Terrestrial Mammal Conservation

Global evidence for the effects of interventions for terrestrial mammals excluding bats and primates

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3. Threat: Agriculture and aquaculture

Background

In many parts of the world, much of the conservation effort is directed at reducing the impacts of agricultural intensification on biodiversity on farmland and in the wider countryside. A number of the interventions that we have captured reflect this. Further substantial threats from agriculture include loss of habitat and pollution (e.g. from fertilizer and pesticide use). Interventions in response to these threats are described in the following chapters: *Habitat restoration and creation*, *Threat: Natural system modifications* and *Threat: Pollution*.

All farming systems

3.1. Establish wild flower areas on farmland

https://www.conservationevidence.com/actions/2359

- **Four studies** evaluated the effects of establishing wild flower areas on farmland on small mammals. Two studies were in Switzerland[2,3], one in the UK[1] and one in Germany[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (4 STUDIES)

- **Abundance (4 studies):** Three of four site comparison studies (including three replicated studies), in Switzerland[2,3], the UK[1]

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and Germany[4], found that sown wildflower areas contained more wood mice[1], small mammals[2,3] and common hamsters[4] compared to grass and clover set-aside[1], grasslands, crop and uncultivated margins[2], agricultural areas[3] and crop fields[4].

BEHAVIOUR (0 STUDIES)

Background

This intervention involves sowing areas with wild flowers, typically through agri-environment schemes. This includes set-aside areas, which are fields taken out of agricultural production and which may also enhance biodiversity within farmland.

See also *Provide or retain set-aside areas in farmland* for studies of set-aside under conventional management where no specific actions were taken to increase the wildflower content.

A site comparison study in 1996–1997 on two arable farms in southern UK (1) found that set-aside comprising a species-rich mix of grasses and native forbs was used more by wood mice *Apodemus sylvaticus* relative to availability, than was a simple grass and clover set-aside. Wood mice used species-rich set-aside proportionally to its availability within home ranges. Wood mice used grass/clover set-aside in lower proportion than its availability in home ranges. Data were presented as preference indices. Vegetation in the grass and forb set-aside was more species-rich than that in the grass and clover set-aside, though it was shorter and less dense. Grass and forb set-aside was established in 10-m strips adjacent to crops and hedgerows at one site. Grass and clover set-aside was established on 20-m margins and a 5-ha block at the second site. Nine wood mice were radio-tracked over three nights at each farm, in May–July of 1996 and 1997.

A replicated, site comparison study in 2003 on a farmed plain in Switzerland (2) found that sown wildflower strips contained more small mammals than did conventionally farmed grasslands, autumn-sown wheat fields and uncultivated herbaceous field margins. These comparisons were not tested for statistical significance. Small mammal densities varied greatly between sampling periods but peak densities were estimated at 1,047/ha in wildflower strips, 86/ha in farmed grasslands, 568/ha in wheat crops and 836/ha in herbaceous strips. Two small mammal species were caught in wildflower strips, with two each also in grassland and wheat and six in herbaceous margins. Wildflower strips (15 × 185 m) were sown with native species on fallow arable land. Grasslands (average 0.88 ha) were cut ≥5 times, each April–October and were fertilized. Autumn-sown wheat fields (average 1.3 ha) were harvested at the end of July. Herbaceous strips (5 × 320 m) comprised a range of herbaceous plant species along field margins. Small mammals were live-trapped on three fields of each treatment during 60-hour trapping sessions in March, May and July 2003. Densities were estimated using a capture-recapture method.

A replicated, site comparison study in 2005 in four agricultural areas in Switzerland (3) found that in most cases, following restoration, wildflower areas did not host more small mammals than nearby agricultural areas. In five of nine comparisons (between restored wildflower areas and wheat, maize and tobacco, over three sample seasons), there was no significant difference in the average abundance of small mammals in wildflower areas (458–1,285 animals/ha) and arable fields (34–682 animals/ha). In four of nine comparisons, small mammal abundance was significantly higher in restored wildflower areas (458–1,285 animals/ha) than in nearby arable fields (0–12 animals/ha). In four sites, live traps were placed in restored wildflower areas, wheat fields, maize fields, and tobacco fields. In each area, in May, July, and September 2005, three traps were placed every 5 m along two parallel 45-m-long transects, giving a total of 60 traps/area. Traps were operated over three nights and days at each area. Population sizes were estimated by mark-recapture techniques based on fur clipping of captured animals.

A replicated, site comparison study in 2013 on 28 fields in a mainly arable agricultural area in Bavaria, Germany (4) found that fields sown with wild flowers under an agri-environment scheme contained more common hamsters *Cricetus cricetus* than did crop fields. Hamster burrow density was higher in wildflower fields (3.2 hamster burrows/ha) than in crop fields (0.3 hamster burrows/ha). Fourteen wildflower fields were paired with similarly sized fields of maize, barley, oilseed rape, wheat or sugar beet. The study area measured approximately 50

× 20 km. Paired field were ≥200 m apart and wildflower fields were 440–21,500 m apart. Most wildflower fields were established on less-favoured arable land. They were sown, between 2008 and 2010, with annual and perennial wild and cultivated plants, and were unmanaged thereafter. Burrows, in which hamsters had overwintered and reopened the entrance on emergence in spring, were mapped in May–June 2013.

(1) Tattersall F.H., Fagiano A.L., Bembridge J.D., Edwards P., Macdonald D.W. & Hart B.J. (1999) Does the method of set-aside establishment affect its use by wood mice? *Journal of Zoology*, 249, 472–476, https://doi.org/10.1111/j.1469-7998.1999.tb01218.x

(2) Aschwanden J., Holzgang O. & Jenni L. (2007) Importance of ecological compensation areas for small mammals in intensively farmed areas. *Wildlife Biology*, 13, 150–158, https://doi.org/10.2981/0909-6396(2007)13[150:ioecaf]2.0.co;2

(3) Arlettaz R., Krähenbühl M., Almasi B., Roulin A. & Schaub M. (2010) Wildflower areas within revitalized agricultural matrices boost small mammal populations but not breeding barn owls. *Journal of Ornithology*, 151, 553–564, https://doi.org/10.1007/s10336-009-0485-0

(4) Fischer C. & Wagner C. (2016) Can agri-environmental schemes enhance non-target species? Effects of sown wildflower fields on the common hamster (*Cricetus cricetus*) at local and landscape scales. *Biological Conservation*, 194, 168–175, https://doi.org/10.1016/j.biocon.2015.12.021

3.2. Create uncultivated margins around intensive arable or pasture fields

https://www.conservationevidence.com/actions/2365

- **Nine studies** evaluated the effect of creating uncultivated margins around intensive arable, cropped grass or pasture fields on mammals. Six studies were in the UK[1,2,3,5,8,9], two were in Switzerland[4,6] and one was in the USA[7].

COMMUNITY RESPONSE (1 STUDY)

- **Richness/diversity (1 study):** One replicated, controlled study in the UK[2] found more small mammal species in uncultivated field margins than in blocks of set-aside.

POPULATION RESPONSE (9 STUDIES)

- **Abundance (9 studies):** One replicated, randomized, controlled study in the USA[7] found more small mammals in uncultivated and unmown field margins than in frequently mown margins. Three of seven replicated, site comparison studies (one randomized), in the UK[1,2,3,5,9] and Switzerland[4,] found that uncultivated field margins had higher numbers of small mammals[1,2,4,5,9], bank voles[3] and brown hares[6] relative to crops (including grassland)[1,4] and set-aside[2]. The other four studies reported mixed or no effects on bank voles, wood mice and common shrews[3], small mammals[5,9] and brown hares[6]. One site comparison study in the UK[8] found that brown hares used grassy field margins more than expected based on their availability.

BEHAVIOUR (0 STUDIES)

Background

This intervention entails allowing field margin vegetation to regenerate naturally, typically without planting. It can involve some subsequent mowing. Field margins are not fertilized. This intervention includes field margins that run alongside waterways, where these are not otherwise managed, such as by planting trees (for which, see *Habitat Restoration and Creation -Restore or create riparian forest*).

A replicated, site comparison study in 1992–1998 on farms across southern UK (1) found that on uncultivated field margins, more small mammals were caught than in open crop fields. Results were not analysed for statistical significance. More small mammals were trapped in field margins (139 individuals) than in open fields (78 individuals) on conventional farms. The same pattern held on organic farms (margin: 142 individuals; field: 86). A higher proportion of individuals was trapped in margins at two primary study sites for wood mouse *Apodemus sylvaticus* (margin: 40–80%; field: 20–60%), bank vole *Myodes glareolus* (margin: 75–95%; field: 5–25%) and common shrew *Sorex aranaeus* (margin: 40–90%; field: 10–60%). Small mammals were sampled on two farms over 10 nights, four times/year, in 1992–1998. Live traps were set at 0, 1, 2, 3, 4, 5, 10, 20, 40 m into each field from the boundary. Sample areas included four each of conventional margins, organic margins, conventional crops and organic crops. An unspecified number (≥12) of additional farms was also sampled, each in a single (unspecified) year. The study reports 54 sites were sampled. It is unclear if each of these was a different field. Further elements of the sampling design (such as margin dimensions and the proportion of traps that were in or outside of margins) are unclear.

A replicated, controlled study in 1996–1997 at two farms in Gloucestershire, UK (2) found that uncultivated field margins next to hedgerows hosted more small mammal individuals and species than did blocks of set-aside. Uncultivated margins had more small mammals (21 individuals, eight species/trap session) than did set-aside blocks (11 individuals, five species/trap session). Wood mice *Apodemus sylvaticus* comprised 76% of animals caught in margins and 50% of those caught in set-aside blocks. Species richness was higher in margins (2.6 species/trap session) than in blocks (2.1 species/trap session). Diversity did not differ significantly between margins and blocks (result presented as indices). Margins (one/farm) comprised 20-m wide sections, covering 5 ha, adjacent to hedgerows. Blocks of set-aside (one/farm) also covered 5 ha. Set-aside was established by sowing a grass/clover mix in 1995. This was cut annually, in July or August. Grids of 49 live traps were set in the centre of set-aside blocks and spanning the margin and adjacent hedgerow and crop. Traps operated over five nights in March, June, September and December of 1996–1997.

A replicated, controlled study in 1999–2000 on an arable farm in North Yorkshire, UK (3) found that in uncultivated grassy field margins, more bank voles *Clethrionomys glareolus* were caught than in cultivated field edges in autumn, but not in spring, while numbers of wood mice *Apodemus sylvaticus* or common shrews *Sorex aranaeus* caught did not differ between uncultivated or cultivated margins. Total bank vole captures each autumn were higher in 3-m-wide grassy margins (13–14 individuals) and 6-m-wide grassy margins (26–38 individuals) than in cultivated field edges (1 individual) but differences between these treatments were not tested for statistical significance. There were no differences in spring (3-m margin: 9–10; 6-m margin: 2–7; cultivated:

0–18 individuals). Wood mouse catches did not differ significantly between field margin types (3-m margin: 1–29; 6-m margin: 0–18; cultivated: 7–22 individuals), nor did those of common shrew (3-m margin: 2–15; 6-m margin: 0–13; cultivated: 1–4 individuals). Grassy field margins were sown in autumn 1997. Small mammals were live-trapped in four 3-m grassy margins, four 6-m grassy margins and four cultivated field edges, over four weeks in spring (April–May) and four weeks in autumn (September–October) in each of 1999 and 2000.

