

1                   **Scientific Assessment on Livestock Predation in South Africa**

2  
3                   **CHAPTER 7**

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5                   **BIOLOGY AND ECOLOGY OF THE BLACK-BACKED JACKAL AND CARACAL**

6                   Liaan Minnie<sup>1,2</sup>, Nico L. Avenant<sup>3</sup>, Marine Drouily<sup>4</sup> & Igshaan Samuels<sup>5</sup>

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8                   <sup>1</sup> Centre for African Conservation Ecology, Nelson Mandela University, PO Box 77000, Port  
9                   Elizabeth, 6031, South Africa

10                   <sup>2</sup> School of Biology and Environmental Sciences, University of Mpumalanga, Private Bag  
11                   X11283, Nelspruit, 1200, South Africa

12                   <sup>3</sup> Department of Mammalogy, National Museum, and Centre for Environmental  
13                   Management, University of the Free State, Bloemfontein, 9301, South Africa

14                   <sup>4</sup> Institute for Communities and Wildlife in Africa, Department of Biological Sciences,  
15                   University of Cape Town, Rondebosch, 7700, South Africa

16                   <sup>5</sup> Agricultural Research Council-Animal Production Institute, Private Bag X17, Bellville, 7535,  
17                   South Africa  
18

19                   **Introduction**

20                   Globally, several carnivore species have been implicated as livestock predators, ranging in  
21                   body size from mongoose (e.g., Minnie, 2009) to lions (Gusset, Swarner, Mponwane,  
22                   Keletile & McNutt, 2009; Van der Merwe, Avenant & Lues, 2009) and bears (e.g., Li,  
23                   Buzzard, Chen & Jiang, 2013). However, medium-sized canids and felids are most often  
24                   implicated in livestock predation. For example, red foxes (*Vulpes vulpes*) – the most widely  
25                   distributed canid species apart from domestic dogs (*Canis lupus familiaris*) – attack and kill  
26                   livestock both in their natural and introduced ranges (Sillero-Zubiri, Hoffmann & Macdonald,  
27                   2004); coyotes (*Canis latrans*) and dingoes (*Canis lupus dingo*) are the dominant predators  
28                   of livestock in North America and Australia, respectively (Sillero-Zubiri *et al.*, 2004). In  
29                   addition, golden jackals (*Canis aureus*) prey on livestock in Africa, Europe and the Middle  
30                   East (e.g., Yom-Tov, Ashkenazi & Viner, 1995). Further, the Eurasian lynx (*Lynx lynx*) and to  
31                   a lesser extent bobcats (*Lynx rufus*) have been implicated in livestock predation in Europe  
32                   and North America, respectively (see Inskip & Zimmermann, 2009 for review). However, in  
33                   contrast to the Canidae, the larger species of the Felidae are more often implicated as  
34                   livestock predators, apart from caracal (*Caracal caracal*) and Eurasian lynx (Inskip &  
35                   Zimmermann, 2009).

36                   In a southern African context, mesopredators (see Chapter 1 for definition) – most  
37                   notably black-backed jackals (*Canis mesomelas*) and caracal – are the dominant predators  
38                   of livestock (predominantly sheep and goats, and to a lesser extent cattle) and valued  
39                   wildlife species (van Niekerk, 2010; Chapter 3). Several reasons for the relatively large

40 impact of mesopredators on the livestock industry have been posited (e.g., mesopredator  
41 release; see Chapter 8). However, livestock predation by black-backed jackal and caracal is  
42 probably rooted in their ethological and ecological plasticity, which allows them to persist  
43 despite centuries of population reduction efforts (Minnie, Gaylard & Kerley, 2016a; Chapter  
44 2). This, in turn, has exacerbated their impacts on the livestock industry.

45 In South Africa, humans have been relatively unsuccessful in eliminating the  
46 livestock losses caused by black-backed jackals and caracals, despite >350 years of lethal  
47 management (Kerley *et al.*, 2017). This may be due to the fact that predation management  
48 focusses on reducing mesopredator population size and does not take the ecology and  
49 biology of the target predator into account, and may thus produce unexpected population  
50 responses. The effective management of any animal population requires a basic  
51 understanding of its biology and ecology (e.g. Knowlton *et al.* 1999) to assist in predicting  
52 the responses of these populations to suggested/implemented management plans (du  
53 Plessis, 2013; Hone, Duncan & Forsyth, 2010; Chapter 6). Furthermore, the application of  
54 adaptive management is grounded in animal ecology/biology (Chapter 1). Without this basic  
55 background information, policy or management plans will not be effective in achieving  
56 management objectives.

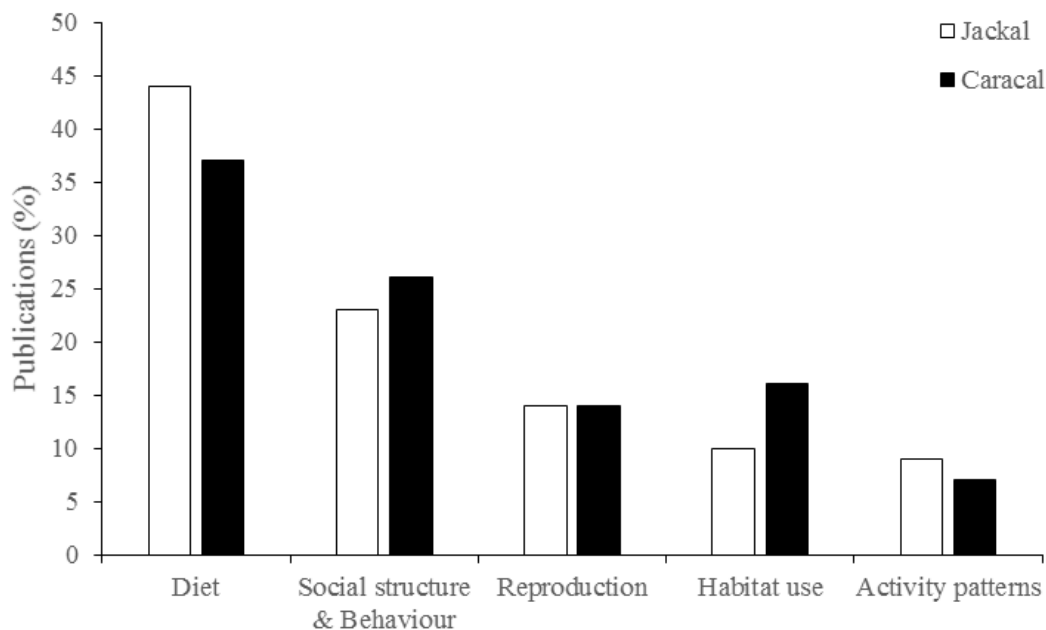
57 Developing effective management regimes aimed at reducing predation requires an  
58 understanding as to why carnivores attack livestock. Achieving this requires an  
59 understanding of the aspects of the carnivores' environment, biology and ecology which  
60 predispose them to livestock predation (Breck, 2004). A recent review indicated that there is  
61 a general paucity of information regarding the biology and ecology of black-backed jackals  
62 and caracals in southern Africa (du Plessis, Avenant & De Waal, 2015). In addition, the  
63 existing information is spatially biased, focussing on a subset of South African biomes, and  
64 predominantly on nature reserves (du Plessis *et al.*, 2015). The dynamic nature of both  
65 black-backed jackals and caracals make generalisations across habitats and land uses  
66 difficult. However, this is required given the general lack of information and the spatially  
67 biased nature thereof. This chapter will synthesise the available knowledge of black-backed  
68 jackal and caracal ecology and biology, and will identify any research gaps and opportunities  
69 for future research. Additionally, where information is lacking, we make reference to  
70 ecological surrogates (e.g., coyote for black-backed jackal and lynx for caracal) to highlight  
71 the importance of basic biological and ecological research as it relates to adaptive  
72 management.

73

#### 74 **Diet**

75 Resource acquisition plays a fundamental role in influencing carnivore growth, maintenance  
76 and reproduction (Fuller & Sievert, 2001). Various factors influence the ability of carnivores

77 to obtain appropriate resources to sustain these vital processes, including inter- and  
 78 intraspecific competition (Leo, Reading & Letnic, 2015), local environmental conditions  
 79 (Sacks, 2005), and availability, abundance and dispersion of resources (Todd & Keith, 1983;  
 80 Klare, Kamler, Stenkewitz & Macdonald, 2010). In addition, anthropogenic habitat  
 81 modifications such as habitat reduction and fragmentation, as well as predator management  
 82 (lethal and non-lethal) may further augment the functional responses of carnivore diets to  
 83 local environmental conditions (e.g., Benson, Mahoney & Patterson, 2015). The diet of  
 84 black-backed jackals and caracals is the most widely studied part of their biology and  
 85 ecology (Figure 1), which is not surprising given their role as livestock predators.



86  
 87 Figure 1: The proportion of research (peer-reviewed publications, and theses and  
 88 dissertations) conducted on the biology and ecology of black-backed jackals ( $n = 58$ ) and  
 89 caracals ( $n = 29$ ) between 1960 and 2013 (adapted from du Plessis *et al.*, 2015).

90  
 91 *Black-backed jackal*

92 Until recently (see prey selection below), black-backed jackals, like other small- to medium-  
 93 sized canids (e.g., dingo, Allen & Leung, 2014; coyote, Murray *et al.*, 2015), were considered  
 94 generalist omnivores, with a catholic diet that varies according to local food availability  
 95 (Fourie, Tambling, Gaylard & Kerley, 2015; Kok & Nel, 2004; Loveridge & Macdonald, 2003).  
 96 The diet is dominated by small- to medium-sized mammals, and is often supplemented by  
 97 birds, reptiles, carrion, invertebrates, and fruit (Brassine & Parker, 2012; Kamler, Klare &  
 98 Macdonald, 2012; Minnie, 2016; Morwe, 2013; van de Ven, Tambling & Kerley, 2013).  
 99 Hayward *et al.* (2017) reported that black-backed jackals may have evolved to optimally prey  
 100 on small- and medium-sized mammals. This is substantiated by the predominance of small-

101 and medium-sized mammals in the diet of black-backed jackals irrespective of location and  
102 season (Brassine, 2011; Kaunda & Skinner, 2003; Morwe, 2013; van de Ven *et al.*, 2013).

103 However, when small- and medium- size mammals become rare, black-backed  
104 jackals, like other canids, may consume a wider variety of food items (i.e., wider niche  
105 breadth) to maintain energy intake (Kaunda & Skinner, 2003). This has also been  
106 documented in coyotes (Gese, Ruff & Crabtree, 1996) and dingoes (Corbett & Newsome,  
107 1987); when carcass availability was reduced, subordinate individuals were out-competed by  
108 dominant individuals and were forced to prey on small mammals. Additionally, black-backed  
109 jackals have been shown to prey extensively on the fawns of hider species (i.e., fawns/lambs  
110 hidden in the vegetation; Klare *et al.*, 2010). This results in seasonal fluctuations in the  
111 consumption of ungulate species, with fawns of hider species being consumed more in the  
112 breeding season (Klare *et al.*, 2010; Morwe, 2013). Therefore, black-backed jackals have the  
113 ability to vary their diet in response to variations in resource variability. Opportunistic feeding  
114 habits and dietary flexibility, amongst other factors, is posited as a causative factor in the  
115 persistence of black-backed jackal populations despite concerted population reduction  
116 efforts (Grafton, 1965).

117 This dietary flexibility is probably due to the opportunistic foraging strategy of black-  
118 backed jackals. Atkinson, Rhodes, Macdonald & Anderson (2002) found that both side-  
119 striped (*Canis adustus*) and black-backed jackals follow an optimal foraging pattern which  
120 allows them to opportunistically access spatially and temporally variable resources. Black-  
121 backed jackals are cursorial predators and during foraging black-backed jackals typically  
122 consume the first food source encountered (Bothma, 2012; Kok & Nel, 2004). Additionally,  
123 black-backed jackals may also access larger prey species by scavenging from apex predator  
124 kills (see resource provisioning by apex predators below), predation on fawns/lambs, or may  
125 be facilitated by group hunting. Black-backed jackals generally hunt singularly or in pairs, but  
126 may occasionally hunt in groups to improve the success of capturing larger prey (McKenzie,  
127 1990; Moehlman, 1987). For example, black-backed jackals in Botswana formed temporary  
128 “packs” of six to 12 individuals to successfully attack and kill adult impala (McKenzie, 1990);  
129 and black-backed jackals in Namibia displayed similar opportunistic co-operative hunting to  
130 kill an adult springbuck (Krofel, 2008).

131 Given their opportunistic feeding habits, black-backed jackals, like other canids, show  
132 intraspecific variation in diet in accordance with local resource abundance and dispersion  
133 (Macdonald & Sillero-Zubiri, 2004). For example, the diet of black-backed jackals on  
134 reserves in arid and semi-arid areas is dominated by small antelopes (Brassine, 2011;  
135 Fourie *et al.*, 2015; Kamler *et al.*, 2012; Minnie, 2016; van de Ven *et al.*, 2013). Whereas  
136 black-backed jackal diet in more mesic areas is dominated by small mammals accompanied  
137 by a concomitant decrease in the consumption of antelope species (Kaunda & Skinner,

138 2003; Rowe-Rowe, 1983). However, few studies quantify the dietary shifts of black-backed  
139 jackals between areas with heterogeneous resource availability.

