

Foraging theory provides a useful framework for livestock predation management

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29 Foraging theory provides a useful framework for livestock predation management.

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50 **Abstract**

51 A societal shift toward plant dominant diets and a reduction in livestock rearing could have broad
52 social, environmental and conservation benefits. Livestock husbandry, however, has a wealthy
53 cultural history, strong support and high consumer demand. It is therefore likely to continue as a
54 major land use and conservation issue for predators. From a producer's perspective, the primary goals
55 of livestock protection are maximising, or at least maintaining, production by minimising losses and
56 mitigating detriment to stock welfare. Lethal removal of predators remains a commonplace solution.
57 Such management measures are questionable as they raise animal welfare and conservation concerns,
58 risk inhibiting ecological processes, are often expensive, and in some circumstances, exacerbate
59 livestock predation problems. Non-lethal alternatives can facilitate co-existence between livestock
60 farmers and predators, ideally reducing the ecological impact of pastoralism and achieving
61 conservation goals. The need for rigorous study of non-lethal approaches has however been recently
62 highlighted. Tools and methods involved in livestock protection, as well as the theoretical basis of
63 how we perceive and manage the problem, require deeper consideration. Non-lethal approaches
64 require knowledgeable implementation and an effective decision making system is a prerequisite for
65 successful practice. Livestock predation and its prevention are fundamentally influenced by the
66 underlying principles of foraging ecology and risk theory. We propose that manipulating elements of
67 Brown's (1988) quitting harvest rate model provides a useful conceptual framework for reducing
68 livestock predation and encouraging coexistence.

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70 **Keywords**

71 Livestock; Non-lethal; Foraging; Predation; Harvest rate, Risk

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75 **Introduction**

76 While perhaps politically and industrially unfavourable, there is justifiable discourse and concern
77 regarding the social and environmental footprint of the livestock industry (Westhoek *et al.* 2014;
78 Hallström, Carlsson-Kanyama & Börjesson 2015). Public concern with livestock welfare presents a
79 longstanding contention (Deemer & Lobao 2011). Resource efficiency and issues relating to health
80 and nutrition present direct concerns for effectively meeting nutritional needs of a growing human
81 population through livestock products (Baroni *et al.* 2007; Westhoek *et al.* 2014; WWF 2016).
82 Disease transmission and antibiotic resistance pose additional health concerns for humans, livestock
83 and wildlife (Thompson 2013; Gottdenker *et al.* 2014; Hudson *et al.* 2017). Pastoralism's freshwater
84 consumption and land use are also intensive, with habitat modification, ecological degradation,
85 emissions, effluent and contribution to climate change all providing grave concerns (Baroni *et al.*
86 2007; Westhoek *et al.* 2014; Hallström, Carlsson-Kanyama & Börjesson 2015). Alongside indirect
87 implications for wildlife conservation, livestock directly compete with and have replaced much wild
88 biodiversity (Bar-On, Phillips & Milo 2018).

89 Some champion the potential conservation benefits of well managed livestock but often neglect to
90 place such benefits in context, failing to draw comparisons with unmodified systems (Franzluebbers
91 *et al.* 2012). The overall benefits for wildlife conservation are however contentious; livestock grazing,
92 for example, can adversely affect species conservation, ecosystem structure, function and composition
93 (Reading & Jofre 2015; Eldridge *et al.* 2016; Sharps *et al.* 2016). Livestock biomass now far exceeds
94 that of wild mammals and competition for forage can negatively impact both wild herbivores and their
95 predators (Latham 1999; Bar-On, Phillips & Milo 2018).

96 Native predators can be completely excluded from pastoral landscapes or exterminated altogether, e.g.
97 large carnivores in the British Isles (Brown, McMorran & Price 2011). Cultural and social bias against
98 predators may often exist in rural areas, regardless of personal experience with livestock predation
99 (Chavez, Gese & Krannich 2005). Actual impacts can be small relative to other factors including
100 disease, birthing problems, weather and accidents (Breck & Meier 2004; Dar *et al.* 2009). A small

101 proportion of producers in predation hotspots may, however, absorb the majority of losses, increased
102 husbandry costs and decreased animal performance (Breck & Meier 2004; Shelton 2004). Damage to
103 livelihoods can reduce support for conservation initiatives (Anthony 2007; Anthony, Scott & Antypas
104 2010). Livestock predation often results in disproportionate deaths of the animals deemed responsible
105 and persecution of predators is common (Meriggi & Lovari 1996; Shivik 2006; Eggermann *et al.*
106 2011). Lethal control of predators to pre-empt or in response to livestock predation has become
107 common management in many contexts (Macdonald & Baker 2004; Treves *et al.* 2006).