A replicated, site comparison study in 2003 on a farmed plain in Switzerland (4) found that uncultivated herbaceous field margins contained more small mammals than did conventionally farmed grasslands and autumn-sown wheat fields, though fewer than did sown wildflower strips. These comparisons were not tested for statistical significance. Small mammal densities varied greatly between sampling periods but, at their peak, were estimated at 836/ha in herbaceous margins, 86/ha in farmed grasslands, 568/ha in wheat crops and 1047/ha in wildflower strips. Six small mammal species were caught in herbaceous margins compared to two in each of the other treatments. Herbaceous field margins (5 × 320 m) mainly comprised thistles *Cirsium* spp., common teasel *Dipsacus sylvestris*, St John's wort *Hypericum perforatum*, common mallow *Malva sylvestris* and mulleins *Verbascum* spp. Grasslands (average 0.88 ha) were cut ≥5 times each April–October and were fertilized. Autumn-sown wheat fields (average 1.3 ha) were harvested at the end of July. Wildflower strips (15 × 185 m) were sown with native species. Small mammals were live-trapped on three fields of each treatment during 60-hour trapping sessions in March, May and July 2003. Densities were estimated using a capture-recapture method.

A replicated, site comparison study in 2003–2004 in Yorkshire, UK (5) found that uncultivated field margins hosted similar numbers of small mammals compared to set-aside and farm woodland. There was no significant difference in the annual average numbers of small mammals caught in 2-m margins (2.9–4.4 individuals), 6-m margins (2.5–3.6), set-aside (1.6–2.0) and farm woodland (2.4–2.8). In the first year, more common shrews *Sorex aranaeus* were caught in 2-m margins (1.4 individuals) than in set-aside (0.6) or farm woodland (0.6) and more wood mice *Apodemus sylvaticus* were in 6-m margins (1.1) and farm woodland (1.4) than in set-aside (0.5). No other species differences between treatments were found. Field margins, sown with grass, were 2 m wide (cut every 2–3 years) or 6 m wide (cut every 1–3 years). Set-aside areas were fallow for ≥5 years, with ≥90% of the area cut annually. Farm woodland comprised young trees (age not stated), fenced and with grass generally uncut. Twelve small mammal traps were set in each of 20 plots/treatment (1 m from the habitat boundary) for four days in November–December in each of 2003 and 2004.

A replicated, site comparison study in 1992–2008 on 58 lowland arable and grassland sites in Switzerland (6) found that establishing uncultivated field margins, in the form of herbaceous strips alongside hedgerows, was associated with higher brown hares *Lepus europaeus* density in arable sites but not in grassland sites. Relative effects of herbaceous strips and hedgerows could not be separated. Hares density along herbaceous strips and adjacent hedgerows was higher than in the landscape as a whole in predominantly arable sites but there was no difference in densities in predominantly grassland sites (data presented as statistical models). Fifty-eight sites (40 mostly arable, 18 mostly grassland), of 71–1,950 ha extent (total area approximately 400 km^2) were studied. Forty-three sites included areas managed under agri-environment funding. This entailed establishing 6-m-wide unfertilised herbaceous strips, cut once/year, alongside hedgerows, establishing set-aside areas and low-intensity management of meadows. Herbaceous strips and hedgerows covered 0.17% of arable sites and 0.13% of grassland sites. Vehicle-based spotlight surveys for hares were conducted twice in February–March. Ten sites were surveyed annually from 1992 to 2008 and 48 were, on average, surveyed biennially over that period.

A replicated, randomized, controlled study in 2009 of arable field margins at a site in North Carolina, USA (7) found that uncultivated and unmown field margins supported more small mammals than did frequently mown margins. There were more hispid cotton rats *Sigmodon hispidus* in margins planted with native grasses and flowers (average 8.8 animals/margin) or flowers only (7.5) and unmanaged fallow margins (3.3) than in unplanted mown margins (0). There were also more house mice *Mus musculus* in grass and flower margins (average 9.5 animals/margin), flower only margins (10.1) and unplanted fallow margins (8.8) than in unplanted mown margins (1.8). Three organic crop fields were each planted with soybeans, corn or hay crop and orchard grass. Four sections of margin (0.08 ha) within each of the three fields were assigned to the four treatments, of: planting native warm-season grasses and native prairie flowers, planting native prairie flowers only, leaving fallow without mowing and mowing 2–3 times/month. Small mammals were live-trapped for three consecutive weeks in October and November 2009.

A site comparison study in 2009–2010 in a mixed farming area in North Yorkshire, UK (8) found that agri-environment grassy field margins had disproportionately high usage by brown hares *Lepus europaeus* during both feeding and resting periods, relative to available habitat areas. Hares spent 6.9% of time in grassy field margins during their main activity period and 13.0% during their inactive period, compared to margins covering of 3.5% of the study site. A total length of 10.8 km of grassy margins was established at field edges and along waterways within a 311-ha study area, through agri-environment funding. Margins comprised 2-m-wide strips and 6-m-wide 'conservation headlands'. They were seeded with a commercial field margin grass mixture, were not sprayed and were cut every two to three years. Fourteen adult hares were radio-tracked, for an average of 186 days each, between July 2009 and August 2010.

A replicated, controlled study in 2005–2011 on an arable farm in Buckinghamshire, UK (9) found that in wide grassy or grass and flower margins on arable fields, small mammal abundance in spring increased over the study period, but it remained stable in narrow, conventionally managed field margins. Small mammal abundance in spring rose by 140% on wide grassy margins and grass and flower margins over the first five years following establishment. There was no significant abundance change on conventional margins, nor any differences between margins in autumn population changes. Absolute counts are not presented in the paper. There were five replicates of three treatments, each on 43–70 ha of farmland. Treatments were conventional management (uncultivated, 2 m-wide field margins or 1 m margins alongside ditches), 6 m-wide grassy margins and 6 m-wide grass and wildflower margins. Margins were established in 2005. Small mammals were live-trapped, over three nights and two days, in November–December 2005, 2006, 2008 and 2010 and each following May.

(1) Brown R.W. (1999) Margin/field interfaces and small mammals. *Aspects of Applied Biology*, 54, 203–206.

(2) Tattersall F.H., Hart B.J., Manley W.J., Macdonald D.W. & Feber R.E. (1999) Small mammals on set-aside blocks and margins. *Aspects of Applied Biology*, 54, 131–138.

(3) Shore R.F., Meek W.R., Sparks T.H., Pywell R.F. & Nowakowski M. (2005) Will Environmental Stewardship enhance small mammal abundance on intensively managed farmland? *Mammal Review*, 35, 277–284, https://doi.org/10.1111/j.1365-2907.2005.00072.x

(4) Aschwanden J., Holzgang O. & Jenni L. (2007) Importance of ecological compensation areas for small mammals in intensively farmed areas. *Wildlife Biology*, 13, 150–158, https://doi.org/10.2981/0909-6396(2007)13[150:ioecaf]2.0.co;2

(5) Askew N.P., Searle J.B. & Moore N.P. (2007) Agri-environment schemes and foraging of barn owls *Tyto alba*. *Agriculture, Ecosystems & Environment*, 118, 109–114, https://doi.org/10.1016/j.agee.2006.05.003

(6) Zellweger-Fischer J., Kéry M. & Pasinelli G. (2011) Population trends of brown hares in Switzerland: The role of land-use and ecological compensation areas. *Biological Conservation*, 144, 1364–1373, https://doi.org/10.1016/j.biocon.2010.11.021

(7) Moorman C.E., Plush C.J., Orr D.B., Reberg-Horton C. & Gardner B. (2013) Small mammal use of field borders planted as beneficial insect habitat. *Wildlife Society Bulletin*, 37, 209–215, https://doi.org/10.1002/wsb.226

(8) Petrovan S.O., Ward A.I. & Wheeler P.M. (2013) Habitat selection guiding agri-environment schemes for a farmland specialist, the brown hare. *Animal Conservation*, 16, 344–352, https://doi.org/10.1111/acv.12002

(9) Broughton R.K., Shore R.F., Heard M.S., Amy S.R., Meek W.R., Redhead J.W., Turk A. & Pywell R.F. (2014) Agri-environment scheme enhances small mammal diversity and abundance at the farm-scale. *Agriculture, Ecosystems & Environment*, 192, 122–129, https://doi.org/10.1016/j.agee.2014.04.009

3.3. Provide or retain set-aside areas on farmland

https://www.conservationevidence.com/actions/2377

- **Four studies** evaluated the effects on mammals of providing or retaining set-aside areas on farmland. Three studies were in the UK[1,2,3] and one was in Switzerland[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (3 studies):** Three replicated studies (including two site comparison studies), in the UK[1,3] and Switzerland[4], found that set-aside did not enhance small mammal numbers relative to cropland[1] or to uncultivated field margins and farm woodland[3], or brown hare numbers relative to numbers on farms without set-aside areas[4].

BEHAVIOUR (1 STUDY)

- **Use (1 study):** A before-and-after study in the UK[2] found that use of uncut set-aside areas by wood mice increased after crop harvesting.

Background

Allocation of some farmland to set-aside (fields taken out of production) was compulsory under European Union agricultural policy from 1992 until 2008. The idea was to reduce production. However, set-aside has also been promoted as a method of enhancing biodiversity on farmland. Set-aside can be rotational (in a different place every year or two) or non-rotational (same place for 5–20 years) and fields can either be sown with fallow crops or left to naturally regenerate. Unlike fallow land, set-aside is not ploughed or harrowed except for the purpose of sowing. However, set-aside often is managed by cutting and/or spraying. In some cases, set-aside land has had wild flowers sown on it. Evidence for the effects of this management has been included under the intervention, *Establish wild flower areas on farmland*.

A replicated, controlled study in 1995 of set-aside on two farms in Gloucestershire, UK (1) found that establishing one-year set-aside areas on cropland did not increase small mammal abundance. Trapping success was lower in set-aside (0.6% of traps activated) than in the adjoining unharvested cereal crop (13% of traps activated) and hedgerow (30% of traps activated). Long-tailed field mouse *Apodemus sylvaticus* was the only species caught in set-aside. Sampling at two sites on each farm covered a hedgerow, a 20-m-wide strip of set-aside with adjacent cereal crop on one side of the hedge and a block of either set-aside (two sites) or cereal crop (two sites) on the other side. Set-aside was sown with a mix of wheat *Triticum aestivum* and oilseed rape *Brassica napus* (three sites) or left to regenerate naturally (one site). Fifty Longworth live traps were operated at each site for five nights/month in June–August 1995.

A before-and-after study in 1996–1997 on an arable farm in Wiltshire, UK (2) found that use of uncut set-aside areas by wood mice *Apodemus sylvaticus* increased after crop harvesting. After crop harvesting, uncut set-aside was used more than expected by chance, as were hedgerows. Cut set-aside was used less than expected by chance (results shown as preference indices). Use of cropped areas declined to an average 13% of wood mouse ranges after harvesting, from 54% before harvesting. Across two arable fields, a 3-ha block of set-aside and 3 km of 20-m-wide set-aside field margins were sown (grass/clover mix) in October 1995. In August 1996 and 1997, twenty-four alternate 50 × 6-m patches of cut and uncut set-aside were created alongside a hedge. The remaining 14-m width of set-aside was cut. Thirty-four wood mice were radio-tracked over ≥3 nights in June–July and September–November of 1996 and 1997.

