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1 **Abstract**

2 **Capsule:** The winter diet of common buzzards on a red grouse moor was dominated by small
3 mammals, whilst grouse were a minor prey item.

4 **Aims:** To assess winter buzzard diet from pellets collected at roost sites on and around a managed
5 red grouse moor, and to explore temporal, spatial and age-related variation in diet composition.

6 **Methods:** Forty-four winter roost sites were located during two winters using a combination of
7 observations from vantage points and individual buzzards equipped with either radio or satellite
8 transmitters. Pellets were collected between October and March each winter and analysed to assess
9 dietary composition.

10 **Results:** Small mammals were the main prey in both years, comprising 60-67% of items and
11 occurring in 88-92% of pellets. Diet varied between years, with more lagomorphs and birds
12 (passerines, corvids and pigeons) but less red grouse eaten when grouse abundance declined.
13 Grouse formed 1.1% and 0.6% of prey items, and occurred in 3% and 2% of pellets from each winter
14 respectively.

15 **Conclusion:** Buzzards rely on small mammal prey during winter. When available, red grouse are a
16 minor dietary component, the amount of which reflects their abundance in the environment. The
17 opportunism of buzzards can result in temporal variation in winter diet.

18 Introduction

19 Assessment of dietary composition is an important component of many ecological studies, including
20 assessing the impact of raptors on gamebirds (Park *et al.* 2008), which is a contentious and topical
21 issue (Lees *et al.* 2013; Elston *et al.* 2014; Parrott 2015). Most studies of raptor diet are conducted
22 during the breeding season, owing to the concentration of activity at a nest (Lewis *et al.* 2004).
23 However, raptor diet varies between seasons (Mañosa & Cordero 1992; Amar *et al.* 2003) and their
24 impact on gamebirds can occur year-round (Redpath & Thirgood 1999). The dearth of raptor diet
25 studies during the non-breeding season therefore presents a gap in our understanding of the
26 potential impact of raptors on gamebirds.

27 In Britain, the common buzzard *Buteo buteo* (hereafter 'buzzard') has extended its winter range by
28 an estimated 74% in the last 30 years (Balmer *et al.* 2014). In most areas this represents a
29 recolonisation of previously occupied range, following decades of persecution and indirect organo-
30 chlorine poisoning (Newton 1979; Dare 2015). Buzzards are now the most abundant diurnal raptor in
31 Britain (Clements 2002), with a recent population estimate of 56-77,000 breeding pairs (Musgrove *et*
32 *al.* 2013). This population increase and range expansion has reignited conflict between stakeholders
33 concerned with raptor conservation and those involved in gamebird management (Lees *et al.* 2013;
34 Parrott 2015). During the summer, buzzards eat red grouse *Lagopus lagopus scotica* alongside their
35 preferred small mammal and lagomorph prey (Graham *et al.* 1995; Francksen *et al.* 2016), yet their
36 winter diet is relatively unknown (Schindler *et al.* 2012).

37 Several studies have investigated buzzard habitat use during the winter in continental Europe with
38 reference to its effects on diet (Wuczyński 2005; Wikar *et al.* 2008; Schindler *et al.* 2012; Baltag *et al.*
39 2013), yet none of these assessed diet composition itself. Whilst Mañosa & Cordero (1992) analysed
40 buzzard stomach contents during winter to obtain diet composition data, this method required
41 access to recently deceased birds and is therefore not feasible for many studies of diet. The winter
42 diet of raptors has also been assessed by conducting carcass searches (Watson *et al.* 2007); by radio-
43 tracking individuals to kill sites (Kenward *et al.* 1981) and by analysing regurgitated pellets collected
44 from roost sites (Clarke *et al.* 2008; Rexer-Huber & Bildstein 2012). Here we used satellite and radio-
45 tracking, supplemented with observations, to locate winter buzzard roosts on and around a moor
46 managed for red grouse shooting. We explored whether buzzards roosted alone, or communally as
47 they do in Central Europe when exploiting sporadic food sources outside the breeding season
48 (Newton 1979). From these roost sites, we collected pellets to determine winter buzzard diet
49 composition. Raptor diet composition can vary over time as abundances of prey in the environment

50 fluctuate (Redpath & Thirgood 1999). Therefore, we hypothesised that any changes in buzzard diet
51 between successive winters would reflect fluctuations in their main field vole *Microtus agrestis* or
52 alternative red grouse prey. We also hypothesised that buzzard diet composition would vary
53 according to local habitat composition, which influences the availability of different prey types to
54 raptors (Thirgood *et al.* 2003), and with variation in buzzard age, which can affect hunting
55 proficiency and prey choice (Rutz *et al.* 2006; Penteriani *et al.* 2013).