108 The simplest way to resolve many of these problems would be to substantially reduce livestock
109 production and move to plant dominant diets on a societal level (Eshel *et al.* 2014; Poore & Nemecek
110 2018). Changing consumer habits should not be overlooked as a potential nature conservation tool.
111 Suitable damage related taxation may offer some assistance to this end (Springmann *et al.* 2017).

112 Discouraging unnecessary consumption and encouraging financial divestment by consumers offers an
113 additional route to achieving sustainability (Ripple *et al.* 2017). Such a large-scale transition may,
114 however, prove difficult where habitat, technology, international trade, culture, affluence or
115 knowledge makes livestock products one of few viable food production methods or an easily
116 accessible dietary option. Livestock farming also has a long and enduring cultural significance
117 (McClure 2015; Holmes 2016; Pitikoe 2017). High levels of meat, egg and dairy consumption are
118 prevalent in many societies and a global shift away from this is currently unlikely, with human
119 populations and demand for animal products increasing globally (Kearney 2010; Westhoek *et al.*
120 2014). Livestock production is likely to continue as a major land use and livestock predation remains
121 an issue for both pastoralists and conservationists.

122 The ecological impacts, efficiency and morality of lethal control are questionable (Treves, Krofel &
123 McManus 2016). Lethal control of predators and decline in their numbers can result in loss of
124 ecological services and stability (Wallach *et al.* 2010; Ripple *et al.* 2014). Lethal control may not
125 always be economically viable if loss of regulatory services by predators results in high costs where
126 wild herbivores compete for forage with domestic stock (Wicks & Allen 2012). Lethal control can
127 also disrupt social structure, exacerbating livestock predation problems (Wallach *et al.* 2009), or lead

128 to compensatory reproduction, thereby minimising the effect of control (Minnie, Gaylard & Kerley
129 2016; 2017). A range of non-lethal alternatives exist that can assist mitigation of livestock predation
130 problems and encourage coexistence (Shivik 2006; Stone *et al.* 2017). Societal preference for
131 coexistence has led to greater adoption of such approaches (Chapron *et al.* 2014). Non-lethal livestock
132 predation management can, although may not always, be equally or more effective than lethal control
133 of predators (McManus *et al.* 2015; Stone *et al.* 2017; van Eeden *et al.* 2018a). Some non-lethal tools
134 have been well tested but further robust experimentation is required to assess efficacy, encourage
135 producer adoption and guarantee return on investments (Eklund *et al.* 2017; Scasta, Stam & Windh
136 2017; van Eeden *et al.* 2018b).

137 We refer readers to van Eeden *et al.* (2018b) for a useful synthesis of the current evidence base but
138 recognise that in practice, one approach is rarely used in isolation of others, effectiveness will be
139 context dependent and action is still required while the necessary testing of tools is conducted.
140 Practitioners require a holistic and adaptive management system to more easily and effectively
141 implement non-lethal programmes across a broad range of contexts. Applying existing scientific
142 theory to real world issues should prove productive for both study and practice. The predation and
143 protection of livestock are fundamentally influenced by the principles of both foraging and risk
144 theory. We propose that Brown's (1988) quitting harvest rate model provides a useful theoretical
145 framework for managing livestock predation and achieving conservation goals.

146 **Brown's (1988) quitting harvest rate model as a management framework**

147 Foraging theory suggests animals attempt to make the best of foraging scenarios by trading-off costs
148 against benefits (Emlen 1966; MacArthur & Pianka 1966; Charnov 1976). Decisions to prey upon
149 livestock instead of wild prey may be based in energetics (Polisar *et al.* 2003), but there is little
150 evidence of predators preferentially hunting livestock where it has been tested (Lyngdoh *et al.* 2014;
151 Hayward *et al.* 2017). Brown's (1988) quitting harvest rate model provides a useful framework with
152 which to examine the mitigation of livestock harvest by predators. Where food patches are depletable,
153 animals should abandon patches once gains (H) become equal to or fall below costs (Brown 1988;