140 Diet shifting in black-backed jackals may occur when alternative resources are  
141 provisioned. Various factors may influence the type and amount of resources available to  
142 black-backed jackals. In a South African context, the most pertinent variation in prey base  
143 occurs between various land uses. Black-backed jackal diets differ considerably between  
144 agricultural and natural habitats. This may be due to dietary shifts in response to resource  
145 provisioning. Here, we contrast the diet of black-backed jackals in natural systems – which  
146 include carcass provisioning by apex predators – and livestock farms – which include  
147 livestock provisioning.

148

#### 149 Resource provisioning by apex predators

150 Given the black-backed jackal's reputation as a scavenger, the influence of prey provisioning  
151 by apex predators has been widely investigated in South Africa. However, there is a  
152 disagreement whether the provisioning of scavenging opportunities actually influences black-  
153 backed jackal diet. Some authors suggest that this is not the case (e.g., Brassine & Parker,  
154 2012; Yarnell *et al.*, 2013), whereas others show that black-backed jackals consume larger  
155 prey species in the presence of apex predators (e.g., Fourie *et al.*, 2015; Minnie, 2016). This  
156 suggests that scavenging from carcasses may be context-dependent and varies according  
157 to local environmental conditions.

158 The presence of apex predators may also negatively affect black-backed jackal  
159 populations through predation (i.e., interspecific competition), and the continuum between  
160 facilitation and competition may be related to apex predator density and the species  
161 involved. For example, at low wolf densities, smaller wolf packs leave larger portions of a kill  
162 unconsumed thereby providing more scavenging opportunities for wolverines (*Gulo gulo*),  
163 with the converse holding at high wolf densities (Khalil, Pasanen-Mortensen & Elmhagen,  
164 2014). Therefore, in reserves with low densities of apex predators, facilitation may play a  
165 more important role than competition resulting in resource provisioning (Minnie, 2016), but  
166 this also depends on how the carnivores partition the habitat. Given the context-dependent  
167 nature of black-backed jackal foraging behaviour and the contrasting results obtained in  
168 various studies, more research is required to estimate how black-backed jackal diets vary in  
169 response to varying densities of apex predators (i.e., facilitation *versus* competition).

170

#### 171 Resource provisioning by humans

172 The provisioning of naïve livestock breeds will undoubtedly affect black-backed jackal diets.  
173 Due to domestication, most sheep and goats have lost their anti-predator responses, and  
174 have been introduced into rangelands with limited predation refuges, making them easy

175 targets to predators. Black-backed jackals, like caracals, successfully attack and kill  
 176 livestock. This resource represents an optimal food source which provides the maximum  
 177 energy return for minimal effort. Several dietary studies conducted on livestock farms  
 178 indicate that livestock may contribute a large proportion of the diet (25 - 48%; Kamler *et al.*,  
 179 2012), but other studies show that this is not the case (e.g., 16%; Minnie, 2016). Thus, in  
 180 agricultural areas, black-backed jackals may shift their diet by including livestock and thus  
 181 consuming relatively less small- to medium-sized ungulates (predominant prey on nature  
 182 reserves; e.g. Minnie, 2016). However, this shift in diet is context-dependent, as several  
 183 studies have indicated that black-backed jackals on farms consume more small mammals  
 184 and small ungulates than on nature reserves (Bothma, 1971b; Minnie, 2016). This suggests  
 185 that black-backed jackals prefer natural prey over livestock (Table 1). For this reason, it has  
 186 been hypothesised that abundant natural prey may buffer livestock losses (Avenant & du  
 187 Plessis, 2008; Bothma, 2012; Hayward *et al.*, 2017; Natrass, Conradie, Drouilley & O'Riain,  
 188 2017). This buffering has been documented for coyotes, where a reduction in natural prey  
 189 resulted in an increase in livestock predation (Stoddart *et al.*, 2001). Thus, maintaining a  
 190 healthy natural prey base may reduce predation on livestock, but this hypothesis has not  
 191 been tested for black-backed jackals.

192

193 **Table 1: Prey preferences of black-backed jackals, indicating if prey is significantly**  
 194 **avoided, consumed in accordance with abundance, or significantly avoided (extracted**  
 195 **from Hayward *et al.*, 2017). The asterisk (\*) indicates estimated avoidance and**  
 196 ***Insufficient data* indicates that too few studies incorporated these species to allow for**  
 197 **statistical analyses.**

198

199

Prey species	Avoided	In accordance	Preferred	Prey species	Avoided	In accordance	Preferred	Prey species	Avoided	In accordance	Preferred
Aardwolf				Grysbok, Sharpe's	<i>Insufficient data</i>			Rhebuck, grey	<i>Insufficient data</i>		
Baboon	<i>Insufficient data</i>			Hare, Cape				Roan	<i>Insufficient data</i>		
Birds				Hare, scrub	<i>Insufficient data</i>			Rodents			
Blesbok				Hares				Sable	*		
Bontebok	<i>Insufficient data</i>			Hartebeest, red				Sheep			
Buffalo				Hippopotamus	<i>Insufficient data</i>			Small mammals			
Bushbuck				Impala				Springbuck			

Bushpig			Klipspringer	<i>Insufficient data</i>	Springhare		
Cattle	*		Kudu		Steenbok		
Duiker, blue	<i>Insufficient data</i>		Lagomorphs		Suids		
Duiker, common			Lechwe	<i>Insufficient data</i>	Tsessebe	*	
Eland			Livestock		Warthog		
Elephant	*		Nyala	*	Waterbuck		
Gemsbok			Oribi	<i>Insufficient data</i>	Wildebeest, black		
Giraffe	*		Ostrich	*	Wildebeest, blue		
Goat	*		Reedbuck, common	*	Zebra, mountain	<i>Insufficient data</i>	
Grysbok, Cape	<i>Insufficient data</i>		Reedbuck, mountain		Zebra, plains		

200

201

202 Prey preference

203 Although, black-backed jackals may alter diets in response to resource fluctuations, they do  
204 display an optimal foraging strategy (Hayward *et al.*, 2017). A recent study determined the  
205 prey preferences of black-backed and golden jackals (*Canis aureus*) and found that black-  
206 backed jackals prefer to consume birds, common duiker, bushbuck and springbuck (Table  
207 1), and prefer to prey on species with an average body mass (3/4 adult female body mass)  
208 of  $21.7 \pm 3.5$ kg (range: 14 - 26 kg; Hayward *et al.*, 2017). In general, black-backed jackals  
209 prefer to prey on natural prey whilst consuming livestock in accordance with abundance  
210 (Table 1; Hayward *et al.*, 2017).

211 The available dietary information for black-backed jackals indicates that they have a  
212 flexible diet, and prefer to prey on small- to medium-sized mammals. Additionally it indicates  
213 that black-backed jackals do consume livestock (hunting or scavenging), but prefer natural  
214 prey over livestock (Hayward *et al.*, 2017), although exceptions may occur. Further, dietary  
215 descriptions do not provide information on the impact on the livestock- and game farming  
216 industries. This would require the identification and quantification of prey killed by black-  
217 backed jackals (Chapter 3).

218

219 *Caracal*

220 Caracals are generalist predators, but have a more specialized diet than black-backed  
221 jackals (Braczkowski *et al.*, 2012; Jansen, 2016; Kok & Nel, 2004; Melville, 2004b; Pohl,

222 2015). Although their diet is dominated by mammals, they may consume birds, reptiles,  
223 invertebrates, fruit and seeds, and vegetation (Avenant & Nel, 2002; Braczkowski *et al.*,  
224 2012; Jansen, 2016; Melville, 2004b; Palmer & Fairall, 1988). Caracals predominantly prey  
225 on small- to medium-sized mammals ranging in size from rodents to ungulates (~50kg; Pohl,  
226 2015). The prey base of caracals is similar to that of black-backed jackals, suggesting that  
227 these two species may compete when they occur in sympatry. However, no research on  
228 resource partitioning has been conducted.

229 Caracals may use one of two strategies to access prey: 1) an optimal foraging  
230 strategy may be employed when moving directly between core areas where food is  
231 abundant (Avenant & Nel, 1998; Melville & Bothma, 2006; Stuart, 1982), or 2) when prey  
232 abundance is relatively low, caracals may employ a random foraging strategy where they  
233 move randomly through their range and consume food as it is encountered (Avenant & Nel,  
234 1998; Melville & Bothma, 2006; van Heezik & Seddon, 1998). Caracals usually prey on the  
235 most abundant prey species (Avenant & Nel, 1997, 2002) but, like black-backed jackals, are  
236 capable of switching prey in response to spatial and temporal fluctuations in resource  
237 abundance and dispersion, albeit to a lesser extent. In the driest parts of southern Africa,  
238 caracals predominantly consume mammals (Grobler, 1981; Melville, 2004b; Pohl, 2015),  
239 whereas in more mesic areas the consumption of alternate prey items, particularly birds,  
240 increase (e.g., Cape Peninsula, Western Cape Province, South Africa, Leighton, G. *pers.*  
241 *comm.*). Seasonal variation in mammalian prey consumption has also been noted for  
242 caracals, where they consumed more springbuck when females were lactating or  
243 provisioning kittens (Avenant & Nel, 1997, 1998, 2002). Further, the occurrence of sympatric  
244 carnivore remains in caracal scats is not unusual (Avenant & Nel, 1997, 2002; Braczkowski  
245 *et al.*, 2012; Melville, 2004b; Palmer & Fairall, 1988). Melville (2004b) ascribed the presence  
246 of carnivores in caracal diet to the low density of ungulate prey. This further highlights the  
247 opportunistic feeding of the caracal.

248

#### 249 Resource provisioning by humans

250 Similar to black-backed jackals, diet shifts may occur when alternate resources are  
251 provisioned. However, caracals rarely scavenge (Avenant, 1993; Mills, 1984; Nowell &  
252 Jackson, 1996), but scavenging was documented in Etosha National Park where a caracal  
253 scavenged on a springbuck killed by a cheetah (Nowell & Jackson, 1996). Thus, in contrast  
254 to black-backed jackals, resource provisioning by apex predators appears to be of little  
255 importance. The diet of caracals differs with land use, with caracals on livestock farms  
256 supplementing their diet with livestock (Avenant & Nel, 2002; Kok & Nel, 2004; Melville,  
257 2004b; Pringle & Pringle, 1979; Skinner, 1979; Stuart, 1982), particularly during the livestock  
258 lambing season (Pohl, 2015), or when a female caracal is lactating, or accompanied by



259 young (Avenant, 1993; Avenant & Nel, 1998). However, despite this livestock provisioning by  
260 humans, small mammals such as lagomorphs and rock hyraxes still constitute an important  
261 part of their diet (Grobler, 1981; Jansen, 2016; Melville, 2004b; Pohl, 2015). For example, on  
262 livestock farms in the Bedford district, Eastern Cape Province, caracals fed predominantly on  
263 wild prey (Pringle & Pringle, 1979), and on the farms surrounding the West Coast National  
264 Park, Western Cape Province, predation on livestock increased when the abundance of  
265 rodents decreased (Avenant & Nel, 1997, 1998, 2002). This suggests that, like black-backed  
266 jackals, caracals prefer to prey on natural prey and abundant natural prey may buffer  
267 livestock losses.

268

### 269 Prey preference

270 Although most studies indicate that caracals prey predominantly on small- to medium-sized  
271 mammals, few studies have quantified prey consumption relative to prey availability, which is  
272 essential in estimating prey preference. Several studies have showed that caracals are non-  
273 selective, consuming the prey with the highest abundance (Avenant & Nel, 2002; Moolman,  
274 1984). However, a single, localised study indicated that caracals prefer to prey on rock  
275 hyraxes, rodents and lagomorphs and avoided medium-sized ungulates such as common  
276 duiker, steenbok and springbuck (Jansen, 2016). Similar to black-backed jackals, caracals  
277 on farms avoided sheep and goats and preferred to prey on natural prey (Jansen, 2016),  
278 providing additional support for the hypothesis that abundant natural prey may buffer  
279 livestock losses. However, more research relating prey abundance to prey consumption is  
280 required to determine the prey preferences of caracals across South Africa.

281 The available dietary information on caracals indicates that they are generalist and  
282 opportunistic predators that may include domestic livestock in their diet. However, they  
283 prefer to prey on natural prey and consume relatively less livestock than black-backed  
284 jackals (Chapter 3; Jansen, 2016). Although the diet of caracals has been studied more than  
285 any other aspect of its ecology (Figure 1; du Plessis *et al.*, 2015), most studies have been  
286 conducted in protected areas. Thus, more research is required to determine the diet of  
287 caracal on livestock and game farms, as well as its impact on the livestock and game  
288 ranching industries.

289

### 290 **Social structure & Reproduction**

#### 291 *Black-backed jackal*

292 Relative to caracals, black-backed jackals have a complex social structure. In a stable social  
293 system, black-backed jackals are monogamous (Moehlman 1987). Pair formation may be an  
294 evolutionary advantageous strategy, as it increases hunting success (Lamprecht, 1978) and  
295 is critical for territorial defence and the successful rearing of pups (Moehlman, 1987).