56 **Methods**

57 Study site

58 The study was conducted on approximately 221-km² of moorland at Langholm in south-west
59 Scotland (55.1 – 55.3°N, 3.0 – 2.8°W), including 76-km² designated as the Langholm – Newcastleton
60 Hills Site of Special Scientific Interest and Special Protection Area. The site included 120-km²
61 managed under the Langholm Moor Demonstration Project (LMDP) (Langholm Moor Demonstration
62 Project 2014), plus a 2-km buffer zone to include roosts of buzzards which may hunt on the LMDP
63 area (Graham *et al.* 1995). The study site was a mosaic of heather *Calluna vulgaris* dominated
64 moorland and acidic grassland, with improved grassland and commercial coniferous and mixed
65 deciduous woodland dominating the buffer zone (Francksen *et al.* 2016). Management for red
66 grouse, including control of corvids, red foxes *Vulpes vulpes*, stoats *Mustela erminea* and weasels *M.*
67 *nivalis*, as well as burning, cutting and re-seeding of heather, was undertaken by a team of five
68 gamekeepers within the LMDP area. The study was conducted during two winters (October – March
69 inclusive) in 2013/14 & 2014/15. Both winter periods were similarly mild and wet with no significant
70 periods of snow cover (www.metoffice.gov.uk).

71 Small mammals, especially voles *Microtus spp.*, are a main component of buzzard diet throughout
72 Europe (Valkama *et al.* 2005), and the abundance of field voles fluctuates on an approximately three
73 – to four-year cycle at Langholm Moor (Redpath & Thirgood 1997). For this study, vole abundance
74 was assessed each March (at the end of each winter period) from 50 snap-traps set over two nights
75 at 10 sites across the site, i.e. 1000 trap nights per annum (see Redpath *et al.* 1995). Traps were set
76 unbaited in vole runways at approximately 10m intervals. Data were expressed as the number of
77 voles caught per 100 trap nights.

78 We used line-transect distance sampling (Buckland *et al.* 2001; Warren & Baines 2011) to survey red
79 grouse. Grouse were counted each March or early-April on ten 0.5km² blocks containing line-
80 transects spaced 150-m apart, and on 18 separate line-transects (mean transect length = 1.95 km,

81 range = 0.96 – 3.46) across the study site. Surveyors walked each transect whilst systematically
82 working a pointer dog on both sides of the transect line. When grouse were located, all birds were
83 counted and the perpendicular distance from the transect line to the grouse was measured using a
84 GPS. We analysed data separately for each year using the program DISTANCE 6.0 (Thomas *et al.*
85 2010). Frequency histograms of the perpendicular distance of grouse from the transect line were
86 plotted with candidate detection probability models during the exploratory stage of the analysis. We
87 used the conventional distance sampling analysis engine with a half-normal key function and cosine
88 adjustment, and selected models giving the best fit based on minimum Akaike's Information
89 Criterion (AIC) scores and χ^2 goodness-of-fit tests (Warren & Baines 2011). The models provided
90 detection probabilities, expressed as effective strip widths (ESWs), of 40.0m and 47.7m for 2014 and
91 2015 respectively. Mean densities (grouse/km²) were then calculated for each block or transect
92 using:

$$\text{Grouse density} = \frac{\text{Total grouse counted}}{\text{Total transect length} \times (\text{ESW} \times 2)}$$

93 Mean abundances of voles on the ten trapping lines, and of grouse on the 28 count areas (blocks
94 and transects combined), were compared between years with paired t-tests.

95 Identification of roost sites

96 To help locate roosts, we fitted remote tracking tags to nine buzzards between October 2013 and
97 January 2014. Birds were caught as non-target species in pre-baited live-catching traps (a.k.a. ladder-
98 traps) used to control carrion crows *Corvus corone* by the LMDP gamekeepers. Five buzzards were
99 fitted with satellite (GPS) tags (model: Ecotone SAKER-4 GPS/GSM): three immature birds, i.e. two or
100 three years old (two males and one female); and two juveniles (one male and one female). The other
101 four were fitted with radio (VHF) tags (model: Biotrack TW-3 2/3AA): three immature females and
102 one juvenile male. All traps were checked at least once a day by field workers or gamekeepers, and
103 any buzzards caught were tagged and released on discovery.