154 Brown & Kotler 2007). The concept is described in the equation $H = C + P + MOC$, where $H =$
155 harvest rate (food gain per unit time), $C =$ energetic costs (to obtain food), $P =$ predation costs
156 (cost/likelihood of losing fitness by interacting with predators) and $MOC =$ missed opportunity costs
157 (food or fitness enhancing benefits available elsewhere) (Brown 1988; Brown & Kotler 2007). Like
158 Berger-Tal et al. (2009), we also included risk of injury (RI) or mortality (e.g. from objects like
159 electric fencing, terrain ruggedness, the stock themselves, or a device worn by stock) as an additional
160 cost that may be incurred during livestock predation but discuss it alongside P for ease of discussion
161 and implementation.

162 From a producer's perspective, the primary goals of livestock protection are maximising, or at least
163 maintaining, production by minimising losses and mitigating detriment to stock welfare. Practitioners
164 and wildlife managers should aim to manipulate predator foraging behaviour to reduce livestock
165 predation; intentionally causing predators to quit livestock patches more quickly and harvest less, or
166 ideally, no stock (Table.1). Ideally, livestock could be made so unprofitable comparable to wild prey
167 that they become less preferable and are rarely preyed upon. Here we highlight considerations that
168 may offer some utility but should be contemplated only in relation to individual context by giving
169 thought to all model components.

170 *Harvest rate (H)*

171 Initial harvest rate (H) of livestock patches could be reduced to increase how quickly predators give
172 up on livestock patches. Predators can be attracted to anthropogenic food subsidies, adapting their
173 behaviour to utilise them (Ciucci *et al.* 1997; Newsome *et al.* 2014; Morehouse & Boyce 2017).
174 Refuse sites in pastoral areas are likely to attract predators and lead to increased conflict (Wilson *et al.*
175 2006; Kolowski & Holekamp 2008). Removal of carcasses, livestock pits or waste dumps in the
176 vicinity of livestock would provide sensible starting points to reducing patch attractiveness. Herd size
177 (i.e. food availability) may also provide an attractant. Farms with larger herds may be more likely to
178 experience livestock predation (Treves *et al.* 2004; Bradley & Pletscher 2005; Pimenta *et al.* 2017).

179 Herd size could potentially be reduced, although there is likely an economic disincentive to do so
180 (Pimenta *et al.* 2017).

181 *Missed opportunity costs (MOC)*

182 Costs to predators of foraging in livestock patches can also be increased. Raising or ensuring high
183 missed opportunity costs (MOC) relative to livestock patches should accelerate giving up on
184 livestock. Often overlooked as a mitigation measure, ensuring viable wild prey populations (e.g. via
185 harvest regulations, habitat restoration, reinforcement or reintroduction) is pivotal in sustaining large
186 carnivore populations and minimising livestock predation (Meriggi & Lovari 1996; Polisar *et al.*
187 2003; Barja 2009). Predators will increasingly target livestock, which increase in relative value, as
188 wild prey decline (Kolowski & Holekamp 2006). Low energy state foragers also tend to take higher
189 risks (Brown 1988; Brown, Morgan & Dow 1992). Ensuring higher predator energy states by
190 maintaining suitable wild prey stocks could reduce the marginal value of livestock as a food source.
191 Livestock production and the maintenance of wild prey stocks are however most likely best kept
192 somewhat apart. Abundant wild prey in pastoral areas could cause increased livestock predation
193 (Stahl *et al.* 2001; Bradley & Pletscher 2005; Amirkhiz *et al.* 2018). Carnivores are attracted to high
194 quality habitat and conflicts may be more likely to occur where human activities, including livestock
195 farming, overlap (Wilson *et al.* 2006; Odden *et al.* 2008). Livestock could be kept away from
196 preferable wildlife habitat or better protected where this is not feasible. Habitat improvement and
197 suitable limitation to wild herbivore harvest could also be employed in areas set aside from
198 pastoralism. Excepting large land owners, this will require regional level intervention. Livestock
199 producers can however make their properties less attractive to wild herbivores, e.g. protecting hay
200 supplies, using livestock guardian dogs, *Canis lupus familiaris*, or hazing habituated wildlife (Bradley
201 & Pletscher 2005; Kloppers, St. Clair & Hurd 2005; Gehring *et al.* 2010).