A replicated, site comparison study in 2003–2004 in Yorkshire, UK (3) found that set-aside had similar numbers of small mammals compared to uncultivated field margins and farm woodland. There was no significant difference in the annual average numbers of small mammals caught in set-aside (1.6–2.0), 2-m margins (2.9–4.4 individuals), 6-m margins (2.5–3.6) and farm woodland (2.4–2.8). In the first year, fewer common shrews *Sorex aranaeus* were caught in set-aside (0.6) or farm woodland (0.6) than in 2-m margins (1.4 individuals) and fewer wood mice *Apodemus sylvaticus* were caught in set-aside (0.5) than in 6-m margins (1.1) and farm woodland (1.4). No other species differences between treatments were found. Set-aside areas were fallow for ≥5 years, with ≥90% of the area cut annually. Field margins, sown with grass, were 2 m wide (cut every 2–3 years) or 6 m wide (cut every 1–3 years). Farm woodland comprised young trees (age not stated), fenced and with grass generally uncut. Twelve small mammal traps were set in each of 20 plots/treatment (1 m from the habitat boundary) for four days in November–December in each of 2003 and 2004.

A replicated, site comparison study in 1992–2008 on 58 lowland arable and grassland sites in Switzerland (4) found that set-aside areas on farmland were not associated with higher brown hares *Lepus europaeus* densities. Set-aside areas were not associated with hare density in either predominantly arable or predominantly grassland areas (data presented as statistical models). Fifty-eight sites (40 mostly arable, 18 mostly grassland), of 71–1,950 ha extent (total area approximately 400 km^2) were studied. Forty-three sites included areas managed under agri-environment funding. This entailed establishing set-aside areas (not mown or fertilized, usually sown with wildflower seeds and retained for 2–6 years), maintaining hedgerows (with adjacent herbaceous strips) and low intensity management of meadows. Set-aside covered 3.0% of arable sites and 4.6% of grassland sites. Vehicle-based spotlight surveys for hares were conducted twice in February–March. Ten sites were surveyed annually in 1992–2008 and 48 were, on average, surveyed biennially over that period.

(1) Tattersall F.H., Macdonald D.W., Manley W.J., Gates S., Feber R. & Hart B.J. (1997) Small mammals on one-year set-aside. *Acta Theriologica*, 42, 329–334, https://doi.org/10.4098/at.arch.97-33

(2) Tattersall F.H., Macdonald D.W., Hart B.J., Manley W.J. & Feber R.E. (2001) Habitat use by wood mice (*Apodemus sylvaticus*) in a changeable arable landscape. *Journal of Zoology*, 255, 487–494, https://doi.org/10.1017/s095283690100156x

(3) Askew N.P., Searle J.B. & Moore N.P. (2007) Agri-environment schemes and foraging of barn owls *Tyto alba*. *Agriculture, Ecosystems & Environment*, 118, 109–114, https://doi.org/10.1016/j.agee.2006.05.003

(4) Zellweger-Fischer J., Kéry M. & Pasinelli G. (2011) Population trends of brown hares in Switzerland: The role of land-use and ecological compensation areas. *Biological Conservation*, 144, 1364–1373, https://doi.org/10.1016/j.biocon.2010.11.021

3.4. Maintain/restore/create habitat connectivity on farmland

https://www.conservationevidence.com/actions/2381

- We found no studies that evaluated the effects on mammals of maintaining, restoring or creating habitat connectivity on farmland.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Habitat destruction and fragmentation are important factors in the decline of some mammal populations. Small patches of habitat support smaller populations and if individuals are unable to move to other suitable areas, populations become isolated. This can make them more vulnerable to extinction. Maintaining, restoring or creating corridors of native vegetation between patches of suitable habitat in agricultural landscapes may help to maintain populations. Some specific actions that may encourage movements through farmland are covered in other interventions, including *Plant new or maintain existing hedgerows on farmland* and *Create uncultivated margins around intensive arable or pasture fields*.

3.5. Manage hedgerows to benefit wildlife on farmland

https://www.conservationevidence.com/actions/2382

- We found no studies that evaluated the effects on mammals of managing hedgerows to benefit wildlife on farmland.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Hedgerows can be key habitats for farmland biodiversity, but they may need managing to maximize their value. Managing hedgerows to benefit wildlife involves one or more of the following management changes: reduce cutting frequency; reduce or avoid spraying; mow vegetation beneath hedgerows; fill gaps in hedges; coppice or lay to restore traditional hedge structure. See also *Plant new or maintain existing hedgerows on farmland*.

3.6. Plant new or maintain existing hedgerows on farmland

https://www.conservationevidence.com/actions/2383

- **Three studies** evaluated the effects on mammals of planting new or maintaining existing hedgerows on farmland. Two studies were in the UK[1,2] and one was in Switzerland[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (3 studies):** One of two replicated, site comparison studies, in the UK[2] and Switzerland[3], found that retaining and enhancing hedgerows along with other field boundary features was associated with higher brown hare density in arable sites but not in grassland sites[3] while the other study found that Irish hare numbers did not increase[2]. A replicated, site comparison study in the UK[1] found that establishing hedgerows alongside arable land increased small mammal abundance.

BEHAVIOUR (0 STUDIES)

Background

Agricultural intensification, including increases in field sizes and pesticides use, has resulted in a loss of field margin habitats, such as hedgerows. These features can provide a relatively undisturbed habitat for wildlife in intensively managed agricultural landscapes. Hedge planting and maintenance of existing hedges has, therefore, been proposed as a means of preserving and enhancing biodiversity. Such management is sometimes funded through agri-environmental schemes.

A replicated, site comparison study in 1999 on three primarily arable farms in Yorkshire, UK (1) found that establishing hedgerows alongside arable land increased small mammal abundance. Average small mammal abundance in hedgerows and adjacent rough margins (0.83 individuals/trap) was higher than on arable land (0.35 individuals/trap). Five species were caught in hedgerows and two in arable plots. Four hedgerows and ten 10 arable plots were surveyed. Hedgerow age and composition were not specified in the paper. Arable plots were sown with winter cereals and contained little cover. Small mammals were surveyed using Longworth live traps over four continuous days and nights, between 22 November and 4 December 1999.

A replicated, site comparison study in 2005 on 200 plots covering a range of agricultural habitats in Northern Ireland, UK (2) found that retaining and enhancing field boundaries, such as hedgerows and banks, as part of a wider suite of agri-environment measures, did not increase numbers of Irish hares *Lepus timidus hibernicus*. The effects of retaining and enhancing field boundaries cannot be separated from those of other agri-environment measures, which included reducing grazing intensity and managing nutrient systems. Hare abundance in agri-environment plots (0.45 hares/km transect) did not significantly differ from that in non-agri-environment plots (0.41 hares/km transect). One hundred and fifty 1-km^2 plots, on land enrolled into an agri-environment scheme 10–17 years previously, were selected along with 50 non-enrolled 1-km^2 plots, chosen to match enrolled plots for landscape characteristics. Hares were surveyed at night, in mid-winter, by spotlighting from a vehicle.

A replicated, site comparison study, in 1992–2008, on 58 lowland arable and grassland sites in Switzerland (3) found that maintenance of hedgerows (with adjacent herbaceous strips) on farmland was associated with higher brown hare *Lepus europapaeus* density in arable sites but not in grassland sites. Relative effects of hedgerows and herbaceous strips could not be separated. Hare density along hedgerows and adjacent herbaceous strips was higher than in the landscape as a whole in predominantly arable sites but there was no difference in densities in predominantly grassland sites (data presented as statistical models). Fifty-eight sites (40 mostly arable, 18 mostly grassland), of 71–1,950 ha extent (total area approximately 400 km^2) were studied. Forty-three sites included areas managed under agri-environment funding. This entailed maintaining hedgerows (unfertilized and unsprayed, with 6-m wide herbaceous strips), establishing set-aside areas and low-intensity management of meadows. Hedgerows and herbaceous strips covered 0.17% of arable sites and 0.13% of grassland sites. Vehicle-based spotlight surveys for hares were conducted twice in February–March. Ten sites were surveyed annually from 1992 to 2008 and 48 were, on average, surveyed biennially over that period.

(1) Moore N.P., Askew N. & Bishop J.D. (2003) Small mammals in new farm woodlands. *Mammal Review*, 33, 101–104, https://doi.org/10.1046/j.1365-2907.2003.00004.x

(2) Reid N., McDonald R.A. & Montgomery W.I. (2007) Mammals and agri-environment schemes: hare haven or pest paradise? *Journal of Applied Ecology*, 44, 1200–1208, https://doi.org/10.1111/j.1365-2664.2007.01336.x

(3) Zellweger-Fischer J., Kéry M. & Pasinelli G. (2011) Population trends of brown hares in Switzerland: The role of land-use and ecological compensation areas. *Biological Conservation*, 144, 1364–1373, https://doi.org/10.1016/j.biocon.2010.11.021

3.7. Plant trees on farmland

https://www.conservationevidence.com/actions/2386

- **Four studies** evaluated the effects on mammals of planting trees on farmland. Two studies were in the UK[1,2], one was in Italy[3] and one was in Australia[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Abundance (2 studies):** Two replicated studies (including one controlled, and one site comparison study), in the UK[1,2], found that farm woodland supported a higher small mammal abundance than on arable land[1] or similar abundance compared to uncultivated field margins and set-aside[2].

BEHAVIOUR (2 STUDIES)

- **Use (2 studies):** A study in Italy found that tree stands were used more by European hares compared to the wider farmed landscape[3]. A replicated study in Australia found that trees planted on farmland were used by koalas[4].

Background

Agricultural intensification, which includes increasing field size and pesticide use, has resulted in a loss of shelter and food resources for wildlife, such as that provided by areas of trees. These features can provide a relatively undisturbed habitat for wildlife in intensively managed agricultural landscapes. Tree planting may therefore diversify habitat availability and, in younger plantations, may also provide areas of longer uncut grass than is available elsewhere in the landscape.

A replicated, controlled study in 1999 on three mainly arable farms in Yorkshire, UK (1) found that establishing new woodland plantations on former arable land increased small mammal abundance. Average small mammal abundance in plantations (1.1 individuals/trap) was higher than on arable land (0.4 individuals/trap). Small mammal species richness in plantations (4–6 species/site) was also higher than on arable land (1–4 species/site), although this difference was not tested for statistical significance. Twelve plantations (0.17–2.0 ha), established in 1992–1997, were surveyed, along with arable plots adjacent to 10 of these. Plantations, predominantly of broad-leaved trees, were on ex-arable land. Dense grasses and other herbaceous plants dominated vegetation at time of surveys. Planted trees were ≤4 m high. Arable plots were sown with winter cereals and contained little cover. Small mammals were surveyed using Longworth live traps over four continuous days and nights, between 22 November and 4 December 1999.

A replicated, site comparison study in 2003–2004 in an agricultural area in Yorkshire, UK (2) found that farm woodland had similar numbers of small mammals compared to uncultivated field margins and set-aside. There was no significant difference in the annual average numbers of small mammals caught in farm woodland (2.4–2.8 individuals), 2-m-wide field margins (2.9–4.4), 6-m-wide field margins (2.5–3.6) and set-aside (1.6–2.0). In the first year, more wood mice *Apodemus sylvaticus* were caught in farm woodland (1.4 individuals) and in 6-m-wide margins (1.1) than in set-aside (0.5), but fewer common shrews *Sorex aranaeus* were in farm woodland (0.6 individuals) or set-aside (0.6) than in 2-m-wide margins (1.4). No other species differences between treatments were found. Farm woodland comprised young trees (age not stated), fenced and with grass generally uncut. Field margins, sown with grass, were 2 m wide (cut every 2–3 years) or 6 m wide (cut every 1–3 years). Set-aside areas were fallow for ≥5 years, with ≥90% of the area cut annually. Twelve small mammal traps were set in each of 20 plots/treatment (1 m from the habitat boundary) for four days in November–December in each of 2003 and 2004.