296 However, the social structure of black-backed jackals is flexible and may consist of family  
297 groups ranging from one to eight individuals (Rowe-Rowe 1978, 1984). Family groups  
298 generally comprise a mated territorial pair and their offspring (Ferguson, Nel & de Wet, 1983;  
299 Loveridge & Macdonald, 2001). However, some groups may also contain older sub-adults  
300 that have delayed dispersal to act as helpers in raising sibling offspring (Ferguson *et al.*,  
301 1983; Moehlman, 1979; Rowe-Rowe, 1982). This is expected to occur under conditions  
302 where food availability is high (Ferguson *et al.*, 1983). Additionally, the territorial pair may  
303 tolerate subordinate individuals on the fringes of their territories (i.e., floaters, Ferguson *et al.*  
304 1983) and cases have been documented where black-backed jackals allowed other mated  
305 pairs, sub-adults or juveniles into their territories (Ferguson *et al.*, 1983; Hiscocks & Perrin,  
306 1988; Loveridge & Macdonald, 2001; Loveridge & Macdonald, 2003; Macdonald, 1979;  
307 McKenzie, 1990; Oosthuizen *et al.*, 1997; Rowe-Rowe, 1982). Such relaxation in territorial  
308 defence may occur when resources are locally abundant (see Box 1).

309 The dominant mated pair defends a mutually exclusive breeding territory and  
310 prevents younger subordinates from reproducing (Loveridge & Nel, 2004). However, extra-  
311 pair reproduction has been recorded and has been attributed to anthropogenic mortality  
312 (Bothma, 2012; McKenzie, 1993; Walton & Joly, 2003). Polygamy – as a mechanism to  
313 compensate for high mortality (e.g., coyote; Kleiman & Brady, 1978) – may counter lethal  
314 management aimed at reducing black-backed jackal population size by allowing more  
315 females to reproduce to compensate for increased mortality (see Box 2).

316 Mating peaks during the winter months (Skead, 1973), but late autumn and early  
317 spring mating have also been recorded (Bothma, 2012; Stuart, 1981). Gestation lasts for  
318 about two months but may extend up to 70 days (Bernard & Stuart, 1992; McKenzie, 1993;  
319 Walton & Joly, 2003). Parturition usually occurs from winter to early spring (Bernard &  
320 Stuart, 1992; Bothma, 1971a; McKenzie, 1993). Additionally, parturition at a regional level  
321 may be asynchronous, as breeding pairs may reproduce within one month of each other  
322 (Bingham & Purchase, 2002). The timing of the reproductive cycle varies spatially and  
323 temporally with local environmental conditions and food availability (Bernard & Stuart, 1992;  
324 Bingham & Purchase, 2002; Fairall, 1968; McKenzie, 1993; Rowe-Rowe, 1978; Walton &  
325 Joly, 2003), as is the case for coyotes (Gese, 2005). Although an earlier onset of  
326 reproduction and an extended reproductive period has been linked to increased resource  
327 availability (Bernard & Stuart, 1992; Walton & Joly, 2003), little information on the variation in  
328 reproductive cycle in response to variation in resources between land uses is available.

329 Black-backed jackal females have one litter per year, and litter size ranges between  
330 one and nine, depending on the female's body condition (Minnie *et al.*, 2016a), social status  
331 (Loveridge & Nel, 2013), and anthropogenic mortality (see Box 2; Minnie *et al.*, 2016a).  
332 Unlike caracal, both parents help raise the pups, which remain in the den from August to

333 November (Ferguson *et al.*, 1983). However, as with most aspects of black-backed jackal  
334 ecology, variation in this basic pattern occurs, as pups have been recorded in dens during  
335 January, March and July (Ferguson *et al.*, 1983). Pups emerge from the natal den after  
336 approximately three weeks and are weaned at eight to nine weeks of age. They start  
337 foraging with their parents at three months of age, but they remain in close proximity (*ca.* 2  
338 km) to the natal den until six months of age (Ferguson *et al.*, 1983; Moehlman, 1987). It is  
339 only when they get older (*ca.* seven months) that immature black-backed jackals start  
340 moving longer distances (see Dispersal).

341 Black-backed jackals become sexually mature at 11 months and young black-backed  
342 jackals can either: 1) become helpers (approximately one third of the litter) which aid in the  
343 raising, provisioning and guarding of subsequent litters, or 2) disperse (approximately two-  
344 thirds of the litter) from their natal range in search of mates and territories (Ferguson *et al.*,  
345 1983; Moehlman, 1987). Families with helpers have significantly higher offspring  
346 survivorship (Moehlman, 1979).

347

#### 348 **Box 1: Influence of clumped, high density resources on social structure**

349 Local resource richness and dispersion may alter carnivore spatial organisation and social  
350 structure. This should be particularly pronounced for scavenging species. Thus, given the  
351 fact that caracals rarely scavenge (see Diet), we do not expect variation in social structure in  
352 response to high-density resources. However, as home range is partly determined by  
353 resource availability, caracal density may increase when resources are locally abundant (see  
354 Home range). However, no research on the variation in caracal social structure in response  
355 to variation in resource density has been conducted. Further research is needed to  
356 determine if increased prey availability (e.g. livestock) results in a reduction in home range  
357 size and a consequent increase in population density.

358 Conversely, in certain instances, black-backed jackals have displayed a temporary  
359 collapse in their normal, mutually exclusive, territorial structure, which may be driven by an  
360 increase in local resource abundance. This is exemplified by variation in territory size and  
361 group size at seal colonies in Namibia. Here, tremendous variation in resource abundance  
362 occurs, with very high prey densities on the coast and low prey densities inland (Jenner,  
363 Groombridge & Funk, 2011). Inland, black-backed jackals display the normal mutually  
364 exclusive territorial structure. Jenner *et al.* (2011) reported that black-backed jackals defend  
365 these low prey density areas to maintain exclusive space to raise offspring successfully.  
366 Consequently, black-backed jackal group size is relatively small and territory size is relatively  
367 large. In contrast, at seal colonies where local resource abundance is relatively high, this  
368 territorial structure of black-backed jackals collapses resulting in territorial overlap (Hiscocks

369 & Perrin, 1988), increased group size and relatively small home ranges (Jenner *et al.*, 2011;  
370 Nel, Loutit, Braby & Somers, 2013).

371         Therefore, a local increase in resource abundance (e.g., livestock, open carcass  
372 dumps, and large animal carcass) will likely produce similar patterns as those observed at  
373 Namibian seal colonies – i.e. increased local abundance and population densities, and  
374 reduced territory size. Increased black-backed jackal densities have been documented  
375 around waterholes, antelope carcasses (Ferguson *et al.* 1983) and at vulture restaurants  
376 (Yarnell *et al.*, 2015). Similar population-level responses to anthropogenic resource  
377 subsidies have been documented for several carnivores (see Newsome *et al.*, 2015 for  
378 review). Further, this may have important consequences for predation on economically  
379 important prey such as livestock and valued wildlife species, which represent “clumped  
380 resources”. For example, Yom-Tov *et al.* (1995) found that illegal garbage dumps around  
381 informal human settlements (which included dead poultry and livestock) resulted in an  
382 increase in golden jackal population size. This, in turn, resulted in increased predation on  
383 cattle calves.

384

#### 385 *Caracal*

386 Caracals display the typical solitary social structure of other felids (e.g., leopard and lynx  
387 spp.), where the territory of a male may overlap with several females (Avenant 1993; see  
388 Home range). Thus, males and females only come together to reproduce. Only females  
389 partake in parental care and family groups may thus consist of an adult female and her  
390 offspring. This territorial structure has been reported throughout their distributional range  
391 with little variation from the basic social structure. This suggests that caracals, unlike black-  
392 backed jackals, do not display a flexible social structure.

393         Unlike black-backed jackals, caracals can reproduce throughout the year. The  
394 oestrous cycle of the female is about 14 days with the oestrous period lasting three to six  
395 days (Bernard & Stuart, 1987; Stuart, 1982). The female may mate with several males  
396 (polygamous) and mating order is determined by the body mass and age of the males  
397 (Weisbein & Mendelssohn, 1989). The gestation period ranges from 78 to 81 days (Bernard  
398 & Stuart, 1987). Parturition occurs throughout the year, but peaks (74% of births) between  
399 October and February in southern Africa (Bernard & Stuart, 1987; Bothma, 2012).

400         The fact that caracals are reproductively active throughout the year suggests that  
401 reproduction is predominantly determined by resource availability. Females need to attain an  
402 appropriate body condition to reproduce successfully. In natural environments with seasonal  
403 fluctuations in resource availability, female body condition is expected to be lower at the end  
404 of winter resulting in peak parturition in summer (Bernard & Stuart, 1987). This may coincide  
405 with the reproductive cycle of their main prey species (see Diet). Additionally, caracals

406 feeding on livestock, which represents an aseasonal resource, may maintain a relatively high  
407 body condition throughout the year allowing them to give birth throughout the year (Bernard  
408 & Stuart, 1987). Research on Canadian lynx indicate that during periods of high prey  
409 availability, young females remained in or close to their natal range where they successfully  
410 reproduced (Slough & Mowat, 1996), increasing the proportion of pregnant females in the  
411 population. If a similar case exists in caracals, the presence of livestock may result in  
412 increased densities and reproduction, which may further exacerbate livestock losses.  
413 However, no research on the reproductive response of caracals to prey base variation has  
414 been conducted.

415 Litter size typically ranges between one and three kittens, with an average of 2.2  
416 kittens per litter (Bernard & Stuart, 1987), although litters as large as six have been reported  
417 (Weisbein & Mendelssohn, 1989). Kittens are weaned between 15 and 24 weeks of age.  
418 Bernard & Stuart (1987) estimated that caracals reach sexual maturity between seven and  
419 10 months of age, after which caracals disperse from their natal range (see Dispersal). It is  
420 unclear if anthropogenic mortality influences the reproduction of the caracal, as is the case  
421 for the black-backed jackal (see Box 2), and thus warrants future research.

422

#### 423 **Box 2: Reproductive responses to anthropogenic mortality**

424 The lethal management of carnivores to reduce population size and the associated livestock  
425 losses may have significant impacts on reproduction. This may result in compensatory  
426 reproduction – which is an increase in reproductive output to compensate for increased  
427 mortality – which may manifest itself as increased litter size, larger proportion of breeding  
428 females, increased reproductive lifespan, or a decrease in age at first reproduction.

429 Compensatory reproduction in caracal is unknown, but has been reported for the  
430 Canadian lynx (Parker, Maxwell, Morton & Smith, 1983) and Eurasian lynx (Bagnard *et al.*,  
431 2016). The higher number of new born kittens could lead to a rapid population recovery after  
432 population reductions (Bothma, 2012). It is further argued that an increase in population  
433 densities due to compensatory breeding may result in predators feeding exclusively on  
434 livestock and introduced wildlife due to their constant availability (du Plessis *et al.*, 2015).  
435 However, no research on the effects of lethal management on caracal reproduction has  
436 been done. It is vitally important to determine the reproductive responses of caracals to  
437 lethal management to determine the effectiveness of these techniques in halting predation.

438 In canids, compensatory reproduction has been documented for red foxes (Cavallini  
439 & Santini, 1996; Harris & Smith, 1987), coyotes (Knowlton, 1972; Sterling, Conley & Conley,  
440 1983) and side-striped jackals (Bingham & Purchase, 2002), but not dingoes (Allen 2015;  
441 Allen *et al.*, 2015). This has also recently been documented for black-backed jackals in

442 South Africa in response to lethal management (Minnie *et al.*, 2016a). On livestock and  
443 game farms where black-backed jackals are lethally managed, younger individuals showed  
444 an increased pregnancy rate in conjunction with larger litters (Minnie *et al.*, 2016a). This was  
445 attributed to a release in density-dependent population regulation and social dominance  
446 (due to anthropogenic mortality) from dominant individuals which usually prevent  
447 subordinates from reproducing. Additionally, a reduction in population density may result in  
448 an increase in resource availability for the remaining individuals, thereby allowing  
449 subordinate individuals to attain a better body condition thus facilitating reproduction (e.g.,  
450 coyote; Knowlton, Gese & Jaeger, 1999). This increased reproductive output may result in  
451 the rapid recovery of populations to pre-management densities, thereby negating population  
452 reduction efforts. However, these findings are based on a single study in the Karoo, Eastern  
453 and Western Cape Provinces, making generalisations across habitats difficult. More  
454 research investigating the reproductive responses of black-backed jackals in conjunction  
455 with estimates of population size pre- and post-management interventions is required.

456

## 457 **Activity patterns**

### 458 *Black-backed jackal*

459 The information on black-backed jackal activity patterns is scant, with less than 10% of  
460 research focussing on this aspect (Figure 1; du Plessis *et al.*, 2015). Black-backed jackals  
461 may be active during any part of the day (Walton & Joly, 2003), but activity tends to peak  
462 during sunrise and sunset (i.e., crepuscular; Kaunda, 2000). For example, in Botswana,  
463 black-backed jackals were predominantly active between 17h00 and 22h00 and between  
464 05h00 and 08h00, with peaks in activity occurring around 18h00 and 06h00 (Kaunda, 2000).  
465 Black-backed jackals in the Kalahari Gemsbok National Park, Northern Cape Province, also  
466 showed a crepuscular activity pattern, but these peaks occurred at between 17h00 and  
467 21h00 and between 05h00 and 09h00. The timing and onset of these activity peaks seem to  
468 vary depending on local conditions, and may be due to several factors.

469 It has been suggested that the activity of black-backed jackals closely follows that of  
470 their main natural prey species (Ferguson, Galpin & de Wet, 1988; Hiscocks & Perrin, 1987;  
471 Kaunda, 2000; Walton & Joly, 2003). In the Gauteng Province, black-backed jackal activity  
472 closely mirrored the peak foraging time of their main rodent prey species on both farms and  
473 reserves (Ferguson *et al.*, 1988). Black-backed jackals foraging at seal colonies do not  
474 display pronounced activity peaks, as they are able to utilise the resource at any given  
475 period (Hiscocks & Perrin, 1988). However, the activity patterns of black-backed jackals are  
476 not always influenced by the activity of their main prey (e.g., Loveridge & Macdonald, 2003).  
477 Apart from a few studies in isolated locations, the activity patterns of black-backed jackals  
478 have been rarely compared to that of their prey, and thus warrant further investigation. This

479 may be particularly important in livestock farming areas, and may direct livestock  
480 management practices outside of black-backed jackal activity peaks.