202 Seasonal declines in wild prey availability (MOC) driven by environmental conditions, seasonal
203 migrations and prey habitat use, especially if coinciding with increased stock availability can lead to
204 prey switching and increased livestock predation (Cavalcanti & Gese 2010; Valeix *et al.* 2012). In a

205 similar fashion the relative value of livestock may increase following seasonal predator food demand
206 and decreases in wild prey vulnerability due to maturing young (Ciucci & Boitani 1998). Practitioners
207 should accordingly increase other costs (C, P or RI) and avoid increasing potential attractants (e.g.
208 young livestock) during these more vulnerable periods.

209 *Energetic cost (C)*

210 The energetic cost (C) of preying on livestock could be increased, especially during periods of
211 vulnerability. Fencing can provide an energetically costly barrier for carnivores to overcome. Fencing,
212 albeit a barrier to wildlife movements, likely reduces losses; however its general efficacy will depend
213 on the problem carnivore's abilities, fence maintenance and the presence of other fence damaging
214 wildlife (Breitenmoser *et al.* 2005; McManus *et al.* 2015). Keeping livestock in predator proof corrals
215 at night can efficiently minimise losses, although crowding can necessitate additional health care, and
216 poor maintenance risks severe losses (Breitenmoser *et al.* 2005; Schiess-Meier *et al.* 2007; Weise *et*
217 *al.* 2018). Corrals and fencing can also be made more disruptive through the addition of perceived or
218 real injury related risk via fladry (Fig.1) and/or electric current (Musiani *et al.* 2003; Lance *et al.*
219 2011).

220 Livestock attributes could also affect the energetic costs of predation. Young, sick and injured animals
221 may incur minimal energetic costs to hunt and can thus be more vulnerable to predation (Chavez &
222 Giese 2006; Cavalcanti & Gese 2010). Producers should monitor and be mindful of herd vulnerability
223 relative to alternative wild prey sources, targeting additional interventions accordingly. Vulnerable
224 livestock, such as sheep, *Ovis aries*, can also be bonded to or housed with herd animals possessing
225 better defensive capabilities (greater aggression, size, strength, armament). For example, llama's,
226 *Lama glama*, long-horned cattle, *Bos taurus*, or donkeys, *Equus africanus*, can provide protective
227 services by increasing injury related risk (RI) and the energetic costs (C) of accessing livestock (Smith
228 *et al.* 2000b). Stock breed could perhaps be altered by selecting more agile or defensive breeds, which
229 retain anti-predator behaviour. Anti-predator defence could also be encouraged within current stocks,
230 for example, some producers attribute fewer wolf, *Canis lupus*, related livestock losses

231 to keeping protective mother cows and encouraging defensive herding behaviour, instead of removing
232 protective mothers and allowing herds to fragment across remote areas (H.Z. Anderson, Tom Miner
233 Basin Project, *Pers comm*).

234 *Predation risk (P) and risk of injury (RI)*

235 There is good evidence to suggest that animals assess and respond to risk (Lima & Dill 1990; Creel &
236 Christianson 2008; Heithaus *et al.* 2009). Fear ecology suggests such interactions may affect
237 landscape use and foraging (Brown, Laundré & Gurung 1999; Brown & Kotler 2007; Laundré,
238 Hernández & Ripple 2010). The mesopredator release hypothesis suggests predators too have things
239 to fear (Crooks & Soulé 1999; Ritchie & Johnson 2009; Newsome *et al.* 2017). Humans are a key
240 factor that alters the context within which predators exist (Haswell, Kusak & Hayward 2017).
241 Humans may be viewed as super predators whose presence provides substantial risk to carnivores,
242 consequently modifying predatory behaviour (Smith *et al.* 2017).