A study in 2005 in an area of arable farmland with scattered woodland cover in Lombardy Region, Italy (3) found that presence of tree stands increased the use of an area by European hares *Lepus europaeus*. Of plots where hare faecal pellets were present, 12% were in poplar groves, compared to 5% of plots where pellets were absent being in poplar groves. In addition, 16% of plots with pellets were in short rotation forestry compared to 6% of plots without pellets. Arboriculture comprised poplar groves and short-rotation (2–5 year) forestry. Habitat use was assessed by recording presence or absence of hare faecal pellets in 150 randomly located plots, of 1-m radius, across an 820-ha study area, in March–May 2005.

A replicated study in 2006 of 19 tree plots in New South Wales, Australia (4) found that trees planted on farmland were used by koalas *Phascolarctos cinereus*. Of the 19 plots surveyed, 14 had evidence of use by koalas. In eight plots, over 40% of trees inspected were used by koalas. Koala pellets were recorded under 16 of 25 tree species or species groups inspected. Trees closer to potential source populations and older trees were more likely to be used by koalas (results presented as statistical model). Nineteen plots (15 linear tree corridors and four patches of trees), aged 6–15 years (planted 1990–2001) were studied (plot sizes not stated). Plots were on 10 farms and in two roadside plantings. Every fifth tree (>2 m high), along pre-determined transects of up to 100 trees/plot, was assessed for presence of koala pellets within a 1-m radius of the tree base.

(1) Moore N.P., Askew N. & Bishop J.D. (2003) Small mammals in new farm woodlands. *Mammal Review*, 33, 101–104, https://doi.org/10.1046/j.1365-2907.2003.00004.x

(2) Askew N.P., Searle J.B. & Moore N.P. (2007) Agri-environment schemes and foraging of barn owls *Tyto alba*. *Agriculture, Ecosystems & Environment*, 118, 109–114, https://doi.org/10.1016/j.agee.2006.05.003

(3) Cardarelli E., Meriggi A., Brangi A. & Vidus-Rosin A. (2011) Effects of arboriculture stands on European hare *Lepus europaeus* spring habitat use in an agricultural area of northern Italy. *Acta Theriologica*, 56, 229–238, https://doi.org/10.1007/s13364-010-0019-4

(4) Rhind S.G., Ellis M.V., Smith M. & Lunney D. (2014) Do koalas Phascolarctos cinereus use trees planted on farms? A case study from north-west New South Wales, Australia. *Pacific Conservation Biology*, 20, 302–312, https://doi.org/10.1071/pc140302

3.8. Pay farmers to cover the costs of conservation measures

https://www.conservationevidence.com/actions/2387

- **Three studies** evaluated the effects on mammals of paying farmers to cover the costs of conservation measures. The three studies were in the UK[1,2,3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (3 studies):** A replicated, controlled study in the UK[1] found that agri-environment scheme enrolment was associated with increased brown hare density in one of two regions studied. A replicated, site comparison study in Northern Ireland, UK[2] found that agri-environment scheme enrolment did not increase numbers of Irish hares. A replicated, controlled study in the UK (3) found that in field margins created through enrolment in an agri-environment scheme, small mammal abundance in spring increased, whereas it remained stable in conventionally managed margins.

BEHAVIOUR (0 STUDIES)

Background

Agri-environment schemes are government or inter-governmental schemes designed to compensate farmers financially for changing agricultural practice to be more favourable to biodiversity and the landscape. Agri-environment schemes represent many different specific interventions relevant to conservation. Where a study can be clearly assigned to a specific intervention, it appears in the appropriate section (e.g. *Create uncultivated margins around intensive arable or pasture fields* and *Establish wild flower areas on farmland*). This section includes broader evidence about the success of agri-environment policies, such as where specific actions are not clearly defined.

A replicated, controlled study, in 1998–2002, on 71 arable farms in two UK regions (1) found that increased semi-natural habitat cover through enrolment in an agri-environment scheme was associated with increases in brown hare *Lepus europaeus* density in one region but not another. In East Anglia, brown hare density on farms enrolled in the scheme increased by 35% from 1998–2003, compared to an 18% decline on non-enrolled farms. In the West Midlands, hare density changes from 1998–2003 did not differ significantly between farm types (enrolled farms: decline of 10.8%; non-enrolled farms: increase of 3.6%). Seventy-one farms were surveyed, 19 enrolled and 18 not enrolled in an agri-environment scheme in East Anglia and 19 enrolled and 15 not enrolled in West Midlands. The scheme (Arable Stewardship Pilot Scheme) incentivised a range of measures which are not specified in the study, but appear to include increasing woodland and set-aside areas. Enrolled farms operated under the scheme from 1998 onwards. Hares were surveyed from November–February in 1998–1999 and 2002–2003 by spotlighting after dark from a vehicle. Usually, ≥20 fields/farm were counted (≥30% of the farm area).

A replicated, site comparison study in 2005 on 200 plots covering a range of agricultural habitats in Northern Ireland, UK (2) found that retaining and enhancing field boundaries, reducing grazing intensity and managing nutrient systems through enrolment in an agri-environment scheme did not increase numbers of Irish hares *Lepus timidus hibernicus*. Hare abundance in agri-environment plots (0.45 hares/km transect) did not significantly differ from that in non-agri-environment plots (0.41 hares/km transect). One hundred and fifty 1-km^2 plots, on land that was enrolled into an agri-environment scheme 10–17 years previously, were selected along with 50 non-enrolled 1-km^2 plots, chosen to match enrolled plots for landscape characteristics. Hares were surveyed at night, in mid-winter, by spotlighting from a vehicle.

A replicated, controlled study in 2005–2011 on an arable farm in Buckinghamshire, UK (3) found that in wide grassy or grass and flower margins created on arable fields through enrolment in an agri-environment scheme, small mammal abundance in spring increased over the study period, but it remained stable in narrow, conventionally managed field margins. Small mammal abundance in spring rose by 140% on wide grassy margins and grass and flower margins over the first five years following establishment. There was no significant abundance change on conventional margins, nor any differences between margins in autumn population changes. Absolute counts are not presented in the paper. There were five replicates of three treatments, each on 43–70 ha of farmland. Treatments were 6 m-wide grassy margins ('Entry Level Scheme') and 6 m-wide grass and wildflower margins ('Entry Level Scheme Extra') both created as part of an agri-environment scheme, and conventional management (uncultivated, 2-m-wide field margins or 1 m margins alongside ditches). Margins were established in 2005. Small mammals were live-trapped, over three nights and two days, in November–December 2005, 2006, 2008 and 2010 and each following May.

(1) Browne S.J. & Aebischer N.J. (2003) *Arable Stewardship: impact of the pilot scheme on the brown hare and grey partridge after five years*. DEFRA contract ref. RMP1870vs3.

(2) Reid N., McDonald R.A. & Montgomery W.I. (2007) Mammals and agri-environment schemes: hare haven or pest paradise? *Journal of Applied Ecology*, 44, 1200–1208, https://doi.org/10.1111/j.1365-2664.2007.01336.x

(3) Broughton R.K., Shore R.F., Heard M.S., Amy S.R., Meek W.R., Redhead J.W., Turk A. & Pywell R.F. (2014) Agri-environment scheme enhances small mammal diversity and abundance at the farm-scale. Agriculture, Ecosystems & Environment, 192, 122–129, https://doi.org/10.1016/j.agee.2014.04.009

3.9. Provide refuges during crop harvesting or mowing

https://www.conservationevidence.com/actions/2389

- We found no studies that evaluated the effects on mammals of providing refuges during crop harvesting or mowing.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

During crop harvesting and mowing operations, mammals may move into adjacent areas of long grass or crops. If mowing/harvesting occurs from the outside of the field inwards, this behaviour can leave them trapped in the centre of the field and killed as the last patch is harvested. However, if unharvested refuges are left in fields then it is possible that mammals remain in them and survive.

3.10. Use repellent on slug pellets to reduce non-target poisoning

https://www.conservationevidence.com/actions/2390

- **One study** evaluated the effects on mammals of using repellent on slug pellets to reduce non-target poisoning. This study was in the UK[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (1 STUDY)

- **Use (1 study):** A replicated, controlled study in the UK[1] found that, at some concentrations, food treated with a bitter substance was consumed less by wood mice but not by bank voles or common shrews.

Background

Poisons used to control slugs may also be ingested by non-target species, such as rodents. Such poisoning can lead to declines in rodent numbers (Shore et al. 1997). Substances that make slug pellets unattractive to small mammals, yet still effective on slugs, may help to reduce small mammal losses.

Shore R.F., Feber R.E., Firbank L.G., Fishwick S.K., Macdonald D.W. & Nøruma, U. (1997) The impacts of molluscicide pellets on spring and autumn populations of wood mice *Apodemus sylvaticus*. *Agriculture, Ecosystems & Environment*, 64, 211–217, https://doi.org/10.1016/s0167-8809(97)00039-x

A replicated, controlled study (year not stated) in an agricultural area in the UK (1) found that treating food with a bitter substance (Bitrex™; as a trial of its efficacy for deterring toxic slug pellet consumption) reduced consumption by wood mice *Apodemus sylvaticus* at some concentrations but did not change consumption rates of bank voles *Clethrionomys glareolus* or common shrews *Sorex aranaeus*. Wood mice avoided food treated with Bitrex at 100 ppm and 300 ppm but showed no avoidance at 50 ppm or 500–1,740 ppm (data not presented). Bank voles and common shrews showed no avoidance of food treated with Bitrex at 100 ppm or 300 ppm (data not presented). Wild small mammals were contained within small enclosures. Wood mice and bank voles were offered barley *Hordeum vulgare*. Common shrews were offered fly pupae. Food was sprayed with the Bitrex solution. Trails ran for eight hours overnight (wood mouse) or six hours night or day (bank vole and common shrew) with treated food only and with choices of treated and untreated food.

(1) Kleinkauf A., Macdonald D.W. & Tattersall F.H. (1999) A bitter attempt to prevent non-target poisoning of small mammals. *Mammal Review*, 29, 201–204, https://doi.org/10.1046/j.1365-2907.1999.00046.x

3.11. Restrict use of rodent poisons on farmland with high secondary poisoning risk

https://www.conservationevidence.com/actions/2391

- We found no studies that evaluated the effects on mammals of restricting use of rodent poisons on farmland that have secondary poisoning risks.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Rodenticides are in common use around farms, houses and industrial sites. The most frequently used forms are anticoagulant rodenticides, which cause death in target animals by inhibiting blood clotting. Death can take several days after ingestion so poisoning may be passed on up the food chain both to predators and to scavengers. In some situations, a high proportion of predators may be exposed to secondary poisoning. For example, in one study 85% of fisher *Pekania pennanti* carcasses collected showed signs of exposure (Thompson *et al*. 2013) whilst another showed signs of exposure in 79% of invasive American Mink, with the risk of exposure being higher in areas with farms (Ruiz-Suárez *et al*. 2016). Restricting use of such poisons may reduce their ingestion by mammalian carnivores.