481         Seasonal variation in activity also occurs, as black-backed jackal activity increases  
482 during the winter mating season (Ferguson, 1980). This seasonal variation in activity also  
483 corresponds to the seasonal variation in sunset and sunrise. This is not surprising, as visual  
484 predators require sufficient ambient light to successfully capture prey. Black-backed jackals  
485 in Zimbabwe were reported to be more active diurnally, which may be due to better light  
486 conditions for hunting and predator avoidance (Loveridge & Macdonald, 2003). Similar to  
487 coyotes (Lehner, 1976), black-backed jackals may have evolved a visual system designed  
488 for crepuscular activity. This suggests that black-backed jackals should be relatively more  
489 active during full moon when light conditions are conducive to hunting. However, Ferguson  
490 *et al.* (1988) showed that this is not the case and ascribed this to the prey easily spotting and  
491 avoiding black-backed jackals during full moon periods. Nocturnal light conditions may have  
492 important consequences for livestock predation. Lehner (1976) suggested that during  
493 nocturnal periods of low ambient light (e.g., new moon), livestock may provide more visual  
494 cues than natural prey, which may lead to increased livestock predation. However, this has  
495 not been investigated for black-backed jackals.

496         Interspecific competition may also augment black-backed jackal activity. Apart from  
497 facilitation (see Black-backed jackal diet), apex predators also attack and kill black-backed  
498 jackals. The intensity of facilitation and competition may affect the activity patterns of  
499 mesopredators which, in turn, may depend on the density of apex predators (Chapter 8;  
500 Newsome *et al.*, 2017). Loveridge & Macdonald (2003) investigated niche partitioning  
501 between black-backed jackals and side-striped jackals in Zimbabwe and showed partitioning  
502 of activity times. In most parts of South Africa, black-backed jackal and caracal are sympatric  
503 yet little information on niche partitioning between these two species exists.

504         Human activities, particularly lethal management, also modify the activity patterns of  
505 black-backed jackals. In areas where black-backed jackals are heavily persecuted, they are  
506 more active at night to avoid humans (Ferguson *et al.*, 1988; Fuller, Biknevicius, Kat,  
507 Valkenburgh & Wayne, 1989; Hiscocks & Perrin, 1988; Rowe-Rowe, 1978). With the  
508 prevalence of call-and-shoot night hunting (Chapter 6), it is hypothesised that black-backed  
509 jackals may become more diurnal to avoid dangerous periods. However, more information  
510 on the responses of black-backed jackals to lethal and non-lethal management is required.  
511 This will provide valuable insights in designing effective adaptive management programmes  
512 aimed at reducing predation on livestock and valued wildlife species.

513

514 *Caracal*

515 Despite the importance of caracals as predators of livestock, little is known about their  
516 activity patterns and the factors influencing it, and only two studies have investigated this in  
517 southern Africa (Figure 1; du Plessis *et al.*, 2015). Caracals have been described as being  
518 mostly nocturnal, but much variation in activity patterns exists across its distributional range  
519 (Skinner, 1979; Stuart, 1982). In the West Coast National Park, Western Cape Province,  
520 caracals were active during the night, but also during cooler winter days ( $\leq 22^{\circ}\text{C}$ , Avenant &  
521 Nel, 1998). Both diurnal and nocturnal activities have been reported throughout their range.  
522 In Turkey, caracals were active during the day and night except for late morning and around  
523 midnight (İlemin & Gürkan, 2010). In Yemen, caracals were more active during the day  
524 (Khorozyan, Stanton, Mohammed, Al-Ra'il & Pittet, 2014), while they were more active late  
525 at night and during crepuscular hours in India (Singh, Qureshi, Sankar, Krausman & Goyal,  
526 2014). Sexual variation in activity is also evident, with males being active for longer periods  
527 and moving longer distances than females. This is probably due to males having larger  
528 territories to patrol (see Home range; Avenant & Nel, 1998).

529 Various factors may influence caracal activity patterns. Several studies have  
530 indicated that rain, moon phase and wind speed do not affect activity (Avenant & Nel, 1998;  
531 Brand, 1989; Moolman, 1986). However, it has been suggested that activity may be  
532 influenced by light intensity and temperature. For example, caracals were active for longer  
533 periods on colder nights ( $< 20^{\circ}\text{C}$ , Avenant & Nel, 1998). Light intensity in combination with  
534 temperature may also impact activity, as males increased diurnal activity during overcast  
535 periods when it was between  $20$  and  $22^{\circ}\text{C}$  (Avenant & Nel, 1998). Diurnal hunting has also  
536 been documented when the weather is cool and overcast (Skinner, 1979). In Israel, caracals  
537 were nocturnal, but displayed seasonal variation in diurnal activity, depending on  
538 temperature and the activity patterns of their prey (Weisbein & Mendelssohn, 1989).

539 The activity patterns of caracals may mirror the activity of their main prey, but little  
540 information on this is available. However, prey size influences activity patterns. When  
541 caracals kill larger prey (e.g., springbuck) they may feed on the carcass for a few days  
542 (Avenant & Nel, 1998). Therefore, periods of high activity linked to foraging on smaller prey  
543 (e.g., rodents and lagomorphs) may be interspersed with periods of low activity linked to the  
544 consumption of larger prey.

545 Caracal activity patterns are therefore context-dependent and vary with biotic and  
546 abiotic factors. They are also likely to be impacted by the intensity of human activities,  
547 especially in areas where caracals are persecuted (Ramesh, Kalle & Downs, 2016). This  
548 may be particularly important, as spotlight hunting is used to manage caracal populations on  
549 livestock farms (Chapter 6), and may result in increased diurnal activity.

550



## 551 **Home range and habitat selection**

### 552 *Black-backed jackal*

#### 553 Home range

554 Home range size of black-backed jackals varies considerably across its range, with ranges  
555 between 1 – 28 km<sup>2</sup> being reported. Unlike caracals, no home range size variation across an  
556 aridity gradient is apparent. For example, in the mesic region of KwaZulu-Natal Province,  
557 average home range size ranges between 6 km<sup>2</sup> (Humphries, Ramesh, Hill & Downs, 2016)  
558 and 18 km<sup>2</sup> (Rowe-Rowe, 1982) whereas in the arid region of the Kalahari, Northern Cape  
559 Province, home range size varies between 2 and 5 km<sup>2</sup>. In Zimbabwe, home range size  
560 varies between 0.3 and 1.3 km<sup>2</sup> (Loveridge & Macdonald, 2001), and in Namibia it ranges  
561 between 7 and 25 km<sup>2</sup> (Hiscocks & Perrin, 1988). Variation in black-backed jackal home  
562 range size may be attributed to variation in food availability and dispersion. For example,  
563 Ferguson *et al.* (1983) showed that in areas with high prey density (e.g., small mammals)  
564 black-backed jackal home range was smaller relative to areas with low prey density (see Box  
565 1).

566 Home range size may also vary seasonally, but is unlikely to be related to seasonal  
567 variation in resources availability (Rowe-Rowe, 1982). Seasonal variation in home range  
568 size is related to the reproductive cycle, with home ranges being larger during the mating  
569 season and smaller during the whelping season (Loveridge & Macdonald, 2001). Humphries  
570 *et al.* (2016) also documented seasonal variation in home range size in agricultural areas in  
571 the KwaZulu-Natal Province, but this was attributed to social status and was based on a  
572 small sample size. Conversely, research on coyotes in modified landscapes indicate that  
573 there is no seasonal variation in home range size (Gehrt, Anchor & White, 2009; Grinder &  
574 Krausman, 2001; Poessel, Breck & Gese, 2016).

575 Few studies have compared black-backed jackal home range size between nature  
576 reserves and livestock farms. However, the home range size of black-backed jackals on  
577 farmlands seems to be larger than those on reserves, and this may be related to a reduction  
578 in natural prey availability on farms (Ferguson *et al.*, 1983). Alternatively, the home range of  
579 black-backed jackals on farms may be smaller than those on reserves, owing to the locally  
580 abundant resources (i.e., livestock provisioning). This may result in increased population  
581 densities, further exacerbating livestock losses. Thus, more research relating seasonal  
582 variation in resource abundance on different land uses to home range size is required.

583 Owing to the monogamous social structure of black-backed jackals, sexual variation  
584 in range size is not apparent among mated pairs, as their home ranges overlap completely  
585 (Ferguson *et al.*, 1983). Some studies report variation in range size between sexes of single  
586 adults (Humphries *et al.*, 2016), whereas other do not (Fuller *et al.*, 1989). However, there is  
587 variation in range size among social classes. For example, the home ranges of adults in the

588 Kalahari Gemsbok National Park, Northern Cape Province and Gauteng Province were  
589 smaller than those of sub-adults. In the Kalahari Gemsbok National Park, Northern Cape  
590 Province, adults had an average home range of 11 km<sup>2</sup> (range: 3 - 22 km<sup>2</sup>) compared to 85  
591 km<sup>2</sup> (range: 2 - 575 km<sup>2</sup>) in sub-adults (Ferguson *et al.* 1983). Similarly, in farming areas in  
592 the Gauteng Province adults had an average home range of 28 km<sup>2</sup> (range: 3 - 92 km<sup>2</sup>)  
593 compared to 133 km<sup>2</sup> (range: 1 - 841km<sup>2</sup>) in sub-adults (Ferguson *et al.*, 1983). This may be  
594 due to subordinate individuals dispersing in search of mates and territories (see Dispersal),  
595 whereas dominant pairs are more resident (Ferguson *et al.*, 1983; Humphries *et al.*, 2016).

596 Home ranges of dominant mated pairs may overlap slightly (less than 10%), but in  
597 general other mated pairs are excluded (Ferguson *et al.*, 1983). However, the home ranges  
598 of subordinate individuals may overlap extensively with both subordinates (82%) and  
599 dominant pairs (Ferguson *et al.*, 1983). Similar patterns were documented in the KwaZulu-  
600 Natal Province where the territories of dominant pairs did not overlap, but there was  
601 considerable overlap with the ranges of subordinate individuals (Rowe-Rowe, 1982).  
602 Additionally, unmated adults may also show large range overlap with dominant mated pairs  
603 (Ferguson *et al.*, 1983).

604 In general, the home ranges of mated pairs appear to be fixed with little overlap in  
605 range with other mated pairs. However, territorial collapse (see Box 1) and range shifts  
606 (Kaunda, 2000) may occur. Range shifts may occur when a neighbouring pair loses its  
607 territory and the dominant pairs expands their territory into the vacant area. This  
608 expansionist strategy has also been documented for red foxes after the removal of  
609 neighbouring groups (Baker, Funk, Harris & White, 2000). However, little information on the  
610 benefits and costs of territorial shifts or expansion is available.

611

#### 612 Habitat selection

613 Black-backed jackals have a wide habitat tolerance and occur in all biomes except forests  
614 (see Minnie *et al.*, 2016b). Comparatively little research has been conducted on habitat use  
615 and selection (Figure 1; du Plessis *et al.*, 2015), thus necessitating generalisations across  
616 habitats. At a local scale, black-backed jackals select habitats with sufficient food resources  
617 (Ferguson, 1980; Kaunda, 2001), shelter from the natural elements, and security from  
618 competitors (Kaunda, 2001). In Zimbabwe, black-backed jackals have an aversion for dense  
619 vegetation, preferring open grasslands and open woodlands (Loveridge & Macdonald,  
620 2002). This is driven by the fact that open habitats have a higher density of preferred prey  
621 and facilitate vigilance against larger predators (Loveridge & Macdonald, 2002). Conversely,  
622 in Botswana, black-backed jackals preferred savannah and bushveld over open grasslands,  
623 which were ascribed to the increased availability of food and shelter (Kaunda, 2001).  
624 Further, in the Namib Desert – which is characterised by sparse vegetation cover and severe

625 temperature fluctuations – black-backed jackals moved to habitats with sufficient cover  
626 against the natural elements (Dreyer & Nel, 1990). Thus, habitat use appears to be driven  
627 predominantly by resource availability and habitat structure.

628 Habitat selection may also be influenced by interspecific competition. For example,  
629 black-backed jackals have been shown to out-compete side-striped jackals for preferred  
630 habitats (Loveridge & Macdonald, 2002). Throughout the livestock and game farming areas  
631 in South Africa, black-backed jackals and caracals occur in sympatry, and this may influence  
632 habitat selection (Ramesh *et al.*, 2016). Anecdotal evidence from farmers indicates that  
633 black-backed jackal predation is focussed on the open plains in the Karoo, Eastern and  
634 Western Cape Provinces, which provides an ideal habitat for a cursorial predator. Whereas  
635 caracals keep to the more densely vegetated and mountainous terrain, which provides more  
636 cover for an ambush predator. However, habitat partitioning between these two predators  
637 has not been investigated.

638 Anthropogenic impacts should also influence the habitat use and selection by black-  
639 backed jackals. It is expected that black-backed jackals should avoid habitats with high  
640 human activity (e.g., Kaunda, 2000), or use habitats providing cover for avoiding humans  
641 (e.g., golden jackal; Jaeger, Haque, Sultana & Bruggers, 2007). However, this aspect of  
642 black-backed jackal ecology has not been investigated either.