104 Data from tagged individuals were collected after four days had elapsed following capture and
105 release to allow resumption of normal behaviour (Kenward 2001). All data were collected between
106 November 2013 and March 2014. GPS tags were set to record bird locations four times per day, but
107 during periods of low light levels the solar panel did not charge causing batteries to drop below
108 operating voltage. Data from GPS tags were received via the GSM (European mobile
109 telecommunication) network to an online server before downloading. A mean of 146 points were

110 obtained from the five GPS tags (range: 66 – 260). VHF tagged individuals were triangulated to an
111 accuracy of circa 100 m three or four times per week. A mean of 40 points were obtained from the
112 four VHF tagged birds (range: 33 – 48). Any positions with an error >100 m (n = 9) were excluded
113 from analysis (Kenward 2001). To reduce the risk of autocorrelation of positions, no two positions
114 were obtained within three hours of each other for both tag types. Roosts of each tagged bird were
115 identified from dawn and dusk locations, whilst repeated fixes at three to five day intervals
116 confirmed continued use of the roost.

117 To increase the sample of roost sites, vantage point watches were conducted at dawn and dusk
118 overlooking apparently suitable sites. To confirm buzzard presence at roosts, all sites were searched
119 for faecal droppings, freshly moulted feathers and down, and fresh pellets (Hardey *et al.* 2013).
120 Twenty-three buzzard roost sites were found during the 2013/14 winter, including one roost site for
121 each of the nine tagged individuals. During the following winter (October 2014 – March 2015) these
122 roosts were revisited, whereby 19 were found to still be used and a further two were found, giving
123 25 separate roosts and 44 roost-years in total.

124 Pellet collection and analysis

125 Roosts were searched fortnightly for pellets between October and March each winter. Pellets were
126 dried and frozen prior to analysis. Remains were identified to the lowest possible taxonomic level.
127 Mammal hairs and bones were identified using descriptions in Teerink (1991) and Yalden (2009).
128 Feathers and feather fragments were identified using descriptions in Brown *et al.* (2003) and
129 matched against reference samples. Invertebrate prey were identified from the presence of
130 undigested appendages and wing-cases of hard-bodied *Coleoptera* or from chaetae of earthworms
131 (Yalden 2009). Remains of prey in pellets were assumed to represent one individual unless it was
132 obvious that more than one individual was present. Prey were assigned to one of six groups:

- 133 1. Small mammals (field vole *Microtus agrestis*; bank vole *Myodes glareolus*; European mole
134 *Talpa europaea*; common shrew *Sorex araneus*; pygmy shrew *Sorex minutus*; small mammal
135 remains unidentified to species).
- 136 2. Lagomorphs (European rabbit *Oryctolagus cuniculus*; brown hare *Lepus europaeus*).
137 Identification of these two species is only reliable by examining the hair cortex widths at the
138 microstructural level (Wolfe & Long 1997) and so were not separated here.
- 139 3. Invertebrates (beetles *Coleoptera spp.* (largely *Carabidae spp.* and *Scarabidae spp.*);
140 earthworms *Megadrilacea spp.*).
- 141 4. Pheasants *Phasianus colchicus*.

- 142 5. Red grouse.
143 6. Other birds (*Passeriformes spp.*; *Corvidae spp.*; *Columbidae spp.* Bird remains unidentified to
144 species).

145 Since pellets usually contained more than one prey item, two measures of prey frequency were
146 derived (Redpath *et al.* 2001): (i) the frequency of a given prey type as a mean percentage of all
147 identified items in pellets between roosts ('mean % of prey'), and (ii) the percentage of all pellets
148 containing a given prey type irrespective of the amount in each pellet ('% occurrence'). Data from
149 pellets are poor at predicting the contribution of prey types to total biomass of raptor diet (Redpath
150 *et al.* 2001), and so data were not converted to biomass here.

