid bias
164 due to recovery from manipulation. Animal location was made daily; during night each
165 individual was radiotracked every 1-2 h ($\bar{x} = 1.2$, SD = 0.3) when they were active and
166 every 10-20 min when inactive to detect the re-start of the activity. During daylight
167 radiotracking was made every 30-60 min. All individuals were tracked for 10-15min after
168 located.

169

170 Activity patterns

171

172 Activity and inactivity behaviour was defined based on time spent outside (activity) or inside
173 (inactivity) the resting site. Diurnal time was set between dawn and dusk for each day and
174 nocturnal between dusk and dawn. Activity (n = 589) versus inactivity (n = 1024) was
175 studied using only radiolocations separated at least 1h to reduce temporal autocorrelation
176 except when individuals changed their behaviour leading to n = 559 and 977 respectively.

177 The influence of sex, age, daylight (diurnal and nocturnal), season (spring-autumn) and
178 number of conspecifics sharing the home range were analysed by means of generalised lineal
179 mixed models (GLMM). Activity was fitted as to a binary distribution, and best model fit was
180 selected based on AIC. Factors were set as fixed effects except for individual that was set as
181 random effect. By considering individual as random effect, we tested individual variation and
182 avoided the problem of different number of repeated measures per individual.

183 For conspecific sharing the territory that also had concurrently radiolocations we
184 analysed if their frequencies of activity per hour were correlated with the activity of the other
185 individual by means of a Pearson correlation. Overall, we had enough concurrently
186 information for two pairs of individuals sharing the space: F1-F3 and M6-M15, and one pair
187 of individuals captured together F10-M11. Radiotracking did not show space overlap
188 between the pair F10-M11 but included it based on the fact that at some point they did share it.

189

190 Space use patterns

191

192 Space use was evaluated based on the home range use in terms of the percentage of the home
193 range utilised during the individuals' daily activity as calculated as lineal meters of river
194 section utilised. Home range size was obtained and exposed in our previously study (Melero
195 et al. 2012). In relation to the movement patterns, we studied the distances travelled during
196 the activity periods per day and the direction of the movement (upstream and downstream)
197 using all radiolocations (n= 1613). Distance travelled per activity bout was defined as the
198 sum of the distances from the resting site to the distal location points without counting
199 sections travelled more than once (because e.g. of forward and backward movements).

200 Percentage of home range used and direction of movement were set to binomial distributions,
201 and distances travelled to a Gaussian distribution. All three variables were tested against the
202 influence of sex, age, daylight (diurnal and nocturnal), season (spring-autumn) and number of
203 conspecifics sharing the home range by means of GLMMs and linear mixed model (LMM)
204 for distances travelled. We followed the same procedure as in the activity analyses for the
205 fixed and random effects.

206 All models were fit in package lme4 and based on Restricted Maximum Likelihood
207 (REML) and package lme done in R. Model selection was based on AIC criteria.

208

209 **Results**

210

211 We obtained the most completed radiotracking and trapping dataset up to date. A total of 30
212 individuals were trapped of which 18 provided enough radiotracking data to study their
213 activity and home range (ten males and eight females). Individuals were tracked for at least 2

214 days and for a maximum of 33 days ($\bar{x} = 25.3$, SD = 10.5; Table 1). The remaining
215 individuals were not radiotracked due to transmitter failure before 2 days of radiotracking.

216

217 Activity pattern

218

219 On average, individuals spent more time inactive than active with 36.51% (SD = 23%) of
220 active radiolocations, 9-10 h of activity per day. In general, the activity of desman was
221 mainly nocturnal although the activity pattern differed between autumn and spring. During
222 autumn, individuals presented two nocturnal, or exceptionally three, activity bouts with an
223 average duration of 5 hours (SD = 1.5) each separated by one (exceptionality 2) inactive
224 period of 100 minutes of average duration (SD = 57.81) commonly happening at 2pm
225 approximately, and a single diurnal activity bout of 73.75 minutes of average (SD = 45.69;
226 Fig. 1a). In spring, however, nocturnal activity was reduced to a single bout ($\bar{x} = 8$ h, SD =
227 1.6) without any inactive period but diurnal activity was longer ($\bar{x} = 102$ min, SD = 52.51;
228 Fig. 1b).