643

#### 644 *Caracal*

##### 645 Home range

646 Sexual variation in home range size is evident, and has been reported in several studies.  
647 Female caracals in the Karoo, Western Cape Province, had smaller home ranges (range: 12  
648 – 27 km<sup>2</sup>) than males (48 km<sup>2</sup>; Stuart, 1982). Similarly, Moolman (1986) found that males in  
649 Mountain Zebra National Park, Eastern Cape Province, had larger home ranges (15 km<sup>2</sup>)  
650 than females (6 km<sup>2</sup>). Caracal males are larger than females thus requiring larger home  
651 ranges to obtain prey, in addition to finding multiple mates (Marker & Dickman, 2005;  
652 Melville, 2004a; Ramesh *et al.*, 2016). Therefore, a single male territory typically overlaps  
653 with that of a number of females (Avenant, 1993; Moolman, 1986; Stuart & Stuart, 2013).  
654 Unlike black-backed jackals, in which there is little territorial overlap, the home ranges of  
655 caracals overlap both within and between sexes (Moolman, 1986). On the west coast of  
656 South Africa, male home ranges almost completely overlap with those of females (81 –  
657 99%), whereas overlap between females was small (0 - 19%, Avenant & Nel, 1998).  
658 Similarly, in Mountain Zebra National Park, Eastern Cape Province, same-sex overlap in  
659 home range was small, with female ranges overlapping between 2.5 and 3% and males  
660 between 2 and 14% (Moolman, 1986). Similar patterns have been documented for the  
661 caracal throughout its distributional range (e.g., Israel, Weisbein & Mendelsohn, 1989).

662 Variation in home range size is also linked to age and social status, with dispersing  
663 sub-adults having larger home ranges than adults. For example, a sub-adult male in the  
664 Stellenbosch area, Western Cape Province, initially ranged over 480 km<sup>2</sup>, and then  
665 established a much smaller home range of 6 km<sup>2</sup> (Norton & Lawson, 1985a). Further,  
666 females with kittens have smaller home ranges than single adult females. For example, a  
667 female caracal reduced her home range size from 9 km<sup>2</sup> to 3 km<sup>2</sup> after parturition and  
668 maintained this smaller home range until her kittens reached four months of age (Avenant &  
669 Nel, 1998).

670 Caracal home range size varies according to habitat, with home ranges in arid  
671 regions being larger than those in more mesic regions. In the southern Kalahari, Northern  
672 Cape Province, the home range of an adult male was large (308 km<sup>2</sup>, Bothma & Le Riche,  
673 1984). Similarly, average home range size of males on Namibian farmlands was 316 km<sup>2</sup>  
674 (Marker & Dickman, 2005). However, in more mesic regions, home ranges are smaller. On  
675 the Langebaan peninsula, Western Cape Province, males (26 km<sup>2</sup>) and females (7 km<sup>2</sup>) had  
676 relatively small home ranges (Avenant & Nel, 1998). Similarly, male (65 km<sup>2</sup>) and female (18  
677 km<sup>2</sup>) home ranges in the Western Cape Province were much smaller than those reported in  
678 arid regions (Norton & Lawson, 1985a; Stuart & Wilson, 1988). This variation in home range  
679 size along the aridity gradient is probably related to prey availability (Avenant & Nel, 1998),  
680 as mesic areas tend to have a higher density of rodent and lagomorph prey.

681 Seasonal fluctuations in prey availability and dispersion may also translate into  
682 seasonal variation in home range size. For example, in Saudi Arabia, a male caracal  
683 increased its range from 270 km<sup>2</sup>, during seasons with a high localised prey density, to 1116  
684 km<sup>2</sup> during seasons with a low prey density (van Heezik & Seddon, 1998). Conversely, in the  
685 West Coast National Park, Western Cape Province, seasonal fluctuations in prey availability  
686 did not influence home range size (Avenant & Nel, 1998). Thus, home range size in caracal  
687 seems to be linked to prey availability, in addition to vegetation cover and abiotic factors  
688 (Avenant & Nel, 1998).

689 Additionally, the range of caracal on reserves may extend onto neighbouring farms,  
690 which may result in increased livestock predation on these farms. For example, some  
691 caracals in Mountain Zebra National Park, Eastern Cape Province, had their territories  
692 confined to the reserve, but others ranged beyond the reserve border (Moolman, 1986). It is  
693 unclear how livestock provisioning will affect caracal home range. In some areas it has been  
694 suggested that caracals prefer to prey on natural prey (see Diet), thus home ranges may be  
695 larger on livestock farms due to reduced density of preferred prey (Marker & Dickman, 2005;  
696 Moolman, 1986; Ramesh *et al.*, 2016). Whereas the converse may hold if caracals prefer to  
697 prey on livestock. This increase in prey densities (i.e. livestock provisioning) may result in a

698 reduction in home range. However, more research on the variation in range size between  
699 different land uses with varying prey bases is required.

700

#### 701 Habitat selection

702 Caracals are widespread within South Africa, occurring in all habitat types (see Avenant *et*  
703 *al.*, in press). Similar to black-backed jackals, very little has been published on the habitat  
704 selection of the caracal (du Plessis *et al.*, 2015), necessitating generalisations across  
705 habitats. In general, the caracal shows a preference for specific habitats in an area, but there  
706 is evidence that some individuals may utilize habitats randomly (Mills, 1984; Stuart, 1981,  
707 1982). Caracals are ambush predators, thus habitat selection is driven, in part, by the  
708 availability of appropriate cover (Norton & Lawson, 1985a). The availability of appropriate  
709 prey also affects habitat selection (Avenant & Nel, 1998; Melville, 2004a; Moolman, 1986;  
710 van Heezik & Seddon, 1998). In an agricultural landscape in the KwaZulu-Natal Province,  
711 caracals preferred modified habitats over natural grasslands and forests, which was ascribed  
712 to the relatively high availability of rodents and livestock (Ramesh *et al.*, 2016). Similar  
713 patterns have been documented for Iberian lynx which vary habitat use in accordance with  
714 the level of vegetation cover and prey availability. Iberian lynx preferred natural vegetation,  
715 but also selected olive groves and heterogeneous agricultural areas with relatively high  
716 densities of preferred prey (Gastón *et al.*, 2016).

717 Therefore, habitat selection by caracals, like other felids, is likely driven by the  
718 availability of suitable vegetation cover (ambush predator) and prey. In the Karoo and  
719 Grassland biomes, we suggest that the mountainous areas may suit caracal more than the  
720 plains owing to increased vegetation cover (Avenant *et al.*, in press). However, little  
721 information on the factors driving habitat selection is available and requires further research.  
722 Knowledge about the factors driving habitat selection may allow for the identification of  
723 predation “hotspots”. For example, Eurasian lynx attacks on livestock were concentrated on  
724 4.5% of the total area where livestock predation occurs (Stahl, Vandell, Herrenschildt &  
725 Migot, 2001), showing that the presence of livestock alone was not sufficient to explain  
726 habitat selection. Identifying such “hotspots” may direct livestock management to less risky  
727 areas.

728

#### 729 **Dispersal**

##### 730 *Black-backed jackal*

731 Literature reporting on dispersal of black-backed jackals is scarce (du Plessis *et al.*, 2015).  
732 Dispersal usually occurs between one to two years of age and mainly during autumn and  
733 winter (April to September) both on farmlands and protected areas (Ferguson *et al.*, 1983). It  
734 is unclear what drives dispersal, but it may be due to intraspecific competition with dominant

735 individuals, and the need to establish a territory, find food and to reproduce (Loveridge &  
736 Macdonald, 2001; Minnie *et al.*, 2016a). Loveridge & Macdonald (2001) suggested that  
737 dispersing black-backed jackals may have one of four options depending on the local  
738 conditions: (1) stay in their natal territory as a helper; (2) move into vacant territories; (3)  
739 move into nearby territories to be incorporated into those territories' resident groups; or (4)  
740 float between their natal territory and adjacent territories.

741 Black-backed jackals have the ability to disperse over long distances, as dispersal in  
742 excess of 100 km has been reported across several habitat types in South Africa (Bothma,  
743 1971a; Ferguson *et al.*, 1983; Humphries *et al.*, 2016; Minnie, 2016). Black-backed jackals  
744 appear to have few absolute dispersal barriers, as tarred roads, railway tracks, rivers and  
745 fences (including electrified "predator-proof" fences) are frequently crossed (Ferguson *et al.*,  
746 1983; Minnie, 2016). However, the permeability of these potential barriers vary (Minnie,  
747 2016). The ability of black-backed jackals to cover large distances without being hampered  
748 by fences suggests that management aimed at reducing local population size may be  
749 counteracted by immigration from other populations (Minnie, 2016).

750 In areas where hunting intensity varies across the landscape (e.g., livestock- and  
751 game farms *versus* nature reserves), black-backed jackals disperse from lightly managed or  
752 unmanaged reserves into heavily managed farms (Minnie *et al.* 2016a). This is driven by the  
753 fact that lethal management disrupts the mutually exclusive social structure, which results in  
754 vacant territories on lethally managed livestock and game farms. Thus, black-backed jackals  
755 disperse from high density populations into these vacant territories (Minnie *et al.*, 2016a),  
756 which may allow the recovery of hunted populations (i.e., compensatory immigration).

757 The combination of compensatory immigration and reproduction (see Box 2) in  
758 hunted black-backed jackal populations contribute to the persistence of black-backed jackals  
759 in the face of severe persecution, and indicates that lethal control of black-backed jackal  
760 populations to reduce livestock losses is unlikely to be successful if recruitment from  
761 un hunted areas persists (Minnie *et al.*, 2016a). However, this conclusion is based on the  
762 results from a single study and spatial replication of this research is required to determine if  
763 this pattern persists across habitats. This is likely the case as similar patterns have been  
764 documented for several lethally managed canids (e.g., dingo, Allen, 2015; coyote, Knowlton  
765 *et al.*, 1999; red fox, Lieury *et al.*, 2015; culpeo fox, *Pseudalopex culpaeus*, Novaro, Funes &  
766 Walker, 2005).

767

#### 768 *Caracal*

769 Caracals may disperse from their natal range between nine months and two years of age  
770 (Drouilly *et al.*, unpubl. data; Serieys, L. *pers. comm.*), and dispersal is likely driven by  
771 intraspecific competition with dominant individuals. Sex-biased dispersal has been

772 documented for several felids, with males dispersing over longer distances than females.  
773 This increases the likelihood of dispersing males coming into contact with livestock, resulting  
774 in male-biased livestock predation (e.g., leopard, Esterhuizen & Norton, 1985; European  
775 lynx, Odden *et al.*, 2002; cougar, Ross, Jalkotzy & Gunson, 1996). This may also be the  
776 case for caracal. Some studies have reported that caracals can disperse over long distances  
777 (> 90 km; Avenant & Nel, 1998; Norton & Lawson, 1985b; Stuart, 1982). Additionally, there  
778 is a general lack of information on dispersal barriers. Dispersal may be prevented by high or  
779 electrified fences, but it is unlikely that fences represent a putative barrier.

780 The lethal management of caracal in livestock farming areas may result in the  
781 immigration (e.g., black-backed jackal; see Black-backed jackal dispersal) of individuals from  
782 neighbouring areas where they are not managed (e.g., nature reserves). According to Visser  
783 (1978), cited in Nowell & Jackson (1996), caracal may recolonize farming areas after  
784 extirpation. This compensatory immigration has been documented for other felids (e.g.,  
785 Iberian lynx, Gaona, Ferreras & Delibes, 1998; mountain lion, *Puma concolor*, Robinson *et*  
786 *al.*, 2014), but no research has been conducted on caracal. Here, we hypothesise that this  
787 may be the case. However, there is a severe lack of information on caracal dispersal and the  
788 factors that may influence it, and is one of the least studied aspects of their biology and  
789 ecology (du Plessis *et al.*, 2015). This lack of information on dispersal and dispersal barriers  
790 hampers our ability to predict the population level responses of caracal to  
791 suggested/implemented management actions aimed at reducing predation.

792

### 793 **Population density**

794 Accurate estimates of population density for black-backed jackals and caracals in South  
795 Africa are lacking, though many farm and reserve managers suggest that black-backed  
796 jackal and caracal densities have increased over the last 10-15 years (Avenant & du Plessis,  
797 2008; du Plessis, 2013). The population density of black-backed jackals and caracals is  
798 likely related to territorial size, social structure, the number of non-territorial individuals in the  
799 population, and the population growth rate. All these factors vary in accordance with local  
800 environmental conditions and resource abundance (Loveridge & Nel, 2008) and may be  
801 augmented by anthropogenic habitat modification and predator and prey management. It is  
802 of the utmost importance to develop accurate assessment methods to estimate population  
803 densities across various land uses for both black-backed jackals and caracals. This will  
804 provide the essential baseline information required for successful adaptive management.