151 The generalist and opportunistic nature of buzzards (Tubbs 1974) can result in large variations in diet
152 between individuals, largely related to local habitat composition (Swann & Etheridge 1995; Rooney
153 & Montgomery 2013). Therefore, we assessed habitat composition in order to explore its effects on
154 buzzard diet. Habitat composition was assessed within an area approximating to the core home
155 range around each of the 19 repeat sampled roosts. Core ranges were estimated from locations of
156 eight of the nine tagged individuals (data from one individual were excluded due to inadequate
157 sample size). The ranges were centred on each roost, excluding excursive locations, which can cover
158 many kilometres and are not directly linked to resource use (Kenward 2001). The average core range
159 area was estimated as a circle with radius 926-m, using cluster analysis of the 95% core range in
160 RANGES V (Kenward & Hodder 1996). This average radius was rounded up to 1 km, giving an average
161 core range area of 3.1 km². Within these areas around each of the 19 roosts, we estimated the broad
162 habitat composition using data from the Centre for Ecology and Hydrology Land Cover Map (LCM)
163 2007 dataset (Morton *et al.* 2011). These data consist of a 25 × 25-m grid, each square categorized
164 by its dominant vegetation class. Data were incorporated into ArcGIS version 10.3 to calculate the
165 habitat proportions in each core range. Heather moorland (aggregate class 'mountain, heath, bog' in
166 the LCM2007 dataset), grassland (aggregate class 'semi-natural grassland') and woodland (aggregate
167 classes 'coniferous and broadleaf woodland') together comprised an average of 97% of total habitat
168 composition across all roost sites (range: 94 – 99%). Heather moorland and woodland cover were
169 significantly negatively correlated ($r = -0.73$, $P < 0.001$). To avoid collinearity between habitat types,
170 we excluded woodland since buzzards are primarily hunters of open country and forests with open
171 canopies (Tubbs 1974; Kenward *et al.* 2001; Hardey *et al.* 2013), whilst much of the forest on our
172 study site was closed canopy commercial coniferous stands, and so the other habitat types were
173 deemed to be biologically more relevant to our exploration of buzzard diet. Our conclusions would
174 not have differed had woodland cover been included in the models. Because heather moorland and

175 grassland together comprised an average of 79% of total habitat composition around roosts (range:
176 53 – 97%), we log transformed the ratio of heather moorland to grassland to create a single habitat
177 variable.

178 Hunting efficiency may increase with age in raptors (Newton *et al.* 1981; Krüger 2005) which can
179 affect prey choice (Rutz *et al.* 2006; Penteriani *et al.* 2013), and so we also explored the effect of
180 buzzard age on diet composition. The buzzard using each roost was aged from plumage patterns on
181 the breast, tail and greater coverts (Svensson *et al.* 2009; Hardey *et al.* 2013) and categorised as
182 ‘adult’ (individuals over 3 years); ‘immature and juvenile’ (individuals less than 3 years); or ‘unknown
183 age’. Data from tagged individuals showed that buzzards were faithful to one roost on 89% of
184 occasions (range: 74% – 100%). Therefore, we assumed that pellets from each roost came from a
185 different individual.

186 Statistical analysis

187 To examine the factors affecting the composition of buzzard diet, compositional analysis was used
188 (Aebischer *et al.* 1993). As the proportions of each of the six prey types identified in pellets from
189 each roost when summed equalled one, and therefore could not be considered independent from
190 each other, data were transformed into five log-ratios with ‘other birds’ used as the denominator in
191 the transformation. The choice of denominator does not affect the outcome of the analysis
192 (Aebischer *et al.* 1993b). Any zeros in the dataset were replaced with 0.1 to allow calculation of log-
193 ratios. Log ratios were then analysed with multivariate analysis of variance (MANOVA), specifying
194 year (two-level) and buzzard age (three-level) as factors and habitat as a covariate. Interaction terms
195 between all effects were tested and main effects were tested with non-significant interaction terms
196 removed. Significance values were tested with Wilk’s Lambda statistic. Only the 19 roosts that were
197 sampled in both years were included in this analysis. To identify which prey groups caused any
198 differences found in the MANOVA, a ranking matrix was constructed by comparing the pairwise
199 differences between log-ratios using contrast analysis (Aebischer *et al.* 1993). Analyses were
200 conducted using the ‘manova’ function in the nlme package of ‘R’ statistical software (Pinheiro *et al.*
201 2014).

202 **Results**

203 Mean field vole abundance per 100 trap nights did not differ between March 2014 (5.3 ± 0.8 SE) and
204 March 2015 (4.4 ± 1.3 SE) ($t = 0.65$, $n = 10$, $P = 0.53$). Over the same period, grouse abundance

205 declined from 86.6 / km² (± 5.9 SE) in March/April 2014 to 69.8 / km² (± 5.2 SE) in March/April 2015
206 (t = 3.54, n = 28, P = 0.001).