229 Best model fit included season and daylight but dismissed sex, age and number of
230 conspecifics in the home range as factors influencing the activity pattern (in addition, in all
231 models $p > 0.1$ for dismissed factors). Both season and daylight had a significant effect on
232 activity ($F = 10.51$, $df = 1$, $p < 0.0001$ and $F = 2.61$, $df = 1$, $p = 0.009$ respectively) although
233 their interaction was not significant ($F = -0.25$, $df = 3$, $p = 0.79$). Overall, individuals
234 presented higher probability of being active at spring nights, followed by autumn nights;
235 however, variability was also highest in them nocturnal spring activity (Fig. 2). Variance due
236 to the random effect was low (7%) indicating low individual variability.

237 All cases where we had enough data on conspecifics sharing the territory showed a
238 significant correlation between their frequencies of activity per hour. This correlation was
239 high in the case of F1 and F3 ($r^2 = 0.83$, $df = 22$, $p < 0.0001$), and lower in the case of M6 and

240 M15 ($r^2 = 0.48$, $df = 18$, $p = 0.001$); similar to the pair trapped together F10 and M11 ($r^2 =$
241 0.31 , $df = 21$, $p = 0.006$) (Fig. 3).

242

243 Space use pattern

244

245 Home range was almost completely utilised during their total nocturnal movements in
246 autumn (average percentatge of utilisation $\bar{x} = 76.03\%$, $SD = 24.09$) with a slightly
247 significant reduction in spring ($\bar{x} = 58.55\%$, $SD = 17.10$; $F = -2.65$, $df = 1$, $p = 0.01$; Fig.
248 4). During the daylight activity bouts home range was only partially utilised (11.6 % in
249 autumn and 6.2 % in spring with not significant differences, $p > 0.1$; Fig. 4). Best model fit
250 included season and daylight but dismissed sex, age and number of conspecifics in the home
251 range as factors influencing the movement distances (in addition, in all models $p > 0.1$ for
252 dismissed factors). There was no significant variability between individuals (variance due to
253 random effect = 0.9%).

254 Distances travelled by the individuals at each activity bout were highest at night and
255 in autumn (268.5 ± 123.9 m), with significant differences between seasons ($F = 13.77$, $df = 1$,
256 $p < 0.0001$) and daylight ($F = 140.89$, $df = 1$, $p < 0.0001$; Fig. 5
257) but not with other factors. As before, best model fit all other factors (in all models $p > 0.07$
258 for dismissed factors). Variability due to individuals was again low (13%). During these
259 displacement movements, individuals were observed to frequently travel from the resting site
260 to the distal site of their home range and afterwards either rest in the same or different resting
261 site or travel to the opposite distal point before resting. In relation to the direction of the
262 movement, best model fit included all factors but there were no differences in the direction of
263 the movement (up or downstream) for any of the models (all p -values > 0.4). Diurnal
264 movements were always one way movement from the resting site and return to the same or,

265 exceptionally, a different resting site. In all cases, individuals' movement was straight
266 forward, without forward and backward movements.

267

268 Spatio-temporal encounters

269

270 Several individuals were found to share the home range for 1- to 24- days (Table 1) and, of
271 them the pairs F1 and F3, and M6 and M15 were both found together in the same location in
272 eight occasions during six and three days of radiotracking respectively. In all the cases did
273 not seem to alter their behaviour for conspecific avoidance. Encounters last from 10 seconds
274 to up 10 min, but no longer than 5 minutes when all individuals were actively moving.

275

276 **Discussion**

277

278 This study provides evidence of the non-avoidance behaviour among individuals of Pyrenean
279 desman. The individual activity and space use patterns of the studied population were not
280 organised to avoid conspecifics. Indeed, we could directly observe encounters between
281 individuals of different or same sex.

282 As previously described by Stone (1987b; 1987a), individuals presented a bimodal
283 activity pattern in spring consisting of primary nocturnal activity bout ($\bar{x} = 8\text{h}$) of average
284 and a short activity bout during daylight ($\bar{x} = 102\text{min}$). However, we observed a shift from
285 this bimodal activity rhythm to a trimodal and exceptionally tetramodal in autumn. At this
286 time individuals included 1 or 2 nocturnal resting bouts ($\bar{x} = 100\text{min}$) and reduced their
287 diurnal activity to a single and shorter bout ($\bar{x} = 73.75\text{min}$) without resting time. This
288 activity rhythm was never observed before, probably to the fact that Stone's previous studies
289 were always done in spring time. This shift in their rhythm is probably related to the
290 individuals' ability to adapt their behaviour to the duration of the night at different seasons.