Thompson C., Sweitzer R., Gabriel M., Purcell K., Barrett R. & Poppenga R. (2013) Impacts of rodenticide and insecticide toxicants from marijuana cultivation sites on fisher survival rates in the Sierra National Forest, California. *Conservation Letters*, 7, 91–102, https://doi.org/10.1111/conl.12038

Ruiz-Suárez., Melero Y., Giela A., Henríquez-Hernández L.A., Sharp E., Boada L.D., Taylor M.J., Camacho M., Lambin X., Luzardo O.P. & Hartley G. (2016) Rate of exposure of a sentinel species, invasive American mink (*Neovison vison*) in Scotland, to anticoagulant rodenticides. *Science of the Total Environment*, 569–570, 1013–1021, https://doi.org/10.1016/j.scitotenv.2016.06.109

Annual & Perennial Non-Timber Crops

3.12. Increase crop diversity for mammals

https://www.conservationevidence.com/actions/2392

- We found no studies that evaluated the effects on mammals of increasing crop diversity.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Some farmland heterogeneity is thought to be key in determining on-farm biodiversity (Benton *et al*. 2003). Therefore, increasing the range of different crops grown in a given year may increase the biological value of a farm.

Benton T.G., Vickery J.A. & Wilson J.D. (2003) Farmland biodiversity: is habitat heterogeneity the key? *Trends in Ecology & Evolution*, 18, 182–188, https://doi.org/10.1016/s0169-5347(03)00011-9

3.13. Create beetle banks on farmland

https://www.conservationevidence.com/actions/2393

- **One study** evaluated the effects on mammals of creating beetle banks on farmland. This study was in the UK[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** One replicated study in the UK[1] found that beetle banks had higher densities of harvest mouse nests than did field margins.

BEHAVIOUR (0 STUDIES)

Background

Beetle banks are raised strips which run through a field, typically planted with grasses. They primarily serve as an overwintering habitat for beetles, which provide pest control in the spring. By dividing the field, beetle banks reduce the distance that predators have to travel to reach the centre of the crop, a potential problem if overwintering habitat occurs only at the field edge. Beetle banks may also harbour other wildlife, such as small mammals.

A site comparison study in 1998 on an arable farm in Leicestershire, UK (1) found that beetle banks had higher densities of harvest mouse *Micromys minutus* nests than did field margins. The density of harvest mouse nests in beetle banks (117/ha) was higher than in field margins (14/ha). Beetle banks, created in 1992–1994, were 2–2.5 m wide, positioned down field centres and sown with tussock-forming grasses. They were cut during the first year but not thereafter. Field margins were ≥1 m wide, comprised perennial grasses and herbs and were mostly uncut. Harvest mouse nests were surveyed in September–November 1998 along 1,800 m length of beetle banks and 9,800 m length of field margins.

(1) Bence S.L., Stander K. & Griffiths M. (2003) Habitat characteristics of harvest mouse nests on arable farmland. *Agriculture, Ecosystems & Environment*, 99, 179–186, https://doi.org/10.1016/s0167-8809(03)00137-3

3.14. Plant crops to provide supplementary food for mammals

https://www.conservationevidence.com/actions/2394

- **Four studies** evaluated the effects on mammals of planting crops to provide supplementary food. Two studies were in the USA[1,2], one was in the UK[3] and one was in Spain[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (3 studies):** Two replicated, controlled studies (including one before-and-after study), in the UK[3] and Spain[4], found that crops grown to provide food for wildlife resulted in a higher abundance of small mammals in winter, but not in summer[3] and increased European rabbit abundance[4]. A replicated, randomized, controlled study in the USA[1] found that triticale (a cross between wheat and rye) held higher overwintering mule deer abundance relative to barley, annual ryegrass, winter wheat or rye.

BEHAVIOUR (2 STUDIES)

- **Use (2 studies):** A replicated, randomized, controlled study in the USA[1] found that mule deer consumed triticale (a cross between wheat and rye) more than they did barley, annual ryegrass, winter wheat or rye. A replicated, randomized, controlled study in the USA[2] found that supplementary food provided for game species was also consumed by lagomorphs and rodents.

Background

Crops may be planted to provide supplementary food for a range of mammal species, either of economic or conservation importance. The intervention includes also studies that measure the response of non-target mammals where the crop is nonetheless planted for a wildlife conservation purpose.

See also: *Species management — Provide supplementary food to increase reproduction/survival*.

A replicated, randomized, controlled study in 1979–1980 in a crop field in Texas, USA (1) found that on triticale (a cross between wheat and rye), overwintering mule deer *Odocoileus hemionus* abundance and crop consumption were higher than on barley, annual ryegrass, winter wheat or rye. The preference index (values >1 indicate selection for that grass and values <1 indicate avoidance) for the quantity of triticale removed by deer (1.37) was higher than for barley (0.90), annual ryegrass (0.99), wheat (0.87) and rye (0.66). Average deer abundance was also higher on triticale (12.8 deer/plot) compared to barley (7.0), annual ryegrass (10.1), wheat (5.8) and rye (9.0). In August 1979, five crop types were planted in five replicate blocks (four plots in each block were 0.125 ha, one was 0.063 ha). Grass species were randomly assigned to plots. Grass production and forage removal by deer were estimated monthly from November 1979 to March 1980 using paired caged and uncaged quadrats. Deer abundance was assessed by time lapse photography.

A replicated, randomized, controlled study in 1996–1997 of cropland on six ranches in Texas, USA (2) found that supplementary food provided for game species was also consumed by rodents and lagomorphs. Rodents ate 47% by biomass of winter oats *Avena sativa* grown for white-tailed deer *Odocoileus virginianus* that were consumed. Lagomorphs ate 10% and deer ate 44% of oats that were consumed. On each of six ranches, 2 ha of winter oats was grown. Twenty-four plots, each 1 m^3, were established at each ranch from December 1996 to March 1997. Six plots were fenced using 10 × 10-cm mesh (to exclude deer), six using 2 × 3-cm mesh (to exclude deer and lagomorphs), six using 0.5 × 0.5-cm mesh (to exclude deer, lagomorphs and rodents) and six were unfenced. Consumption was assessed by comparing remaining oat biomass with that in the finest-mesh fenced plots.

A replicated, controlled study in 2004–2005 on four arable farms in southern UK (3) found that small mammals used plots sown with a wild bird seed mix more than wheat crop in winter but not in summer. In winter, more small mammals were caught on average in the wild bird mix (27 individuals/100 trap nights) than in adjacent crops (8 individuals/100 trap nights). However, in summer, fewer were caught in the wild bird mix (<1 individual/100 trap nights) than in adjacent crops (12 individuals/100 trap nights). A mix of white millet *Echinochloa esculenta*, linseed *Linum usitatissimum*, radish *Raphanus sativus* and quinoa *Chenopodium quinoa* was sown in a 150 × 30-m patch in the centre of a winter wheat crop on each of four farms, in April 2004 and 2005. Small mammals were live-trapped over three days and nights in November–December 2004 and again in May–June 2005.

A replicated, controlled, before-and-after study in 2004–2006 of forest, scrub and grassland mosaics on 14 estates in central Spain (4) found that sown grain crops were used more by, and had a higher abundance of, European rabbits *Oryctolagus cuniculus* relative to uncropped areas. Cropped plots had more rabbit latrines (52 latrines/km transect) than did uncropped plots (19 latrines/km transect). Rabbit relative abundance increased on sown areas (after sowing: 2.0 rabbits/km transect; before: 1.3) but not elsewhere on estates (after sowing: 3.0 rabbits/km transect; before: 3.3). Fourteen private estates in central Spain were studied. Across these, 125 plots were sown with barley and oat seed, at 150 kg/ha, in 2004–2006. There were 3–19 treatment plots/estate of 0.04–43.07 ha extent. For each treatment plot, an unsown control plot, ≥200 m away, with similar broad characteristics, was selected. Rabbit latrines were counted along transects in sown and unsown plots in late spring. Relative abundance was assessed by counting rabbits from transects in spring, before and after sowing.

(1) Wiggers E.P., Wilcox D.D. & Bryant F.C. (1984) Cultivated cereal grains as supplemental forages for mule deer in the Texas panhandle. *Wildlife Society Bulletin*, 12, 240–245.

(2) Donalty S., Henke S.E. & Kerr C.L. (2003) Use of winter food plots by nongame wildlife species. *Wildlife Society Bulletin*, 31, 774–778.

(3) Pywell R.F., Shaw L., Meek W., Turk A., Shore R.F. & Nowakowski M. (2007) Do wild bird seed mixtures benefit other taxa? *Aspects of Applied Biology*, 81, 69–76.

(4) Guil F., Fernández-Olallac M., Martínez-Jáuregui M., Moreno-Opoa R., Agudína S. & San Miguel-Ayanz A. (2014) Grain sowing aimed at wild rabbit *Oryctolagus cuniculus* L. enhancement in Mediterranean environments. *Journal for Nature Conservation*, 22, 552–558, https://doi.org/10.1016/j.jnc.2014.08.011

3.15. Change mowing regime (e.g. timing, frequency, height)

https://www.conservationevidence.com/actions/2399

- We found no studies that evaluated the effects of changing mowing regime (e.g. timing, frequency, height) on mammals.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Numerous studies assess responses of grassland vegetation structure and composition to different mowing regimes. Responses of fauna are less frequently documented with invertebrate responses dominating among those that are published. Some mammalian herbivores may be sensitive to variations in grassland vegetation height and structure (Mero *et al*. 2015). An understanding of responses to changes in mowing regimes may assist with development of tailored management for particular species.

See also: *Habitat Restoration and Creation — Restore or create grassland*.

Mero, TO., Bocz R., Polyak L., Horvath G. & Lengyel S. (2015) Local habitat management and landscape-scale restoration influence small-mammal communities in grasslands. *Animal Conservation*, 18, 442–450, https://doi.org/10.1111/acv.12191

3.16. Leave areas of uncut ryegrass in silage field

https://www.conservationevidence.com/actions/2400

- We found no studies that evaluated the effects on mammals of leaving areas of uncut ryegrass in silage field.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and

report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

This intervention involves leaving areas of uncut ryegrass *Lolium perenne* in silage fields. Ryegrass seeds are a potential food source for small mammals, but cutting ryegrass fields multiple times a year for silage removes seed heads before they can ripen and so reduces the food available the following winter. Leaving fields or plots uncut may provide overwinter food for small mammals and may also provide suitable habitat away from damaging harvesting machinery.

3.17. Leave cut vegetation in field to provide cover

https://www.conservationevidence.com/actions/2401

- **One study** evaluated the effects on mammals of leaving cut vegetation in field to provide cover. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A controlled, before-and-after study in the USA[1] found that increasing cover, by adding cut vegetation (hay), did not increase rodent abundance.

BEHAVIOUR (0 STUDIES)

Background

Leaving cut vegetation in a field, either following cutting or by adding hay from elsewhere, may increase ground-level shelter available to small mammals.