243 Increase in perceived or actual predation costs (P), as well as risk of injury (RI) from other causes,
244 have received most attention in the development of non-lethal mitigation strategy (See Breitenmoser
245 *et al.* (2005) and Shivik (2006) for comprehensive reviews). Wild animals, especially predators, can
246 be particularly sensitive to new stimuli; scare devices using disruptive mechanisms such as
247 neophobia, irritation or pain have consequently been utilised as primary repellents (Shivik, Treves &
248 Callahan 2003; Shivik 2006). Secondary repellents establish a link between a behaviour and a
249 negative outcome through aversive conditioning, e.g. electronic training collars worn by predators or
250 taste aversion collars worn by livestock (Shivik, Treves & Callahan 2003; Shivik 2006). Excessive
251 use of primary repellents risks habituation whereas secondary repellents can require substantial
252 logistical effort and may need to be regularly reinforced to remain effective (Smith *et al.* 2000a;
253 Shivik 2006). Harassment (e.g. rubber bullets) may offer simple implementation but linking aversion
254 and behaviour might prove difficult and thereby limit effectiveness; consistent secondary repellents
255 such as electrified fladry may however prove more efficacious in both application and reinforcement

256 (Shivik 2006). Use of primary and secondary repellents will depend on local laws, additional
257 conservation concerns, and the ethical views of the practitioner.

258 Manipulating risk perception could still prove useful alongside the provision of direct threats. Visual
259 assessment of habitat and its interaction with escape strategies provides one means by which animals
260 may assess and respond to risk (Wirsing, Cameron & Heithaus 2010; Kuijper *et al.* 2013; Camacho
261 2014). Landscape characteristics, such as vegetative cover or woodlands adjacent to pastures, can be
262 associated with higher levels of livestock predation (Ciucci & Boitani 1998; Stahl *et al.* 2001).
263 Mapping risk hotspots could provide an effective decision making tool (Treves *et al.* 2004).

264 Animals also assess risk through auditory means (Berger, Swenson & Persson 2001; Lynch *et al.*
265 2015). Many technological scare devices work through visual or auditory disruptive stimuli, e.g.
266 flashing lights, high beam lights, air horns, propane cannons, and sometimes through a combination,
267 e.g. radio activated guard (RAG) boxes. Repellents such as flashing lights can significantly reduce
268 predation but may not be effective against all carnivores (Ohrens, Bonacic & Treves 2019).

269 Practitioner strategy will need to be context specific as well as adaptive. For example, when
270 nocturnally flashing lights were applied to livestock bomas (protective night pens) in Kenya, Lions,
271 *Panthera leo*, switched to attacking bomas where intervention was not implemented, and
272 subsequently, when installation of lights increased, shifted to diurnal attacks (Lesilau *et al.* 2018).

273 The scent of dominant predators can communicate increased risk to carnivores (Leo, Reading &
274 Letnic 2015; Haswell *et al.* 2018). Manipulation of scent could be useful in manipulating predator
275 landscape use but may not always yield intended outcomes due to the context in which scent is
276 encountered (Jones *et al.* 2016). Placement of scent manipulations could ideally be optimised if
277 context relations are understood, i.e. what scent to place, when, where and how much. Identifying
278 effective components of olfactory communication such as producer diet or social status and their
279 associated compounds could also improve effectiveness (Parsons *et al.* 2018).

280 Direct presence of predation and injury risk are likely to elicit stronger responses than cues such as
281 olfaction alone (Scheinin *et al.* 2006; Vanak, Thaker & Gompper 2009). Livestock guardian animals

282 may provide multiple benefits through olfactory and auditory risk cue provision as well as direct
283 presence (van Bommel & Johnson 2012; McManus *et al.* 2015). Livestock guardian dogs (Fig.2) can
284 increase predation risk (P) and intimidate predators by protecting stock directly or creating landscapes
285 of fear when used in a patrolling manor (Rigg 2001; Hansen, Staaland & Ringso 2002; Rigg *et al.*
286 2011). Guardian dogs may protect livestock without entirely excluding predators from foraging
287 nearby (Allen *et al.* 2017). In some circumstances, the use of dogs may be spatially or seasonally
288 problematic depending on wildlife sensitive periods, farming practices and other landscape users e.g.
289 hikers or hunters. Livestock guardian dogs show good potential in mitigating pastoral wildlife conflict
290 but the most effective methods for their use requires further investigation (Gehring, VerCauteren &
291 Landry 2010; Gehring *et al.* 2010; Lescureux & Linnell 2014).

292

293 **Conclusions**

294 Scientific theory can offer useful frameworks for applied conservation issues. Understanding patterns
295 and processes involved in livestock predation, developing effective ways to mitigate predation and
296 rigorously testing non-lethal deterrents have been identified as areas requiring advancement (Breck &
297 Meier 2004; Purcell *et al.* 2012; Eklund *et al.* 2017). All could be assisted by inclusion of foraging
298 theory and risk ecology frameworks as part of study design and theoretical underpinning for
299 management decision making.