805

### 806 *Black-backed jackal*

807 Several authors have estimated local population densities via extrapolating home range size,  
808 spoor counts and mark-recapture methods. Population density varies with location and

809 recorded densities include: 35 – 40 jackals/100 km<sup>2</sup> in the Giant’s Castle Nature Reserve,  
810 KwaZulu-Natal Province (Rowe-Rowe, 1982); 50 jackals/100 km<sup>2</sup> in the Serengeti National  
811 Park, Tanzania (Waser, 1980); 54 – 97 jackals/100 km<sup>2</sup> in Hwange National Park, Zimbabwe  
812 (Loveridge & Nel, 2013); 400 – 700 jackals/100 km<sup>2</sup> in the Tuli Game Reserve, Botswana  
813 (McKenzie, 1990). Additionally, extremely high densities (2200 jackals/100 km<sup>2</sup>) have been  
814 recorded at the seal colonies in Namibia – which represents a highly abundant year-round  
815 resource (Hiscocks & Perrin, 1988). Although these are crude estimates, it suggests that  
816 increased resource availability is correlated with increased population size. There is no  
817 information on densities on commercial livestock farms, game farms and communal areas.

818

### 819 *Caracal*

820 Caracal density has been estimated for a small number of reserves by extrapolating home  
821 range size. Population density in the Mountain Zebra National Park, Eastern Cape Province,  
822 was estimated at 38 caracals/100 km<sup>2</sup> (Moolman 1986), and in the Postberg Nature  
823 Reserve, Western Cape Province, it ranged between 23 – 47 caracals/100 km<sup>2</sup> (Avenant &  
824 Nel 1998). No other population density estimates exist for the caracal.

825

### 826 **Conclusion**

827 One might expect that research pertaining to the biology and ecology of black-backed  
828 jackals and caracals would be sufficient given their role as livestock predators. However, this  
829 is not the case. Throughout this chapter we highlighted several data deficiencies and  
830 indicated areas where research is urgently required to address predation on livestock and  
831 valued wildlife species (summarised in Box 3). The available research has been biased  
832 towards the feeding ecology of the two species, with comparatively little information on social  
833 behaviour, activity patterns, reproduction, home range and habitat selection, dispersal, and  
834 population densities (du Plessis *et al.*, 2015). Additionally, research is spatially biased,  
835 focussing on a subset of biomes. Given the adaptability of these predators, research needs  
836 to be replicated across several habitats to allow for accurate predictions on variation in  
837 biology and ecology between regions.

838 Most research on black-backed jackals and caracals have been conducted in nature  
839 reserves, with little research emanating from commercial livestock farms, game farms and  
840 communal areas. The anthropogenic impacts (e.g., prey and predator management) vary  
841 tremendously between these land uses, which should translate into variation in the biology  
842 and ecology of black-backed jackals and caracals. However, relatively little research  
843 comparing biological and ecological variation between these land uses (particularly  
844 communal areas) has been conducted (see du Plessis *et al.*, 2015 for review). Further,  
845 research has focussed relatively more on black-backed jackals than caracals (Figure 1). This



846 is not surprising given the fact that across South Africa, black-backed jackals are the most  
847 problematic predators of livestock (Chapter 3).

848 The collection of baseline information on black-backed jackal and caracal biology and  
849 ecology on nature reserves, commercial livestock farms, game farms and communal areas  
850 is needed for the development of evidence-based management strategies for these areas.  
851 Without it, predator management activities will continue to be haphazard and ineffective at  
852 reducing livestock damage. The demographic, ecological, behavioural and dietary plasticity  
853 of black-backed jackals, and to a lesser extent caracals, are probably the main factors  
854 contributing to the persistence of these species across the South African landscape. This  
855 flexibility allows them to adjust to the current prey and predator management regimes. Thus,  
856 any management aimed at modifying black-backed jackal and caracal population densities  
857 should be grounded in a sound knowledge of their biology and ecology. If this is not the  
858 case, current management practices will continue with little success.

859

### 860 **Box 3: Future research**

861 The collection of appropriate baseline biological and ecological data is extremely important.  
862 Without this information the responses of predator populations to prey and predator  
863 management strategies cannot be assessed. Below we highlight the high-priority research  
864 areas which are pertinent in addressing predation by black-backed jackals and caracal.

- 865 • How much livestock and valued wildlife species do black-backed jackals and caracals  
866 kill, and what are the implications of this for the livestock and game farming industries?
- 867 • Do increased densities of natural prey buffer livestock losses?
- 868 • How does variation in predator management (lethal *versus* non-lethal) affect the social  
869 structure, activity patterns, reproduction, home range, population density, habitat  
870 selection and dispersal of mesopredators?
- 871 • Which assessment tools can accurately predict the density of mesopredators?
- 872 • What is the population size and trend of the black-backed jackal and the caracal in South  
873 Africa?
- 874 • Are there “hotspots” of predation where most of the attacks on livestock and valued  
875 wildlife species occur?
- 876 • Is livestock predation a learnt behaviour resulting in a few individuals killing livestock  
877 (i.e., problem individuals), as opposed to the entire population?

878

### 879 **References**

880 Allen, B.L. & Leung, L.K.P. (2014). The (non)effects of lethal population control on the diet of  
881 Australian dingoes. *PLoS One*, 9, e108251.

- 882 Allen, L.R. (2015). Demographic and functional responses of wild dogs to poison baiting.  
883 *Ecological Management & Restoration*, 16, 58-66.
- 884 Allen, B.L., Higginbottom, K., Bracks, J.H., Davies, N. & Baxter, G.S. (2015). Balancing  
885 dingo conservation with human safety on Fraser Island: the numerical and  
886 demographic effects of humane destruction of dingoes. *Australasian Journal of*  
887 *Environmental Management*, 22, 197-215.
- 888 Atkinson, R.P.D., Rhodes, C.J., Macdonald, D.W. & Anderson, R.M. (2002). Scale-free  
889 dynamics in the movement patterns of jackals. *Oikos*, 98, 134-140.
- 890 Avenant, N.L. (1993). *The caracal, Felis caracal caracal SCHREBER, 1776, as predator in*  
891 *the West Coast National Park*. (Unpublished MSc thesis), University of  
892 Stellenbosch, Stellenbosch.
- 893 Avenant, N.L., Drouilly, M., Power, R.J., Thorn, M., Martins, Q., Neils, A. & Do Linh San, E.,  
894 in press. A conservation assessment of *Caracal caracal*. In M.F. Child, L. Roxburgh,  
895 E. Do Linh San, D. Raimondo, H.T. Davies-Mostert (Eds), *The Red List of Mammals*  
896 *of South Africa, Swaziland and Lesotho*. South African National Biodiversity Institute  
897 and Endangered Wildlife Trust, South Africa.
- 898 Avenant, N.L. & du Plessis, J.J. (2008). Sustainable small stock farming and ecosystem  
899 conservation in southern Africa: a role for small mammals? *Mammalia*, 72, 258-263.
- 900 Avenant, N.L. & Nel, J.A.J. (1997). Prey use by four synoptic carnivores in a strandveld  
901 ecosystem. *South African Journal of Wildlife Research*, 27, 86 - 93.
- 902 Avenant, N.L. & Nel, J.A.J. (1998). Home-range use, activity, and density of caracal in  
903 relation to prey density. *African Journal of Ecology*, 36, 347 - 359.
- 904 Avenant, N.L. & Nel, J.A.J. (2002). Among habitat variation in prey availability and use by  
905 caracal *Felis caracal*. *Mammalian Biology*, 67, 18 - 33.
- 906 Bagrade, G., Ruņģis, D.E., Ornicāns, A., Šuba, J., Žunna, A., Howlett, S.J., Lūkins, M.,  
907 Gailīte, A., Stepanova, A., Done, G., Gaile, A., Bitenieks, K., Mihailova, L., Baumanis,  
908 J. & Ozoliņš, J. (2016). Status assessment of Eurasian lynx in Latvia linking genetics  
909 and demography—a growing population or a source–sink process? *Mammal*  
910 *Research*, 61, 337-352.
- 911 Baker, P.J., Funk, S.M., Harris, S. & White, P.C.L. (2000). Flexible spatial organization of  
912 urban foxes, *Vulpes vulpes*, before and during an outbreak of sarcoptic mange.  
913 *Animal Behaviour*, 59, 127-146.
- 914 Benson, J.F., Mahoney, P.J. & Patterson, B.R. (2015). Spatiotemporal variation in selection  
915 of roads influences mortality risk for canids in an unprotected landscape. *Oikos*, 124,  
916 1664-1673.
- 917 Bernard, R.T.F. & Stuart, C.T. (1987). Reproduction of caracal *Felis caracal* in the Cape  
918 Province of South Africa. *South African Journal of Zoology*, 22, 177 - 182.

- 919 Bernard, R.T.F. & Stuart, C.T. (1992). Correlates of diet and reproduction in the black-  
920 backed jackal. *South African Journal of Science*, 88, 292-294.
- 921 Bingham, J. & Purchase, G.K. (2002). Reproduction in the jackals *Canis adustus* Sundevall,  
922 1846, and *Canis mesomelas* Schreber, 1778 (Carnivora: Canidae), in Zimbabwe.  
923 *African Zoology*, 37, 21-26.
- 924 Bothma, J.D.P. (1971a). Control and ecology of black-backed jackal *Canis mesomelas* in the  
925 Transvaal. *Zoologica Africana*, 6, 187-193.
- 926 Bothma, J.D.P. (1971b). Food of *Canis mesomelas* in South Africa. *Zoologica Africana*, 6,  
927 195-203.
- 928 Bothma, J.D.P., 2012. Literatur review of the ecology and control of black-backed jackal and  
929 caracal in South Africa, p. 86. Cape Nature.
- 930 Bothma, J.d.P. & Le Riche, E.A.N. (1984). Range use by an adult male caracal in the  
931 southern Kalahari. *Koedoe*, 37, 105 - 108.
- 932 Braczkowski, A., Watson, L., Coulson, D., Lucas, J., Peiser, B. & Rossi, M. (2012). The diet  
933 of caracal, *Caracal caracal*, in two areas of the Southern Cape, South Africa as  
934 determined by scat analysis. *South African Journal of Wildlife Research*, 42, 111-  
935 116.
- 936 Brand, D.J. (1989). *Die beheer van rooikatte (Felis caracal) en bobbejane (Papio ursinus) in*  
937 *Kaapland met behulp van meganiese metodes*. (Unpublished MSc thesis),  
938 Stellenbosch University, Stellenbosch.
- 939 Brassine, M.C. (2011). *The diet and ecological role of black-backed jackals, Canis*  
940 *mesomelas, in two conservation areas in the Eastern Cape Province, South Africa*.  
941 (Unpublished M.Sc. thesis), Rhodes University, Grahamstown.
- 942 Brassine, M.C. & Parker, D.M. (2012). Does the presence of large predators affect the diet of  
943 a mesopredator? *African Journal of Ecology*, 50, 243-246.
- 944 Breck, S.W., (2004). Minimizing carnivore-livestock conflict: The importance and process of  
945 research in the search for coexistence, In N. Fascione, A. Delach, M.E. Smith (Eds),  
946 *People and predators: From conflict to coexistence*. p. 285. Island Press,  
947 Washington.
- 948 Cavallini, P. & Santini, S. (1996). Reproduction of the red fox *Vulpes vulpes* in Central Italy.  
949 *Ann. Zool. Fennici*, 33, 267-274.
- 950 Corbett, L.K. & Newsome, A.E. (1987). The feeding ecology of the dingo. *Oecologia*, 74,  
951 215-227.
- 952 Dreyer, H.V.A. & Nel, J.A.J. (1990). Feeding-site selection by black-backed jackals on the  
953 Namib Desert coast. *Journal of Arid Environments*, 19, 217-224.

954 du Plessis, J.J. (2013). *Towards the development of a sustainable management strategy for*  
955 *Canis mesomelas and Caracal caracal on rangeland.* (Unpublished PhD thesis),  
956 University of the Free State, Bloemfontein, South Africa.

957 du Plessis, J.J., Avenant, N.L. & De Waal, H.O. (2015). Quality and quantity of the scientific  
958 information available on black-backed jackals and caracals: contributing to human-  
959 predator conflict management? *African Journal of Wildlife Research*, 45, 138-157.

960 Esterhuizen, W.C.N. & Norton, P.M. (1985). The leopard as a problem animal in the Cape  
961 Province, as determined by the permit system. *Bontebok*, 4, 9-16.

962 Fairall, N. (1968). The reproductive seasons of some mammals in the Kruger National Park.  
963 *Zoologica Africana*, 3, 189-210.

964 Ferguson, J.W.H. (1980). *Die ekologie van die rooijakkals Canis mesomelas Schreber, 1778*  
965 *met spesiale verwysing na bewegings en sosiale organisasie.* (Unpublished MSc  
966 thesis), University of Pretoria, Pretoria.

967 Ferguson, J.W.H., Galpin, J.S. & de Wet, M.J. (1988). Factors affecting the activity patterns  
968 of black-backed jackals *Canis mesomelas*. *Journal of Zoology, London*, 214, 55 - 69.

969 Ferguson, J.W.H., Nel, J.A.J. & de Wet, M.J. (1983). Social organization and movement  
970 patterns of black-backed jackals *Canis mesomelas* in South Africa. *Journal of*  
971 *Zoology*, 199, 487-502.

972 Fourie, R.M., Tambling, C.J., Gaylard, A. & Kerley, G.I.H. (2015). Short-term foraging  
973 responses of a generalist predator to management-driven resource pulses. *African*  
974 *Journal of Ecology*, 53, 521-530.

975 Fuller, T.K., Biknevicius, A.R., Kat, P.W., Valkenburgh, B.V. & Wayne, R.K. (1989). The  
976 ecology of three sympatric jackal species in the Rift Valley of Kenya. *African Journal*  
977 *of Ecology*, 27, 313-323.