Indeed, the only factors affecting their activity pattern were seasonality and daylight. It is possible that there is also relation between the duration of the diurnal and nocturnal activity and the biomass intake and/or the individuals' energetic requirements. The probability of activity during spring nights increased because there is no resting period and, thus, the probability of finding an individual active was higher, but the duration of the total nocturnal activity is shorter in spring when nights are also shorter than in the studied months of autumn. However, the duration of the diurnal activity bout increases in this spring, which might be related to a necessity of feeding to maintain its energetic requirements. Unfortunately, our data did not provide information to test this hypothesis.

Coinciding with Stone's previous studies, individual variation in the activity pattern was very low (7% variation due to individual effect) and independent of their sex, age and, more interestingly of the number of conspecifics sharing the home range with them. These results support the previous hypothesis of a common activity pattern between individuals. In fact, for those cases sharing the home range where we had enough data, the activity of the individuals was significantly correlated; information that, together with the model, supports the idea of a similar activity pattern between individuals.

In concordance with the observed activity pattern, seasonality and daylight were also the only factors influencing the range use and movement pattern of the studied population. In both cases, individual desmans utilised higher percentage of their home ranges and travelled longer distances at night and in autumn (76.03% versus 58.55% in spring nights). During the daylight activity bouts home range was only partially utilised (11.6 % in autumn and 6.2 % in spring with no significant differences, $p > 0.1$; Fig. 4). In addition, individual variation was again low (only 0.9% in the case of the home range use and 13% for travelled distances) which indicated a common pattern with independence of the sex, age or number of conspecifics sharing the home range. This finding contradicts the previous view that described their spatial behaviour based on sexual differences and conspecifics avoidance

317 (Stone 1987a; Stone 1985). Under the hypothesis of individuals being solitary and aggressive,
318 the spatial behaviour of males and females was suggested to differ in order to maintain a
319 mutual avoidance. This was based on the observations that the direction of the movements
320 (upstream or downstream) seemed to differ between sexes which was explained as a pattern
321 to avoid encounters with conspecifics occurring even in paired individuals (Stone 1987a;
322 Stone 1985). In addition, males were observed to travel further distances than female while
323 females mainly stayed in the neighbourhood of the resting site. Controversially, our results
324 support a common spatial pattern for both females and males and a lack of mutual avoidance.
325 Indeed, we observed no differences in the direction of the movement (up or downstream)
326 between sexes, ages, daylight (diurnal and nocturnal), season (spring-autumn) or in relation
327 to the number of conspecifics sharing the home range.

328 Our results indicate a general common behavioural pattern between individual
329 desmans with a lack of mutual avoidance. This is supported by our previous findings were
330 individuals on individuals concurrently sharing resting sites with independence of their sex or
331 age (Melero et al. 2012). Activity and space patterns were previously explained based on the
332 hypothesis of conspecific avoidance. However, our results suggest that individuals of
333 Pyrenean desman do not organise their activity neither opposite their spatial behaviour in
334 order to avoid encounters with conspecifics as previously suggested (Stone 1987b; Stone
335 1987a). Indeed, we could directly observe encounters with individuals without evidence of
336 aggressive behaviour between them. The reasons for the differences between our studies and
337 those by Stone are yet unknown. Differences in prey availability could be the first suggestion;
338 however, there is not available data to test this hypothesis and both rivers seem to present
339 similar resources and conditions. Notwithstanding, our current and previous findings are
340 consistent with the behaviour of the most similar species, the Russian desman (Onufrenya
341 and Onufrenya 1993). This species has similar ecological to the desman but it is considered a

342 semi nomadic and non-territorial (Nowak 1999; Onufrenya and Onufrenya 1993) with social
343 interactions between conspecifics.

344 Overall, based on our current observation and our previous study on the shelter use
345 behaviour, we recall for a new understanding on the species behaviour based on a social
346 organization hypothesis where individuals are non-aggressive neither territorial.

347

348 Management and conservation implications

349

350 Our findings are of significant relevance for management and conservation purposes of the
351 species. The species distribution and status is currently being monitored by several national
352 and international projects in Spain, France and Portugal (e.g. LIFE+ Desmania) mostly by
353 means of indirect signs surveys consisting on annual scat surveys to map its distribution and
354 potential expansion/contraction. In the past, the species distribution has also been mapped
355 using other indirect signs that included not only scats but also interview to local residents.

356 This type of information is, however, less reliable than the current methodology based on scat
357 surveys. None of these methodologies allow identifying individuals and thus, estimating the
358 density. Genetic monitoring using the collected scats will allow identifying individual. Until
359 this is achieved, density estimations could be wrongly estimated if the surveys are based on
360 the previous hypothesis. First, under the hypothesis of desmans being solitary and territorial,
361 density has been calculated assuming a maximum of two (mating couple) individuals per
362 mean home range (e.g. two individuals per 200-500m). However, based on our results there
363 could be more than two individuals in the same home range length and thus, density would be
364 underestimated. Estimation of population density based on presence absence data should be
365 thus updated and used with criticism since until now they were done on the basis of
366 individuals being in couples and maintaining fixed territories (e.g. Nores et al. 1998).