300 It is important to understand that there is no ‘silver bullet’ strategy (Treves *et al.* 2006). Interactions
301 between species are context-dependent (Haswell, Kusak & Hayward 2017). Success of non-lethal
302 tools will vary in time and space depending on the structure of the quitting harvest rate model in a
303 given scenario. There will of course also be scenarios where animals don’t follow the model or non-
304 lethal tools aren’t applied correctly. Habituation to repellent devices can also prove problematic
305 (Musiani *et al.* 2003; Shivik 2006; Lance *et al.* 2011). Adaptive, location and time specific
306 management strategies are likely to prove most effective in ensuring protection techniques do not lose
307 risk value (Stone *et al.* 2017; van Eeden *et al.* 2018a). Understanding changes in model components

308 will also help with timing management interventions, e.g. increase in P in unison with seasonal
309 fluctuations of MOC and predator nutritional needs. Identifying areas where predation likelihood is
310 higher and circumstances tip the equation in favour of harvest will prove additionally useful (Treves
311 *et al.* 2004; Treves & Rabenhorst 2017). Foraging theory can provide a useful framework for studying
312 and managing livestock predation. If components of Brown's (1988) model are understood and can
313 be manipulated through management practices then it should be feasible to tip the equation in favour
314 of coexistence.

315

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324

325 **Compliance with ethical standards**

326 The authors declare that they have no conflict of interest in the authorship of this article. Use of
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329

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628 **Table 1. Management options for reducing livestock predation utilising Brown's (1988) quitting harvest rate model, $H = C + P + MOC$.** H = harvest
629 rate, food available per unit time, C = energetic costs, P = predation costs, MOC = missed opportunity costs, alternative fitness enhancing activities e.g.
630 foraging elsewhere, we also add RI = risk of injury. Predators should give up foraging from patches of livestock when the available gains (H) are equal to or
631 less than the costs ($C + P + RI + MOC$). Managers can manipulate and alter components of the model in order to manipulate predator behaviour, reducing
632 livestock harvest or preventing it beginning in the first place.

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Livestock predation management

Decrease H

Reduce herd size, remove carcasses, remove anthropogenic food sources, any intervention which increases the time taken for predation

Increase MOC

Increase P or RI

Increase C

Ensure wild prey stocks

- Ensure suitable habitat and access to forage
- Decrease wild herbivore harvest
- Keep wild prey and livestock separate
- Deter wild prey from pastoral areas

Monitor seasonal fluctuations in wild prey

- Increase P, RI or C if wild prey stocks decline, become less accessible to predators or if predator food needs increase e.g. when predator young are weaned

Guardians

- Use when possible. Humans, dogs or other animals e.g. donkeys
- Use stock with natural defences
- Ensure appropriate numbers and behaviour
- Increase use when needed e.g. during mobile grazing

Scare devices / risk cues e.g. air horn

- Avoid predator habituation
- Use sporadically and when most needed
- Ensure stock are not startled by devices and are habituated

Aversive conditioning e.g. taste aversion collars worn by stock

- Ensure reinforcement

Fencing

- Use corrals when vulnerable e.g. at night or during lambing
- Consider solid stationary or electric mobile corrals as well as positioning
- Apply additional deterrents (P or RI) when needed e.g. fladry

Livestock attributes

- Use more agile & less docile livestock
- Use stock with natural defences e.g. armament or behaviour
- Breed for attributes
- Herding regime, dispersed or herded

Guardian patrols

- Increase when needed e.g. when predator young are weaned

Additional considerations

Terrain

- Avoid known hotspots or landscape contexts where livestock predation is more likely
- If unavoidable increase P, RI or C

Predator monitoring

- Avoid areas well visited by predators e.g. known breeding sites
- Increase P, RI or C when predators are in the vicinity



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644 Fig 1. Sheep in a temporary night time corral made of electrified fladry as part of the wood river wolf
645 project in Blaine County, Idaho.

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655 Fig 2. Livestock guardian dogs can be raised with and kept with stock or used in a patrolling capacity

656 with a handler or range rider. Karakachan female pictured, a rare breed being conserved by S.

657 Sedefchev, Bulgarian Biodiversity Preservation Society, Semperviva.