A controlled, before-and-after study in 1983–1984 on a prairie grassland in Kansas, USA (1) found that increasing cover, by adding cut vegetation (hay), did not increase rodent abundance. Rodent numbers were not significantly different after hay addition (19–28/census) compared to before hay addition (10–25/census). Rodent abundances in plots with no added hay likewise did not differ significantly over the same time periods (after: 14–45/census; before: 9–36/census). Three plots, 0.81 ha each, were established on brome grass *Bromus inermns* and prairie vegetation. One had 16 cm depth of hay added in January 1984. Two were left unmanaged. Small mammals were sampled using 100 Longworth live traps/plot. Trapping occurred over two nights, biweekly, from 12 weeks before hay addition (October 1983) until 26 weeks after hay addition (August 1984).

(1) Kotler B.P., Gaines M.S. & Danielson B.J. (1988) The effects of vegetative cover on the community structure of prairie rodents. *Acta Theriologica*, 33, 379–391, https://doi.org/10.4098/at.arch.88-32

3.18. Establish long-term cover on erodible cropland

https://www.conservationevidence.com/actions/2402

- **One study** evaluated the effects on mammals of establishing long-term cover on erodible cropland. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A replicated, site comparison study in the USA[1], found that establishing long-term cover on erodible cropland did not increase the abundance of eastern cottontails.

BEHAVIOUR (0 STUDIES)

Background

Establishing long-term cover on cropland that is highly susceptible to erosion may be carried out for a number of reasons including conserving soil fertility, limiting carbon emissions and enhancing habitat for biodiversity. The provision of long-term cover has potential to benefit mammals that are able to exploit increased shelter and food resources.

A replicated, site comparison study in 1989–1990 on six areas of mostly arable farmland in Nebraska, USA (1) found that establishing long-term cover on erodible cropland was not associated with increased abundance of eastern cottontails *Sylvilagus floridanus*. The number of cottontails counted in areas with 18–21% long-term cover (2.1–6.7 cottontails/block) did not differ significantly from that in areas with 2–3% long-term cover (4.1–8.8 cottontails/block). Within six 23-km^2 farmland blocks, the proportion of land managed under an agri-environment scheme aimed at diversifying long-term cover types and reducing crop production was determined. In three blocks, 18–21% of cropland was in the scheme and in the other three, 2–3% was in the scheme. Long-term cover, established under 10-year contracts, included establishment of grasses and legumes. Live cottontails were counted from a vehicle while driving at 30–40 km/h, in May and June of 1989 and 1990.

(1) King J.W. & Savidge J.A. (1995) Effects of the Conservation Reserve Program on wildlife in southeast Nebraska. *Wildlife Society Bulletin*, 23, 377–385.

Livestock Farming & Ranching

3.19. Exclude livestock from semi-natural habitat (including woodland)

https://www.conservationevidence.com/actions/2407

- **Nine studies** evaluated the effects of excluding livestock from semi-natural habitat on mammals. Six studies were in the USA[1–5,9], two were in Spain[6,7] and one was in Australia[8].

COMMUNITY RESPONSE (2 STUDIES)

- **Richness/diversity (2 studies):** Two replicated, site comparison studies in the USA[2,4] found more small mammal species[2,4] on areas from which livestock were excluded.

POPULATION RESPONSE (9 STUDIES)

- **Abundance (9 studies):** Four out of eight studies (including four site comparisons and four controlled studies), in the

USA[1,2,3,4,5,9] and Spain[6,7], found that excluding grazing livestock led to higher abundances of mule deer[1], small mammals[4,6] and, when combined with provision of water, of European rabbits[7]. One study found higher densities of some but not all small mammals species[2] when livestock were excluded and the other three studies found that grazing exclusion did not lead to higher abundances of black-tailed hares[3], California ground squirrel burrows[5] or of five small mammal species[9]. A site comparison study in Australia[8] found more small mammals where cattle were excluded compared to high intensity cattle-grazing but not compared to medium or low cattle-grazing intensities.

BEHAVIOUR (0 STUDIES)

Background

This intervention involves preventing livestock from grazing certain semi-natural habitats, such as grasslands and woodland, to benefit wildlife. Mammal responses may be linked to reduction in competition from domestic herbivores or to changes in the vegetation structure.

See also *Reduce intensity of grazing by domestic livestock* for studies where livestock are removed from areas of permanent grassland.

A controlled study in 1982–1984 on a shrubland site in California, USA (1) found that inside a cattle-exclusion fence, there were more mule deer *Odocoileus hemionus* than there were outside it. This result was not tested for statistical significance. Over six sampling events, 192 faecal pellet clumps were counted inside the enclosure compared to 138 outside it. In June 1982, a prescribed burn was carried out across 4 ha of land. A 0.25-ha enclosure (cattle proof but not deer proof) was established on the burned area. Relative deer presence inside and outside the enclosure was assessed by counting pellet-groups in September 1982, February, August, and November 1983 and March and July 1984. Counts were made along 18 transects (5 m long) inside the enclosure and 18 outside the enclosure.

A replicated, site comparison study in 1990–1992 in a desert in south-central California, USA (2) found that excluding livestock led to more small mammal species, and higher densities of some small mammal species, compared to sheep-grazed areas. More species of small nocturnal rodents were found in ungrazed (3.7 species/sample) than in grazed areas (2.5 species/sample), and diversity was higher in ungrazed areas in all three years (data reported as diversity indices). The densities of three of five species were higher in ungrazed than in grazed plots (long-tailed pocket mouse *Chaetodipus formosus*: 26 vs 6 animals/ha; Merriam's kangaroo rat *Dipodomys merriami*: 31 vs 13; southern grasshopper mouse *Onychomys torridus*: 3 vs 0 respectively). The densities of the other two species did not differ significantly between grazed and ungrazed plots (little pocket mouse *Perognathus longimembris*: 29 vs 30 animals/ha; deer mouse *Peromyscus maniculatus*: 1 vs 0). Two pairs of 65-ha plots were established in 1990 with one plot inside an area fenced since 1978–1979 and one outside, in an area grazed by sheep (grazing intensity not stated). Over five periods of four to six nights, in May 1990–March 1992, mammals were caught in 64 Sherman traps/plot, 10 m apart.

A replicated, site comparison study in 1994 in a desert site in California, USA (3) found that in areas where livestock were excluded, there were fewer black-tailed hares *Lepus californicus*, compared to in sheep-grazed unfenced areas that were also driven over by off-road vehicles. Fewer black-tailed hares were found in fenced plots (0–1.5 hares/survey; 11 droppings/m^2) compared to in unfenced plots (1–4 hares/survey; 22–31 droppings/m^2). Two 2.25-ha plots that were fenced in 1980 were compared to two plots that were grazed by sheep (and driven over by off-road vehicles). Sites were matched for environmental variables. Hare numbers were estimated in May and July 1994 by counting the number of hares seen on four 1.25-km-long transects and the number of droppings in sixty 40 × 50-cm sampling units in each plot.

A replicated, site comparison study in 1998–1999 of a riparian grassland area in Pennsylvania, USA (4) found that stream margins, fenced to exclude grazing livestock, had a higher species richness and abundance of small mammals than did unfenced margins. There were more species in fenced stream margins (4.4 species/site) than in unfenced margins (2.6 species/site). More small mammals overall were caught in fenced (21.2/site) than in unfenced (9.7/site) margins. Three species were sufficiently abundant to analyse individually. There were more individuals in fenced than unfenced margins for meadow voles *Microtus pennsylvanicus* (fenced: 8.0; unfenced: 5.3 individuals) and meadow jumping mouse *Zapus hudsonius* (fenced: 9.1; unfenced: 3.5 individuals). No significant difference was found for short-tailed shrew *Blarina brevicauda* (fenced: 3.8; unfenced: 2.4 individuals). Nine 100-m-long riparian margins, fenced one to two years previously, were compared with nine 100-m-long unfenced (cattle-grazed) riparian margins. Three types of small-mammal trap were operated continually throughout April–July in 1998–1999.

A replicated, randomized, controlled study in 1991–1994 in grassland and savanna in California, USA (5) found that excluding grazing livestock did not increase the number of California ground squirrel *Spermophilus beecheyi* burrows. Changes in the number of active ground squirrel burrows, relative to pre-experiment numbers, did not differ between ungrazed and grazed plots (60–100% vs 40–100% of pre-experiment numbers). The spatial distribution of active burrow entrances did not differ between ungrazed and grazed plots (2.6–3.4 vs 2.2–4.1 m between nearest burrows). Three sites, each with four plots, were studied. Half of plots were in grassland, and half were in savanna. Half had cattle-exclusion fencing and half were cattle-grazed from spring to summer. Three ground squirrel colonies were mapped in each plot in autumn 1991 (pre-experiment). Fencing was erected late in 1991 and burrows were further mapped in autumns of 1992–1994.

A replicated, site comparison study in 1999–2001 of a grassland area in Castilla y Lyón, Spain (6) found more small mammals in plots from which cattle were excluded, compared to grazed plots. More individual small mammals were caught in grazing exclusion plots (0–16 individuals/plot) than in grazed plots (0–3 individuals/plot). Three species of mammal were found; white-toothed shrew *Crocidura russula* (61.6% of captures), common vole *Microtus arvalis* (31.9%), and wood mouse *Apodemus sylvaticus* (6.5%). Six grazing exclusion plots (2–10 ha) were established in reforestation areas in grasslands grazed by 2–10 cattle/ha. These areas were reforested in 1990, but few planted trees survived. Eight live traps were placed in each of 22 trapping plots (11 inside and 11 outside cattle exclosures). Traps were operated for three consecutive nights during September–October 1999 and 2000 and in June 2000 and 2001.

A controlled study in 2005–2007 in open forest and scrubland at a site in Córdoba province, Spain (7) found more European rabbits *Oryctolagus cuniculus* in a plot that was fenced to exclude large herbivores and with artificial warrens and water provided, than in an unmanaged area. Interventions were all carried out in the same plot, so their relative effects could not be separated. Average rabbit pellet counts were higher in the plot where the interventions were deployed (first year: 0.33 pellets/m^2/day; second year: 1.08 pellets/m^2/day) than in the unmanaged plot (first year: 0.02 pellets/m^2/day; second year: 0.03 pellets/m^2/day). A 2-ha plot was fenced to exclude large herbivores in March 2005. Rabbits and predators could pass through the fence. Five artificial warrens were installed and water was provided at one place. No management was carried out in an otherwise similar plot. Rabbit density was determined by monthly counts of pellets, from March 2005 to March 2007, in 0.5-m^2 circles every 100 m along a 1-km transect in each plot.

A site comparison study in 1993–2007 on a shrubland site in South Australia, Australia (8) found that excluding cattle increased abundances of small mammals compared to high intensity cattle grazing but not to medium or low grazing intensities. The average number of small mammals/sample at ungrazed points (3.6 individuals) was higher than with intensive cattle grazing (1.7 individuals) but not higher than the numbers with medium-(5.0) or low-intensity cattle grazing (7.7). Species richness followed a similar pattern (ungrazed: 1.7 species; intensive grazing: 1.2 species; medium grazing: 1.7, low intensity grazing: 2.2 species). Livestock were fenced out from an approximately 9 × 9-km area in 1986. Small mammals were sampled using pitfall traps for a 10-day period in either December or January 1993–1996 and again in 2007. Five points were sampled inside the enclosure (ungrazed) with 13 outside (grazed). Cattle grazing intensity was determined by dung counts. Low intensity grazing was <12 dung/ha, medium grazing was 12–100 dung/ha and intensive grazing was >120 dung/ha.