367 In addition, as observed in our previous study Melero et al. (2012) home ranges might not be
368 fixed over the seasons and/or years. Thus, density could also be overestimated based when
369 working with the hypothesis of fixed territories. Furthermore, this hypothesis of fixed
370 territories can overestimate the species distribution, and connectivity between populations.
371 This is due because, as with the density, distribution and connectivity are estimated based on
372 presence absence data (direct captures or presence – absence of signs consisting mainly of
373 scat surveys) assuming desmans do not change their territories. However, we have provided
374 evidences of individuals with passing areas and temporal displaced home ranges.

375 Hence, we recommend population monitoring include shared territories and social
376 interactions that allow more than two desmans per home range. In addition, based on our
377 current and previous results (Melero et al. 2012) we also recommend to include the existence
378 of passing areas and temporal home ranges (individuals changing the size and location of
379 their home ranges) and to prioritize those river sections that are permanently occupied versus
380 those temporally occupied.

381

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391

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- 450

451 **Table 1** Radiotracked individuals, number of tracked days and of radiolocations, season,
 452 percentage of active radiolocations, size of the home range (meters of river section),total
 453 number of conspecifics in their home range for 2- to 24- days and season Adapted from
 454 Melero el at. (2012).

Indiv.	Sex	Age at capture	No. of tracked days	No. radiolocations	Season	% active radiolocations	Home range (m)	Conspecifics in home range
F1	Female	Adult	25	111	Autumn	42.34	570	F3
F2	Female	Adult	21	126	Autumn	37.30	520	-
F3	Female	Adult	24	130	Autumn	41.54	430	F1
F4	Female	Adult	9	37	Autumn	35.13	530	M2*
F6	Female	Adult	8	64	Autumn	57.81	450	M5
F9	Female	Juvenile	3	11	Autumn	45.45	-	-
F10	Female	Juvenile	17	136	Spring	42.65	350	-
F11	Female	Adult	19	117	Autumn	19.66	660	-
M1	Male	Adult	34	206	Spring	34.95	530 –	-
							2300 [†]	
M4	Male	Adult	20	112	Spring	40.18	620	F5*
M5	Male	Adult	2	6	Autumn	0	-	F6
M6	Male	Adult	33	232	Spring	31.03	550-	F7*, F8, M*
					&		1350 [†]	M15
					Autumn			
M7	Male	Adult	4	20	Spring	30	670	M10*, M12*,
								M8
M8	Male	Juvenile	16	134	Autumn	35.07	650	M10*, M12*,
								M7

M9	Male	Juvenile	3	4	Spring	0	-	-
M11	Male	Juvenile	7	48	Spring	41.67	320	-
M15	Male	Adult	7	37	Autumn	37.83	450	M6
M16	Male	Adult	8	75	Autumn	37.33	510	-

455 *marked individuals that did not provide enough information for the analyses.

456 †Outliers due to exceptional one day long movements. Outliers were not taken into account in
457 the analyses.

458

459 **Figure 1** Percentage and standard error of activity per hour of the studied population of
460 Pyrenean desman in (a) autumn ($n = 994$) and (b) spring ($n = 669$) seasons. Data was
461 gathered by means of radiolocation.

462

463 **Figure 2** Estimated probability of being active for the studied population of Pyrenean
464 accordingly to daylight (diurnal and nocturnal) and season (autumn and spring). Values are
465 given as mean and their standard error calculated from the GLMM.

466

467 **Figure 3** Estimated activity correlation between pairs of the studied population of Pyrenean
468 desman F3-F1, M15-M6 and F10-M11. Values are given as between percentage of active
469 radiolocations per hour (%). Dotted lines stand for the estimated correlation.

470

471 **Figure 4** Estimated percentage of home range utilised of the studied population of Pyrenean
472 desman accordingly to daylight (diurnal and nocturnal) and season (autumn and spring).
473 Values are given as mean and their standard error calculated from the GLMM.

474

475 **Figure 5** Estimated total distance travelled during the activity bouts of the studied population
476 of Pyrenean desman accordingly to daylight (diurnal and nocturnal) and season (autumn and
477 spring). Values are given as mean and their standard error calculated from the GLMM.

478