978 Fuller, T.K. & Sievert, P.R., (2001). Carnivore demography and the consequences of  
979 changes in prey availability, In J.L. Gittleman, S.M. Funk, D. Macdonald, R.K. Wayne  
980 (Eds), *Carnivore Conservation*. pp. 163-178. Cambridge University Press,  
981 Cambridge.

982 Gaona, P., Ferreras, P. & Delibes, M. (1998). Dynamics and viability of a metapopulation of  
983 the Endangered Iberian lynx (*Lynx pardinus*). *Ecological Monographs*, 68, 349-370.

984 Gastón, A., Blázquez-Cabrera, S., Garrote, G., Mateo-Sánchez, M.C., Beier, P., Simón, M.A.  
985 & Saura, S. (2016). Response to agriculture by a woodland species depends on  
986 cover type and behavioural state: insights from resident and dispersing Iberian lynx.  
987 *Journal of Applied Ecology*, 53, 814 – 824.

988 Gehrt, S.D., Anchor, C. & White, L.A. (2009). Home range and landscape use of coyotes in a  
989 metropolitan landscape: conflict or coexistence? *Journal of Mammalogy*, 60, 1045-  
990 1057.

- 991 Gese, E.M., 2005. Demographic and spatial responses of coyotes to changes in food and  
992 exploitation, In Proceedings of the 11<sup>th</sup> Wildlife Damage Management Conference. eds  
993 D.L. Nolte, K.A. Fagerstone, pp. 271 - 285. The Wildlife Society, Traverse City,  
994 Michigan.
- 995 Gese, E.M., Ruff, R.L. & Crabtree, R.L. (1996). Intrinsic and extrinsic factors influencing  
996 coyote predation of small mammals in Yellowstone National Park. *Canadian Journal*  
997 *of Zoology*, 74, 784-797.
- 998 Grafton, R.N. (1965). Food of the black-backed jackal: A preliminary report. *Zoologica*  
999 *Africana*, 1, 41-53.
- 1000 Grinder, M.I. & Krausman, P.R. (2001). Home range, habitat use, and nocturnal activity of  
1001 coyotes in an urban environment. *The Journal of Wildlife Management*, 65, 887-898.
- 1002 Grobler, J.H. (1981). Feeding behaviour of the caracal *Felis caracal* Schreber 1776 in the  
1003 Mountain Zebra National Park. *South African Journal of Zoology*, 16, 259-262.
- 1004 Gusset, M., Swarner, M.J., Mponwane, L., Keletile, K. & McNutt, J.W. (2009). Human-wildlife  
1005 conflict in northern Botswana: livestock predation by Endangered African wild dog  
1006 *Lycaon pictus* and other carnivores. *Oryx*, 43, 67-72.
- 1007 Harris, S. & Smith, G.C. (1987). Demography of two urban fox (*Vulpes vulpes*) populations.  
1008 *Journal of Applied Ecology*, 24, 75-86.
- 1009 Hayward, M.W., Porter, L., Lanszki, J., Kamler, J.F., Beck, J.M., Kerley, G.I.H., Macdonald,  
1010 D.W., Montgomery, R.A., Parker, D.M., Scott, D.M., O'Brien, J. & Yarnell, R.W.  
1011 (2017). Factors affecting prey preferences of jackals (*Canidae*). *Mammalian Biology*.
- 1012 Hiscocks, K. & Perrin, M.R. (1987). Feeding observations and diet of black-backed jackals in  
1013 an arid coastal environment. *South African Journal of Wildlife Research*, 17, 55-58.
- 1014 Hiscocks, K. & Perrin, M.R. (1988). Home range and movements of black-backed jackals at  
1015 Cape Cross Seal Reserve, Namibia. *South African Journal of Wildlife Research*, 18,  
1016 97-100.
- 1017 Hone, J., Duncan, R.P. & Forsyth, D.M. (2010). Estimates of maximum annual population  
1018 growth rates ( $r_m$ ) of mammals and their application in wildlife management. *Journal of*  
1019 *Applied Ecology*, 47, 507 - 514.
- 1020 Humphries, B.D., Ramesh, T., Hill, T.R. & Downs, C.T. (2016). Habitat use and home range  
1021 of black-backed jackals (*Canis mesomelas*) on farmlands in the Midlands of  
1022 KwaZulu-Natal, South Africa. *African Zoology*, 51, 37-45.
- 1023 İlemin, Y. & Gürkan, B. (2010). Status and activity patterns of the Caracal, *Caracal caracal*  
1024 (Schreber, 1776), in Datça and Bozburun Peninsulas, Southwestern Turkey. *Zoology*  
1025 *in the Middle East*, 50, 3-10.
- 1026 Inskip, C. & Zimmermann, A. (2009). Human-felid conflict: a review of patterns and priorities  
1027 worldwide. *Oryx*, 43, 18-34.

1028 Jaeger, M.M., Haque, E., Sultana, P. & Bruggers, R.L. (2007). Daytime cover, diet and  
 1029 space-use of golden jackals (*Canis aureus*) in agro-ecosystems of Bangladesh.  
 1030 *Mammalia*, 71, 1-10.

1031 James, R.S., Scott, D.M., Yarnell, R.W. & Overall, A.D.J. (2017). Food availability and  
 1032 population structure: How do clumped and abundant sources of carrion affect the  
 1033 genetic diversity of the black-backed jackal? *Journal of Zoology*, 301, 184-192.

1034 Jansen, C. (2016). *Diet of key predators responsible for livestock conflict in Namaqualand,*  
 1035 *South Africa.* (Unpublished MSc thesis), Stellenbosch University, Stellenbosch.

1036 Jenner, N., Groombridge, J. & Funk, S.M. (2011). Commuting, territoriality and variation in  
 1037 group and territory size in a black-backed jackal population reliant on a clumped,  
 1038 abundant food resource in Namibia. *Journal of Zoology*, 284, 231-238.

1039 Kamler, J.F., Klare, U. & Macdonald, D.W. (2012). Seasonal diet and prey selection of black-  
 1040 backed jackals on a small-livestock farm in South Africa. *African Journal of Ecology*,  
 1041 50, 2099-2307.

1042 Kaunda, S.K.K. (2000). Activity patterns of black-backed jackals at Mokolodi Nature  
 1043 Reserve, Botswana. *South African Journal of Wildlife Research*, 30, 157-162.

1044 Kaunda, S.K.K. (2001). Spatial utilization by black-backed jackals in southeastern Botswana.  
 1045 *African Zoology*, 36, 143-152.

1046 Kaunda, S.K.K. & Skinner, J.D. (2003). Black-backed jackal diet at Mokolodi Nature  
 1047 Reserve, Botswana. *African Journal of Ecology*, 41, 39 - 46.

1048 Kerley, G.I.H., Behrens, K.G., Carruthers, J., Diemont, M., du Plessis, J., Minnie, L.,  
 1049 Richardson, P.R.K., Somers, M.J., Tambling, C.J., Turpie, J., van Niekerk, H.N. &  
 1050 Balfour, D. (2017). Livestock predation in South Africa: The need for and value of a  
 1051 scientific assessment. *South African Journal of Science*, Art. #a0198.

1052 Khalil, H., Pasanen-Mortensen, M. & Elmhagen, B. (2014). The relationship between  
 1053 wolverine and larger predators, lynx and wolf, in a historical ecosystem context.  
 1054 *Oecologia*, 175, 625-637.

1055 Khorozyan, I., Stanton, D., Mohammed, M., Al-Ra'il, W. & Pittet, M. (2014). Patterns of co-  
 1056 existence between humans and mammals in Yemen: some species thrive while  
 1057 others are nearly extinct. *Biodiversity and Conservation*, 23, 1995-2013.

1058 Klare, U., Kamler, J.F., Stenkewitz, U. & Macdonald, D.W. (2010). Diet, prey selection, and  
 1059 predation impact of black-backed jackals in South Africa. *Journal of Wildlife*  
 1060 *Management*, 74, 1030 - 1042.

1061 Kleiman, D. & Brady, C., (1978). Coyote behavior in the context of recent canid research:  
 1062 problems and perspectives, In Bekoff, M. (Ed), *Coyotes: biology, behavior, and*  
 1063 *management.* pp. 163-188. Academic Press, New York.

1064 Knowlton, F.F. (1972). Preliminary interpretations of coyote population mechanics with some  
1065 management implications. *The Journal of Wildlife Management*, 36, 369-382.

1066 Knowlton, F.F., Gese, E.M. & Jaeger, M.M. (1999). Coyote depredation control: An interface  
1067 between biology and management. *Journal of Range Management*, 52, 398-412.

1068 Kok, O.B. & Nel, J.A.J. (2004). Convergence and divergence in prey of sympatric canids and  
1069 felids: opportunism or phylogenetic constraint? *Biological Journal of the Linnean*  
1070 *Society*, 83, 527–538.

1071 Krofel, M. (2008). Opportunistic hunting behaviour of black-backed jackals in Namibia.  
1072 *African Journal of Ecology*, 46, 220-222.

1073 Lamprecht, J. (1978). On diet, foraging behaviour and interspecific food competition of  
1074 jackals in the Serengeti National Park, East Africa. *Zeitschrift fur Saugtierkunde*, 43,  
1075 210-223.

1076 Lehner, P.N. (1976). Coyote behavior: Implications for management. *Wildlife Society*  
1077 *Bulletin*, 4, 120-126.

1078 Leo, V., Reading, R.P. & Letnic, M. (2015). Interference competition: odours of an apex  
1079 predator and conspecifics influence resource acquisition by red foxes. *Oecologia*,  
1080 179, 1033-1040.

1081 Li, X., Buzzard, P., Chen, Y. & Jiang, X. (2013). Patterns of livestock predation by  
1082 carnivores: Human–wildlife conflict in Northwest Yunnan, China. *Environmental*  
1083 *Management*, 52, 1334-1340.

1084 Lieury, N., Ruelle, S., Devillard, S., Albaret, M., Drouyer, F., Baudoux, B. & Millon, A. (2015).  
1085 Compensatory immigration challenges predator control: An experimental evidence-  
1086 based approach improves management. *The Journal of Wildlife Management*, 79,  
1087 425-434.

1088 Loveridge, A.J. & Macdonald, D.W. (2001). Seasonality in spatial organization and dispersal  
1089 of sympatric jackals (*Canis mesomelas* and *C. adustus*): implications for rabies  
1090 management. *Journal of Zoology*, 253, 101-111.

1091 Loveridge, A.J. & Macdonald, D.W. (2002). Habitat ecology of two sympatric species of  
1092 jackals in Zimbabwe. *Journal of Mammalogy*, 83, 599-607.

1093 Loveridge, A.J. & Macdonald, D.W. (2003). Niche separation in sympatric jackals (*Canis*  
1094 *mesomelas* and *Canis adustus*). *Journal of Zoology, London*, 259, 143-153.

1095 Loveridge, A.J. & Nel, J.A.J., 2004. Black-backed jackal *Canis mesomelas* Schreber, 1775  
1096 Least Concern (2004), In C. Sillero-Zubiri, M. Hoffman, D.W. Macdonald (Eds),  
1097 *Canids: Foxes, Wolves, Jackals and Dogs. Status survey and conservation action*  
1098 *plan*. pp. 161-166. IUCN/SSC Canid Specialist Group, Gland, Switzerland and  
1099 Cambridge, UK.

1100 Loveridge, A.J. & Nel, J.A.J., 2008. *Canis mesomelas*. IUCN 2013. IUCN Red List of  
 1101 Threatened Species.

1102 Loveridge, A.J. & Nel, J.A.J., (2013). *Canis mesomelas* Black-backed Jackal, In J. Kingdon,  
 1103 M. Hoffman (Eds), *Mammals of Africa: Volume V: Carnivores, Pangolins, Equids and*  
 1104 *rhinoceroses*. pp. 39-44. Bloomsbury Publishing, London.

1105 Macdonald, D.W. (1979). The flexible social system of the golden jackal, *Canis aureus*.  
 1106 *Behavioral Ecology and Sociobiology*, 5, 17-38.

1107 Macdonald, D.W. & Sillero-Zubiri, C. eds., (2004). *The Biology and Conservation of Wild*  
 1108 *Canids*. Oxford University Press, New York.

1109 Marker, L. & Dickman, A. (2005). Notes on the spatial ecology of caracals (*Felis caracal*),  
 1110 with particular reference to Namibian farmlands. *African Journal of Ecology*, 43, 73-  
 1111 76.

1112 McKenzie, A.A. (1990). *Co-operative hunting in the black-backed jackal, Canis mesomelas,*  
 1113 *Schreber*. (Unpublished Ph.D. thesis), University of Pretoria, Pretoria.

1114 McKenzie, M.M. (1993). Biology of the black-backed jackal *Canis mesomelas* with reference  
 1115 to rabies. *Onderstepoort Journal of Veterinary Research*, 60, 367-371.

1116 Melville, H. (2004a). *Behavioural ecology of the caracal in the Kgalagadi Transfrontier Park,*  
 1117 *and its impact on adjacent small stock production units*. (Unpublished M.Sc. thesis),  
 1118 University of Pretoria, Pretoria.

1119 Melville, H.I.A.S. & Bothma, J.d.P. (2006). Using spoor counts to analyse the effect of small  
 1120 stock farming in Namibia on caracal density in the neighbouring Kgalagadi  
 1121 Transfrontier Park. *Journal of Arid Environments*, 64, 436 - 447.

1122 Melville, H.I.A.S., Bothma, J.d.P. and Mills, M.G.L. (2004b). Prey selection by caracal in the  
 1123 Kgalagadi Transfrontier Park. *South African Journal of Wildlife Research*, 34, 67 - 75.