A replicated, controlled study in 1998–2006 in sagebrush shrubland previously affected by wildfire in California, USA (9) found that excluding livestock did not alter the abundance of five small mammal species. Over eight years, abundance of San Joaquin antelope squirrel

Ammospermophilus nelson did not differ significantly between areas where livestock were excluded (4–38 animals/plot) and grazed areas (2–29 animals/plot). The same pattern was true for short nosed kangaroo rat *Dipodomys nitratoides nitratoides* (1–55 vs 3–58 animals/plot), Heermann's kangaroo rat *Dipdomys heermanni* (0–4 vs 0–22), giant kangaroo rat *Dipodomys ingens* (0–4 vs 0–3), and San Joaquin pocket mouse *Perognathus inornatus inornatus* (1–10 vs 1–17). Four 2.6-km^2 areas were grazed by cattle and four 25-ha areas were fenced to exclude livestock. To estimate antelope squirrel abundance, 64 traps, baited with oats, at 40-m intervals, were established in each plot. To estimate abundance of other small mammals, 144 traps, baited with bird seed, were established in each plot at 10-m intervals. Traps were set for six consecutive days and nights in July–September 1998–2006.

(1) Roberts T.A. & Tiller R.L. (1985) Mule deer and cattle responses to a prescribed burn. *Wildlife Society Bulletin*, 13, 248–252.

(2) Brooks M.L. (1995) Benefits of protective fencing to plant and rodent communities of the western Mojave Desert, California. *Environmental Management*, 19, 65–74, https://doi.org/10.1007/bf02472004

(3) Brooks M. (1999) Effects of protective fencing on birds, lizards, and black-tailed hares in the western Mojave Desert. *Environmental Management*, 23, 387–400, https://doi.org/10.1007/s002679900194

(4) Giuliano W.M. & Homyack J.D. (2004) Short-term grazing exclusion effects on riparian small mammal communities. *Journal of Range Management*, 57, 346–350, https://doi.org/10.2111/1551-5028(2004)057[0346:sgeeor]2.0.co;2

(5) Fehmi J.S., Russo S.E. & Bartolome J.W. (2005) The effects of livestock on California ground squirrels (*Spermophilus beecheyi*). *Rangeland Ecology & Management*, 58, 352–359, https://doi.org/10.2458/azu_rangelands_v58i4_bartolome

(6) Torre I., Diaz M., Martínez-Padilla J., Bonal R., Vinuela J. & Fargallo J.A. (2007) Cattle grazing, raptor abundance and small mammal communities in Mediterranean grasslands. *Basic and Applied Ecology*, 8, 565–575, https://doi.org/10.1016/j.baae.2006.09.016

(7) Catalán I., Rodríguez-Hidalgo P. & Tortosa F.S. (2008) Is habitat management an effective tool for wild rabbit (Oryctolagus cuniculus) population reinforcement? *European Journal of Wildlife Research*, 54, 449–453, https://doi.org/10.1007/s10344-007-0169-0

(8) Read J.L. & Cunningham R. (2010) Relative impacts of cattle grazing and feral animals on an Australian arid zone reptile and small mammal assemblage. *Austral Ecology*, 35, 314–324, https://doi.org/10.1111/j.1442-9993.2009.02040.x

(9) Germano D.J., Rathbun G.B. & Saslaw L.R. (2012) Effects of grazing and invasive grasses on desert vertebrates in California. *The Journal of Wildlife Management*, 76, 670–682, https://doi.org/10.1002/jwmg.316

3.20. Reduce intensity of grazing by domestic livestock

https://www.conservationevidence.com/actions/2408

- **Thirteen studies** evaluated the effects on mammals of reducing the intensity of grazing by domestic livestock. Six studies were in the USA[1,2,3a,3b,9,10], six were in Europe[4,5,7,8,11,12] and one was in China[6].

COMMUNITY RESPONSE (3 STUDIES)

- **Richness/diversity (3 studies):** Two of three site comparison or controlled studies, in the USA[3a,3b] and Norway[12], found that reduced livestock grazing intensity was associated with increased species richness of small mammals[3b,12] whilst one study did not find an increase in species richness[3a].

POPULATION RESPONSE (13 STUDIES)

- **Abundance (13 studies):** Six of nine site comparison or controlled studies (including seven replicated studies), in the USA[2,3a,3b,9], Denmark[4], the UK[5], China[6], Netherlands[11] and Norway[12], found that reductions in livestock grazing intensity were associated with increases in abundances (or proxies of abundances) of small mammals[2,3b,4,5,9,11], whilst two studies showed no significant impact of reducing grazing intensity[3a,12] and one study showed mixed results for different species[6]. Two replicated studies (including one controlled and one site comparison study), in the UK[7] and in a range of European countries[8], found that reducing grazing intensity did not increase numbers of Irish hares[7] or European hares[8]. A controlled, before-and-after study, in the USA[1] found that exclusion of cattle grazing was associated with higher numbers of elk and mule deer. A replicated, site comparison study in the USA[10] found that an absence of cattle grazing was associated with higher numbers of North American beavers.

BEHAVIOUR (0 STUDIES)

Background

Overgrazing is responsible for the degradation of habitats across the world, being especially damaging in arid environments, where the removal of vegetation can quickly lead to soil erosion. Reducing grazing intensity may reduce the damage to vegetation and can also help reduce disturbance to mammals and accidental loss of nests of small mammal species.

A controlled, before-and-after study in 1981–1982 in a forest and meadow mosaic in Arizona, USA (1) found that an absence of cattle grazing was associated with higher numbers of elk *Cervus canadensis* and mule deer *Odocoileus hemionus*. There were 0.13 elk/km counted on transects in absence of cattle grazing and 0.01/km after grazing commenced whereas, concurrently, on a continually ungrazed pasture, 0.21 and 0.50 elk/km respectively were counted. The number of mule deer counted on transects fell from 0.07/km in absence of grazing to 0.00/km after grazing commenced whereas 0.02 mule deer/km were counted on a continually ungrazed pasture during both time periods. The 135 km^2-study area was divided into two pastures. One was ungrazed in both years. The other was ungrazed in 1981 and stocked with cattle, at a rate of one animal unit (equivalent to a cow and suckling calf)/3 ha in May–July 1982. Elk and mule deer were counted in July and August, along a 48-km driving transect, 20 times in 1981 and 14 times in 1982.

A site comparison study in 1981–1983 on a grassland ranch in Arizona, USA (2) found that reducing grazing intensity by excluding livestock increased rodent abundance. More rodents were caught in an ungrazed area (428 individuals) than in a grazed area (328 individuals). This was the case for hispid pocket mouse *Perognathus hispidus* (38 vs 16 individuals), western harvest mouse *Reithrodonromys megalotis* (26 vs 4), white-footed mouse *Peromyscus leucopus* (45 vs 24), southern grasshopper mouse *Onychomys torridus* (42 vs 8) and hispid cotton rat *Sigmodon hispidus* (118 vs 49). Merriam’s kangaroo rat *Dipodomys merriami* was less abundant in the ungrazed than the grazed area (5 vs 92 individuals). Silky pocket mouse *Perognathus flavus* abundance did not differ significantly between ungrazed and grazed areas (8 vs 5 individuals) and nor did deer mouse *Peromyscus maniculatus* abundance (146 vs 130). Livestock were fenced out of part of a 300-ha study area from 1968 onwards. The grazed part was stocked with approximately one cow/10 ha. Rodents were live-trapped, from two hours before sunset to two hours after sunrise, on 71 occasions, from July 1981 to January 1983.

A replicated, site comparison study in 1989–1991 of shrub grassland in a national park in Utah, USA (3a) found that reducing grazing intensity by excluding cattle from small enclosures did not increase small mammal abundance or species richness. Small mammal abundance in ungrazed enclosures (1.9 individuals/100 trap-nights) did not significantly differ from that in grazed areas (2.3 individuals/100 trap-nights). Small mammal species richness in enclosures (1.5 species/trap grid) did not significantly differ from that in grazed areas (1.6 species/trap grid). Cattle were excluded from four enclosures, three for six years prior to the study and one for 38 years. Enclosures measured 0.1–0.8 ha. Grazing outside enclosures was by 1,500 Animal Units (equivalent to a cow and suckling calf) across 35,499 ha in October–May. Small mammals were sampled in grids of Sherman live traps, one grid inside each enclosure. An identical grid was sampled simultaneously >500 m away from each enclosure. Grids were trapped for four consecutive days, between 1 May and 31 June. Three enclosures were sampled annually in 1989–1991, and one in 1990–1991.

A replicated, site comparison study in 1990 of shrub grassland at eight sites in two national parks in Utah, USA (3b) found that reducing grazing intensity by excluding cattle from areas of grassland increased small mammal abundance and species richness. Small mammal abundance in ungrazed sites (1.8 individuals/100 trap-nights) was higher than in grazed sites (1.0 individuals/100 trap-nights). Small mammal species richness in ungrazed sites (1.5 species/site) was higher than in grazed sites (1.0 species/site). Eight sites were sampled; four ungrazed for ≥30 years and four in a region grazed by 1,500 Animal Units (equivalent to a cow and suckling calf) across 35,499 ha in October–May. All sites were on large (≥ 100 ha) areas of shrub-grassland and were selected to match geological and soil characteristics. Each site was sampled using a grid of Sherman live traps, for four consecutive days, between 1 May and 31 June 1990.

A replicated, controlled study in 1998–2000 of pasture at a site in Denmark (4) found that in plots with reduced livestock grazing intensity, small mammal biomass was higher. Small mammal biomass peaks across the study in each of two plots/treatment were higher in ungrazed plots (287–959 g), intermediate in low-intensity sheep plots (251–801 g) and lowest in high-intensity cattle plots (64–195 g). The estimated population of field voles *Microtus agrestis* (the most abundant species recorded) was higher each year in ungrazed plots (29–94/plot) than in high-intensity cattle plots (3–27/plot), but was higher still in low-intensity sheep plots in two of three years (32–63/plot). In 1997, two meadows were divided into 70 × 300-m pens. One plot on each meadow was assigned to high-intensity cattle grazing (4.8 steers/ha), one to low intensity sheep grazing (4.5 ewes plus lambs/ha) and one was ungrazed. Grazing occurred from mid-May to mid-October, though was prevented on half of each pen until after hay cutting (late-June to early-July). The delayed grazing part was reversed the following year. Small mammals were live-trapped over three days and nights, every four weeks, over 31 trapping sessions, from June 1998 to October 2000.

A replicated, randomized, paired sites, controlled, before-and-after study in 2002–2004 on upland grassland in Scotland, UK (5) found that reducing sheep grazing intensity increased the abundance of field voles *Microtus agrestis*. In the first year of grazing treatments, the percentage of quadrats with vole signs was higher in ungrazed plots (20%), intermediate in lightly grazed plots (12%) and lowest in heavily grazed plots (4%). The same pattern held in the second year of treatments (ungrazed: 24%; lightly grazed: 11%; heavily grazed: 7%). Before grazing treatments were implemented, there was no significant difference in the frequency of vole signs between plots. Plots were all grazed similarly (stocking rate not stated) up to 2002. From spring 2003, there were six replicates (3.3 ha each) of no livestock grazing, light grazing (three ewes/plot) and heavy grazing (nine ewes/plot). Five 25 × 25-cm quadrats at each of five points/plot were searched for vole signs in April and October 2002–2004.