207 All identified roost sites were occupied by a single buzzard and the minimum between-roost
208 distance was 254 m, justifying our assumption that pellets from one roost came from one individual.
209 Searches of 23 roosts during 2013/14 yielded 409 pellets (mean pellets per roost = 18, range = 12 –
210 32), while 355 pellets were collected from 21 roost sites in 2014/15 (mean pellets per roost = 17,
211 range = 10 – 28). Categorising roost sites according to buzzard age in 2013/14 showed that 203
212 pellets were collected from eight roosts of young (immature/juveniles) buzzards, 117 pellets from
213 eight roosts of adult buzzards, and 89 pellets from seven roosts of buzzards of unknown age. In
214 2014/15, 139 pellets were collected from eight roost sites occupied by young buzzards, 157 from
215 nine roost sites occupied by adults and 59 pellets from four roost sites of unknown buzzard age.
216 Overall, 2,100 prey items were identified from all pellets (2013/14 = 1,107 prey items; 2014/15 = 993
217 prey items). The mean number of prey items per pellet was 2.7 (range = 1 – 7) in 2013/14 and 2.8
218 (range = 1 – 8) in 2014/15. The majority of pellets collected from all 44 roosts contained small
219 mammals, which were also the most frequently occurring prey item in both years (Table 1a).
220 Invertebrate remains, which were predominately beetles *Coleoptera* spp., were the second most
221 important prey group in both years.

222 Data across years from the 19 repeat sampled roosts (Table 1b) showed that pellets from adult
223 buzzards contained more small mammals (adults = 66.6% of prey items, young = 60.4% of prey
224 items) and 'other birds' (adults = 5.0%, young = 4.7%), whilst pellets from young buzzards contained
225 more lagomorphs (adults = 8.0%, young = 11.1%), invertebrates (adults = 18.2%, young = 20.7%),
226 pheasants (adults = 1.2%, young = 1.9%) and red grouse (adults = 1.0%, young = 1.2%). However,
227 after removing all non-significant interaction effects, the overall composition of prey in pellets did
228 not differ significantly with buzzard age category ($\Lambda = 0.73$, $P = 0.47$), and this remained non-
229 significant when buzzards of unknown age were removed ($\Lambda = 0.88$, $P = 0.65$). Variation in broad
230 habitat composition around each roost also had no detectable effect on overall composition of prey
231 in pellets ($\Lambda = 0.88$, $P = 0.58$).

232 The composition of prey in pellets differed significantly between years (Wilks' Lambda (Λ) = 0.67, $P =$
233 0.03). A simplified ranking matrix from contrast analysis of prey groups (Table 2) showed an
234 increasing importance of prey groups in 2014/15 compared to 2013/14 in the order: Other birds >
235 Lagomorphs > Small mammals > Invertebrates > Pheasants > Red grouse. In 2014/15, buzzards ate
236 more 'other birds' (mostly small passerines, corvids and columbids) and lagomorphs, but fewer red

237 grouse (relative to other birds and lagomorphs), which reflected the decline in red grouse
238 abundance during this period.

239 **Discussion**

240 The winter diet of raptors, including buzzards, is poorly understood compared to during the breeding
241 season (Lewis *et al.* 2004; Schindler *et al.* 2012). In this study we demonstrated how remote tracking
242 methods, supplemented with observations, could be used to identify winter roost sites of common
243 buzzards for the purpose of collecting and analysing pellets for dietary composition data. We found
244 no evidence that buzzards at Langholm Moor roosted communally, as can be found in Central
245 Europe (Newton 1979). Pellets collected from roost sites indicated that small mammals were the
246 favoured winter prey of buzzards, consistent with other studies in Britain during the breeding season
247 (Swann & Etheridge 1995; Graham *et al.* 1995; Francksen *et al.* 2016) and buzzard diet in Spain
248 during the winter (Mañosa & Cordero 1992). Invertebrates were also an important prey resource
249 numerically, the majority of which were beetles and earthworms, which may reflect the increased
250 time that buzzards spend hunting from the ground during winter (Tubbs 1974; Wuczyński 2005).
251 Both winters of this study were mild with little snow cover, which probably meant that many ground
252 dwelling invertebrates remained available. Numerous studies have recorded reptiles and amphibians
253 in the summer diet of buzzards (Swann & Etheridge 1995; Selås *et al.* 2007; Rooney & Montgomery
254 2013; Francksen *et al.* 2016). However, we found no identifiable remains of reptiles or amphibians,
255 which may reflect both a reduced availability of these prey outside of summer, and their
256 underestimation in pellet analysis (Selås *et al.* 2007; Francksen *et al.* 2016).