1124 Mills, M.G.L. (1984). Prey selection and feeding habits of the large carnivores in the  
 1125 southern Kalahari. *Koedoe*, 281 - 294.

1126 Minnie, L. (2009). *Socio-economic and ecological correlates of leopard-stock farmer*  
 1127 *interactions in the Baviaanskloof Mega-Reserve, Eastern Cape*. (Unpublished M.Sc.  
 1128 thesis), Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

1129 Minnie, L. (2016). *Effects of lethal management on black-backed jackal population structure*  
 1130 *and source-sink dynamics*. (Unpublished Ph.D. thesis), Nelson Mandela  
 1131 Metropolitan University, Port Elizabeth.

1132 Minnie, L., Gaylard, A. & Kerley, G.I.H. (2016a). Compensatory life history responses of a  
 1133 mesopredator may undermine carnivore management efforts. *Journal of Applied*  
 1134 *Ecology*, 53, 379-387.

1135 Minnie, L., Parker, D.M., Butler, H., Kamler, J.F., Du Plessis, J.J. & Drouilley, M., 2016b. A  
 1136 Conservation Assessment of Black-Backed Jackal (*Canis mesomelas*), In The Red



- 1137 List of Mammals of South Africa, Swaziland and Lesotho. eds M.F. Child, L.  
1138 Roxburgh, E. Do Linh San, D. Raimondo, H.T. Davies-Mostert. South African  
1139 National Biodiversity Institute, Endangered Wildlife Trust, Pretoria.
- 1140 Moehlman, P.D. (1979). Jackal helpers and pup survival. *Nature*, 277, 382-383.
- 1141 Moehlman, P.D. (1987). Social organization in jackals. *American Scientist*, 75, 366-375.
- 1142 Moolman, L.C. (1984). 'n Vergelyking van die voedingsgewoontes van die rooikat *Felis*  
1143 *caracal* binne en buite die Bergkwagga Nasionale Park. *Koedoe*, 27, 121 - 129.
- 1144 Moolman, L.C. (1986). *Aspekte van die ekologie en gedrag van die rooikat Felis caracal*  
1145 *Schreber, 1776 in die Bergkwagga Nasionale Park en op die omliggende plase.*  
1146 (Unpublished MSc thesis), University of Pretoria, Pretoria.
- 1147 Morwe, J.B. (2013). *Determining the direct impact of Black-backed jackal (Canis*  
1148 *mesomelas) on the Springbok (Antidorcas marsupialis) population at Maria Moroka*  
1149 *Nature Reserve, Free State, South Africa.* (Unpublished B.Sc. (Hons.) thesis),  
1150 University of the Free State, QwaQwa, South Africa.
- 1151 Murray, M., Cembrowski, A., Latham, A.D.M., Lukasik, V.M., Pruss, S. & St Clair, C.C.  
1152 (2015). Greater consumption of protein-poor anthropogenic food by urban relative to  
1153 rural coyotes increases diet breadth and potential for human–wildlife conflict.  
1154 *Ecography*, 38, 1235-1242.
- 1155 Nattrass, N., Conradie, B., Drouilley, M. & O'Riain, J., 2017. Understanding the black-backed  
1156 jackal, p. 50. Centre for Social Science Research, University of Cape Town, Cape  
1157 Town.
- 1158 Nel, J.A.J., Loutit, R.J., Braby, R. & Somers, M.J. (2013). Resource dispersion, territory size  
1159 and group size of black-backed jackals on a desert coast. *Acta Theriologica*, 58, 189-  
1160 197.
- 1161 Newsome, T.M., Dellinger, J.A., Pavey, C.R., Ripple, W.J., Shores, C.R., Wirsing, A.J. &  
1162 Dickman, C.R. (2015). The ecological effects of providing resource subsidies to  
1163 predators. *Global Ecology and Biogeography*, 24, 1466-8238
- 1164 Newsome, T.M., Greenville, A.C., Ćirović, D., Dickman, C.R., Johnson, C.N., Krofel, M.,  
1165 Letnic, M., Ripple, W.J., Ritchie, E.G., Stoyanov, S. & Wirsing, A.J. (2017). Top  
1166 predators constrain mesopredator distributions. *Nature Communications*, 8, 15467.
- 1167 Norton, D.A. & Lawson, A.B. (1985a). Radio tracking of leopards and caracals in the  
1168 Stellenbosch area, Cape Province. *South African Journal of Wildlife Research*, 15, 17  
1169 - 24.
- 1170 Norton, P.M. & Lawson, A.B. (1985b). Radio tracking of leopards and caracals in the  
1171 Stellenbosch area, Cape Province. *South African Journal of Wildlife Research*, 15,  
1172 17-24.

- 1173 Novaro, A.J., Funes, M.C. & Walker, R.S. (2005). An empirical test of source-sink dynamics  
1174 induced by hunting. *Journal of Applied Ecology*, 42, 910-920.
- 1175 Nowell, K. & Jackson, P. eds., (1996). *Wild Cats: status survey and conservation action*  
1176 *plan*. IUCN, Gland, Switzerland.
- 1177 Odden, J., Linnell, J.D.C., Moa, P.F., Herfindal, I., Kvam, T. & Andersen, R. (2002). Lynx  
1178 depredation on domestic sheep in Norway. *Journal of Wildlife Management*, 66, 98 -  
1179 105.
- 1180 Oosthuizen, W.H., Meyer, M.A., David, J.H.M., Summers, N.M., Kotze, P.G.H., Swanson,  
1181 S.W. & Shaughnessy, P.D. (1997). Variation in jackal numbers at the Van Reenen  
1182 Bay seal colony with comment on likely importance of jackals as predators. *South*  
1183 *African Journal of Wildlife Research*, 27, 26-29.
- 1184 Palmer, R. & Fairall, N. (1988). Caracal and African wild cat diet in the Karoo National Park  
1185 and the implications thereof for hyrax. *South African Journal of Wildlife Research*, 18,  
1186 30 - 34.
- 1187 Parker, G.R., Maxwell, J.W., Morton, L.D. & Smith, G.E.J. (1983). The ecology of the lynx  
1188 (*Lynx canadensis*) on Cape Breton island. *Canadian Journal of Zoology*, 61, 770-  
1189 786.
- 1190 Poessel, S.A., Breck, S.W. & Gese, E.M. (2016). Spatial ecology of coyotes in the Denver  
1191 metropolitan area: influence of the urban matrix. *Journal of Mammalogy*, 97, 1414-  
1192 1427.
- 1193 Pohl, C.F. (2015). *The diet of caracal (Caracal caracal) in the southern Free State*.  
1194 (Unpublished MSc thesis), University of the Free State, Bloemfontein.
- 1195 Pringle, J.A. & Pringle, V.L. (1979). Observations on the lynx *Felis caracal* in the Bedford  
1196 district. *African Zoology*, 14, 1-4.
- 1197 Ramesh, T., Kalle, R. & Downs, C.T. (2016). Space use in a South African agriculture  
1198 landscape by the caracal (*Caracal caracal*). *European Journal of Wildlife Research*,  
1199 63, 11.
- 1200 Robinson, H.S., Desimone, R., Hartway, C., Gude, J.A., Thompson, M.J., Mitchell, M.S. &  
1201 Hebblewhite, M. (2014). A test of the compensatory mortality hypothesis in mountain  
1202 lions: A management experiment in West-Central Montana. *The Journal of Wildlife*  
1203 *Management*, 78, 791-807.
- 1204 Ross, P.I., Jalkotzy, M.G. & Gunson, J.R. (1996). The quota system of cougar harvest  
1205 management in Alberta. *Wildlife Society Bulletin (1973-2006)*, 24, 490-494.
- 1206 Rowe-Rowe, D.T. (1978). The small carnivores of Natal. *Lammergeyer*, 25, 1-48.
- 1207 Rowe-Rowe, D.T. (1982). Home range and movements of black-backed jackals in an African  
1208 montane region. *South African Journal of Wildlife Research*, 12, 79-84.

- 1209 Rowe-Rowe, D.T. (1983). Black-backed jackal diet in relation to food availability in the Natal  
1210 Drakensberg. *South African Journal of Wildlife Research*, 13, 17-23.
- 1211 Sacks, B.N. (2005). Reproduction and body condition of California coyotes (*Canis latrans*).  
1212 *Journal of Mammalogy*, 86, 1036-1041.
- 1213 Sillero-Zubiri, C., Hoffmann, M. & Macdonald, D. eds., (2004). *Canids: Foxes, Wolves,*  
1214 *Jackals and Dogs. Status Survey and Conservation Action Plan.* IUCN/SSC Canid  
1215 Specialist Group, Gland, Switzerland and Cambridge, UK.
- 1216 Singh, R., Qureshi, Q., Sankar, K., Krausman, P.R. & Goyal, S.P. (2014). Population and  
1217 habitat characteristics of caracal in semi-arid landscape, western India. *Journal of*  
1218 *Arid Environments*, 103, 92-95.
- 1219 Skead, D.M. (1973). Incidence of calling in the black-backed jackal. *Journal of the Southern*  
1220 *African Wildlife Management Association*, 3, 28-29.
- 1221 Skinner, J.D. (1979). Feeding behaviour in Caracal *Felis caracal*. *Journal of Zoology*, 189,  
1222 523-525.
- 1223 Slough, B.G. & Mowat, G. (1996). Lynx population dynamics in an untrapped refugium. *The*  
1224 *Journal of Wildlife Management*, 60, 946-961.
- 1225 Stahl, P., Vandell, J.M., Herrenschmidt, V. & Migot, P. (2001). Predation on livestock by an  
1226 expanding reintroduced lynx population: long-term trend and spatial variability.  
1227 *Journal of Applied Ecology*, 38, 674 - 687.
- 1228 Sterling, B., Conley, W. & Conley, M.R. (1983). Simulations of Demographic Compensation  
1229 in Coyote Populations. *The Journal of Wildlife Management*, 47, 1177-1181.
- 1230 Stuart, C.T. (1981). Notes on the mammalian carnivores of the Cape Province, South Africa.  
1231 *Bontebok*, 1, 1 - 58.
- 1232 Stuart, C.T. (1982). *Aspects of the biology of the Caracal (Felis caracal Schreber, 1776) in*  
1233 *the Cape Province, South Africa.* (Unpublished MSc thesis), University of Natal,  
1234 Durban.
- 1235 Stuart, C.T. & Stuart, T., (2013). *Caracal caracal*, In J.S. Kingdon, M. Hoffmann (Eds), *The*  
1236 *Mammals of Africa.* Academic Press, Amsterdam, The Netherlands.
- 1237 Stuart, T.S. & Wilson, V.J., 1988. The cats of southern Africa, p. 32. IUCN/SSC Cat  
1238 Specialist Group, African Carnivore Survey, Chipangali Wildlife Trust.
- 1239 Stoddart, L.C., Griffiths, R.E. & Knowlton, F.F. (2001). Coyote Responses to Changing  
1240 Jackrabbit Abundance Affect Sheep Predation. *Journal of Range Management*, 54,  
1241 15-20.
- 1242 Todd, A.W. & Keith, L.B. (1983). Coyote Demography during a Snowshoe Hare Decline in  
1243 Alberta. *The Journal of Wildlife Management*, 47, 394-404.
- 1244 van de Ven, T.M.F.N., Tambling, C.J. & Kerley, G.I.H. (2013). Seasonal diet of black-backed  
1245 jackal in the Eastern Karoo, South Africa. *Journal of Arid Environments*, 99, 23-27.

- 1246 van der Merwe, S.J., Avenant, N.L. & Lues, J.F.R. (2009). Pastoral farming and wildlife  
1247 management influences on lion/livestock interaction in the Kgalagadi-south,  
1248 Botswana: a synopsis. *Journal for New Generation Sciences*, 7, 203-214.
- 1249 van Heezik, Y.M. & Seddon, P.J. (1998). Range size and habitat use of an adult male  
1250 caracal in northern Saudi Arabia. *Journal of Arid Environments*, 40, 109 - 112.
- 1251 van Niekerk, H.N. (2010). *The cost of predation on small livestock in South Africa by medium*  
1252 *sized predators*. (Unpublished MSc thesis), University of the Free State,  
1253 Bloemfontein, South Africa.
- 1254 Walton, L.R. & Joly, D.O. (2003). *Canis mesomelas*. *Mammalian Species*, 1-9.
- 1255 Waser, P.M. (1980). Small nocturnal carnivores: ecological studies in the Serengeti. *African*  
1256 *Journal of Ecology*, 18, 167-185.
- 1257 Weisbein, Y. & Mendelssohn, H., 1989. The biology and ecology of the caracal (*Felis*  
1258 *caracal*) in the Arava valley of Israel, 1-10. Department of Zoology, Tel-Aviv  
1259 University, Ramat-Aviv, Israel.
- 1260 Yarnell, R.W., Phipps, W.L., Burgess, L.P., Ellis, J.A., Harrison, S.W.R., Dell, S., MacTavish,  
1261 D., MacTavish, L.M. & Scott, D.M. (2013). The influence of large predators on the  
1262 feeding ecology of two African mesocarnivores: the black-backed jackal and the  
1263 brown hyaena. *South African Journal of Wildlife Research*, 43, 155-166.
- 1264 Yom-Tov, Y., Ashkenazi, S. & Viner, O. (1995). Cattle predation by the golden jackal *Canis*  
1265 *aureus* in the Golan Heights, Israel. *Biological Conservation*, 73, 19-22.