257 The diet of generalist predators, including buzzards, varies temporally in relation to changes in local
258 prey abundance (Redpath & Thirgood 1999; Reif *et al.* 2004). We found that buzzard diet varied
259 between years: compared to the first winter buzzards ate more lagomorphs and other birds, but
260 fewer red grouse. The reduced importance of red grouse in the diet of buzzards in the second winter
261 reflected lower grouse abundance. However, in the absence of data on the abundances of
262 lagomorphs and other birds, we cannot conclude whether these results indicate shifts in foraging
263 habits or merely a response to their greater availability as prey to opportunistic buzzards (Tubbs
264 1974; Newton 2013). Studies in Scandinavia have suggested that when preferred small mammal
265 abundances are lower, generalist raptors switch to alternative prey, including more gamebirds (Reif
266 & Tornberg 2004; Tornberg *et al.* 2012). We were unable to assess how buzzards respond
267 functionally during winter to changing small mammal abundance, since vole abundances were
268 similar during both of our study winters. This remains an important avenue of further research, and

269 will require information on the fluctuations in abundance of a range of alternative prey.
270 Nevertheless, since red grouse occurred in just 2-3% of pellets and formed 1% of prey items, it
271 suggests that grouse are merely incidental prey for buzzards during the winter. This figure is slightly
272 lower than the 4% of total identified prey in buzzard pellets collected over three summers at
273 Langholm (Francksen *et al.* 2016), which may also reflect the lower abundance of grouse during the
274 winter (Ludwig *et al.* 2016).

275 Whilst our study has provided a potentially important insight into winter buzzard diet on a moor
276 managed for red grouse, results and their inferences should be treated with caution. Firstly, whilst
277 pellet analysis is widely used to assess raptor diet (Tornberg & Reif 2007), the high digestive
278 efficiency of buzzards (Barton & Houston 1993) and the selective removal of indigestible parts (Dare
279 2015), means that pellet analysis can underestimate the occurrence of avian or soft-bodied prey
280 (such as amphibians or earthworms), whilst overestimating conspicuous or indigestible remains such
281 as wing-cases and exoskeletons of hard-bodied invertebrates (Francksen *et al.* 2016). Advances in
282 molecular techniques for the identification of both predator and prey species (Mumma *et al.* 2014;
283 Evans *et al.* 2016; Hopken *et al.* 2016) may complement traditional methods of understanding
284 predator-prey interactions in the future. Secondly, our analysis of pellets was unable to distinguish
285 between prey that have been scavenged and those that have been killed. Buzzards are known to
286 scavenge carcasses as well as take live prey (Tubbs 1974; Parrott 2015). The possibility that pellets
287 contain remains of scavenged prey, or kills that have been visited over multiple days, means that this
288 method of diet assessment cannot provide accurate information about predation rates (Redpath *et*
289 *al.* 2001). Nevertheless, our results can still provide information on dietary shifts and foraging
290 behaviour, some of which we outlined here. Finally, our estimates of winter home range using
291 remote telemetry would benefit from more data from a larger sample of individuals in order to
292 improve accuracy. An average winter home range area was used to estimate habitat composition
293 around each roost, however all tagged buzzards were either juvenile or sub-adult individuals, which
294 in many raptor species have been shown to roam further than adults, a reflection of inexperience in
295 hunting, mate searching or the lack of an established territory to defend (Newton 1979; Walls &
296 Kenward 1998; Penteriani *et al.* 2013). Different estimates of winter home range may come from
297 inclusion of telemetry data from adult buzzards, although the effect of long range excursions was
298 minimised by considering core ranges only, and in the absence of alternative data it is the most
299 appropriate estimate currently available on our study site.

300 Quantitative assessments of predation on gamebirds are crucial to finding remedies for minimizing
301 conflict between people, predators and game (Elston *et al.* 2014), and assessing dietary composition

302 forms the basis of many studies investigating the impact of raptor predation on gamebirds (Park *et*
303 *al.* 2008). We highlight that red grouse were a minor component of buzzard diet on our study site
304 during the winter, and appeared to reduce in importance as red grouse abundance declined. Further
305 research should assess the effect of fluctuations of a range of prey resources on dietary shifts and
306 foraging habits of buzzards.

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