A replicated, site comparison study in 2001 and 2002 on two winter pasture areas in Sichuan, China (6) found that reduced livestock grazing intensity was associated with higher numbers of the tundra/lacustrine vole *Microtus oeconomus/limnophilus* complex but with lower numbers of Kam dwarf hamster *Cricetulus kamensis*. The numbers of tundra/lacustrine voles in low grazing intensity areas (7 individuals/100 trap nights) was higher than in medium (1/100 trap nights) or high grazing intensity areas (0/100 trap nights). The numbers of Kam dwarf hamster in low (0 individuals/100 trap night) and medium grazing intensity areas (0/100 trap nights) was lower than that in high grazing intensity areas (6/100 trap nights). Surveys were conducted in grassland and shrub areas in valley, wetland and slope habitats in winter pasture at 4,250 m altitude. Sites were grazed, in varying intensities, by yaks, sheep, goats, and horses, each October to early May. Small mammals were surveyed using back-break traps over three nights and days in July 2001 and July 2002.

A replicated, site comparison study in 2005 on 200 plots covering a range of agricultural habitats in Northern Ireland, UK (7) found that reducing grazing intensity as part of a wider suite of agri-environment measures did not increase numbers of Irish hares *Lepus timidus hibernicus*. The effects of reducing grazing intensity cannot be separated from those of other agri-environment measures, which included retaining and enhancing field boundary features and managing nutrient systems. Hare abundance in agri-environment plots (0.45 hares/km transect) did not significantly differ from that in non-agri-environment plots (0.41 hares/km transect). One hundred and fifty 1-km^2 plots, on land that was enrolled into an agri-environment scheme 10–17 years previously, were selected along with 50 non-enrolled 1-km^2 plots, chosen to match enrolled plots for landscape characteristics. Hares were surveyed at night, in mid-winter, by spotlighting from a vehicle.

A replicated, randomized, controlled study in 2002–2004 on grassland in France, Germany, Italy and the UK (8) found that areas with low livestock grazing intensities did not have more European hares *Lepus europaeus* than did areas with moderate livestock grazing intensities. Too few hares were recorded to enable statistical analyses. At the UK site, though, where most hares were recorded, numbers were similar between low intensity (14 hares) and moderate intensity (12 hares) grazing areas. Sites were grazed by the cattle Charolais × Fresian in the UK, Simmental in Germany and Charolais in France and by

Finnish Romanov sheep in Italy. Grazing rates differed, but low grazing intensity was 0.3–0.4 fewer animals/ha than moderate grazing intensity. There were three each of low and moderate intensity grazing paddocks (paddock size 0.4–3.6 ha) at one site in each of the four countries. Hares were counted every two weeks in early morning, from May to October, 2002–2004, during seven minutes of observation and whilst walking a transect in each paddock.

A controlled study in 2008 of a grassland and woodland site in Nevada, USA (9) found that reducing grazing intensity by long-term exclusion of domestic livestock resulted in a higher species richness and abundance of small mammals. More small mammal species were recorded on ungrazed land (six) than on grazed land (four). Small mammal abundance on ungrazed land (0.08 animals/trap night) was higher than on grazed land (0.05 animals/trap night). Three species were caught in sufficient quantities for individual analyses. The Great Basin pocket mouse *Perognathus parvus* was more abundant on ungrazed than grazed land (0.05 vs 0.02 individuals/trap night) as was western jumping mouse *Zapus princeps* (0.02 vs 0.00 individuals/trap night). Deer mice *Peromyscus maniculatus* showed no preference (0.01 vs 0.01 individuals/trap night). Sampling occurred in a 10-ha enclosure, characterised by mixed shrubs and trees, from which domestic livestock were excluded at least 50 years previously and in a similar sized, adjacent cattle-grazed grassland. Small mammals were sampled using lines of snap-traps, over three or four nights, in July 2008.

A replicated, site comparison study in 2013 in a forested area in New Mexico, USA (10) found that an absence of cattle grazing was associated with higher numbers of North American beavers *Castor canadensis*. The relative frequency of beaver dams was higher in the absence of cattle grazing than where cattle grazing was present (data presented as odds ratios). Data were collected along 57 sections of river, each 200 m long, of which 29 had beaver dams and 28 did not have beaver dams, though physical conditions were suitable for their construction. Field data were collected between 15 May and 15 August 2013. Livestock grazing was assessed by collating information on grazing consents and by surveying ungulate faeces.

A replicated, randomized, paired sites, controlled study in 2010–2013 on a coastal salt marsh in the Netherlands (11) found that plots grazed at lower intensity contained more signs of vole *Microtus* spp. presence than did plots grazed at higher intensity. After four years, a greater proportion of surveyed quadrats contained signs of vole presence in plots grazed at lower intensity than in plots grazed at high intensity (data not reported). Twelve plots were established (in three sets of four) on a historically grazed salt marsh. From 2010, six plots (two random plots/set) were grazed at each intensity: low (0.5 animals/ha) or high (1.0 animal/ha). Grazing occurred in summer (June–October) only. Half of the plots were grazed by cows and half by horses. In October 2013, sixty quadrats (2 m^2) were surveyed in the higher elevations of each plot for signs of vole presence (runways, fresh plant fragments or faecal pellets). Some flooded quadrats were excluded from the analysis.

A randomized, replicated, controlled study in 2002–2005 at two heathland sites in Norway (12) found that excluding livestock with fences did not significantly change abundances of field voles *Microtus agrestis.* The number of animals trapped in plots that were fenced to exclude livestock did not differ significantly (6 animals/plot) from that in plots that were not fenced to exclude livestock (4 animals/plot). In 2002, at two sites, four 50 × 50-m plots were fenced to exclude livestock and four plots were not fenced. Sheep density prior to fencing was 32–48 sheep/ha. In June and August 2003–2005, thirty-six live traps baited with sunflower seeds and peanuts and with wool for bedding were placed in each plot and checked twice daily for five days. Captured animals were individually marked and released.

(1) Wallace M.C. & Krausman P.R. (1987) Elk, mule deer, and cattle habitats in Central Arizona. *Journal of Range Management*, 40, 80–83, https://doi.org/10.2307/3899367

(2) Bock C.E., Bock J.H., Kenney W.R. & Hawthorne V.M. (1984) Responses of birds, rodents, and vegetation to livestock exclosure in a semidesert grassland site. *Journal of Range Management*, 37, 239–242, https://doi.org/10.2307/3899146

(3) Rosenstock S.S. (1996) Shrub-grassland small mammal and vegetation responses to rest from grazing. *Journal of Range Management*, 49, 199–203.

(4) Schmidt N.M., Olsen H., Bildsøe M., Sluydts V. & Leirs H. (2005) Effects of grazing intensity on small mammal population ecology in wet meadows. *Basic and Applied Ecology*, 6, 57–66, https://doi.org/10.1016/j.baae.2004.09.009

(5) Evans D.M., Redpath S.M., Elston D.A., Evans S.A., Mitchell R.J. & Dennis P. (2006) To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. *Journal of Applied Ecology*, 43, 499–505, https://doi.org/10.1111/j.1365-2664.2006.01158.x

(6) Raoul F., Quére J-P., Rieffel D., Bernard N., Takahashi K., Scheifler R., Ito A., Wang Q., Qiu J., Yang W., Craig P.S. & Giraudoux P. (2006) Distribution of small mammals in a pastoral landscape of the Tibetan plateaus (Western Sichuan, China) and relationship with grazing practices. *Mammalia*, 70, 214–225, https://doi.org/10.1515/mamm.2006.042

(7) Reid N., McDonald R.A. & Montgomery W.I. (2007) Mammals and agri-environment schemes: hare haven or pest paradise? *Journal of Applied Ecology*, 44, 1200–1208, https://doi.org/10.1111/j.1365-2664.2007.01336.x

(8) Wallis De Vries M.F., Parkinson A.E., Dulphy J.P., Sayer M. & Diana E. (2007) Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 4. Effects on animal diversity. *Grass and Forage Science*, 62, 185–197, https://doi.org/10.1111/j.1365-2494.2007.00568.x

(9) Rickart E.A., Bienek K.G. & Rowe R.J. (2013) Impact of livestock grazing on plant and small mammal communities in the Ruby Mountains, northeastern Nevada. *Western North American Naturalist*, 73, 505–515, https://doi.org/10.3398/064.073.0403

(10) Small B.A., Frey J.K. & Gard C.C. (2016) Livestock grazing limits beaver restoration in northern New Mexico. *Restoration Ecology*, 24, 646–655, https://doi.org/10.1111/rec.12364

(11) van Klink R., Nolte S., Mandema F.S., Lagendijk D.D.G., Wallis De Vries M.F., Bakker J.P., Esselink P. & Smit C. (2016) Effects of grazing management on biodiversity across trophic levels — the importance of livestock species and stocking density in salt marshes. *Agriculture, Ecosystems & Environment*, 235, 329–339, https://doi.org/10.1016/j.agee.2016.11.001

(12) Spirito F., Rowland M., Nielson R., Wisdom M. & Tabeni S. (2017) Influence of grazing management on resource selection by a small mammal in a temperate desert of South America. *Journal of Mammalogy*, 98, 1768–1779, https://doi.org/10.1093/jmammal/gyx106

3.21. Use livestock fences that are permeable to wildlife

https://www.conservationevidence.com/actions/2409

- **Two studies** evaluated the effects on target mammals of using livestock fences that are permeable to wildlife. Both studies were in the USA[1,2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (2 STUDIES)

- **Use (2 studies):** A study in the USA[1] found that wild ungulates crossed a triangular cross-section fence with varying success rates. A replicated, controlled study in the USA[2] found that fences with a lowered top wire were crossed more by elk than were conventional fences.

Background

Fences erected to retain domestic livestock or, in some cases, exclude wild herbivores or carnivores may also act as barriers to non-target species. Fence designs may be adapted to permit crossings and, thus, retain habitat connectivity for specific species. Fence designs are likely to vary between different situations, depending on the nature of the original fence and the species being targeted for continued access.

See also *Install mammal crossing points along fences on farmland*.

A study in 1988–1989 of shrubland and grassland along a national park boundary in Montana, USA (1) found that wild ungulates crossed a fence with a triangular cross-section (buck-and-pole fence) with varying success rates. Fence crossing success rates (away from gates) were mule deer *Odocoileus hemionus*: 85% of fence approaches, pronghorn *Antilocapra americana*: 72%, bison *Bison bison*: 46%, elk *Cervus canadensis*: 17%. Most bison crossings were achieved by damaging the fence. Other animals were generally able to pass through or below it. Some animals that did not cross the fence walked along until they found an open gate. The fence was 3.8 km long, had a width at the bottom of 165–175 cm and narrowed to a point at a height of 165–185 cm. Four rails were set on a slope on one side (the lowest being 25–59 cm above the ground). The other side comprised a single rail, 65–85 cm above the ground. Animal crossings were monitored by identifying tracks in snow, 10.5–109 hours after storms, on eight occasions from 5 January to 8 March 1988 and eight occasions from 16 November 1988 to 14 March 1989.

A replicated, controlled study in 1994 on a grassland site in New Mexico, USA (2) found that fences with a lowered top wire were crossed more by elk *Cersus elaphus* than were conventional fences. Of 10 fence designs trialled, two were crossed significantly more frequently than were conventional 100-cm high fences comprising four barbed wires. The two designs crossed most both involved lowering the top wire and fastening it to the second wire down, 80 cm above the ground. One also had the third wire attached to the bottom wire. These fences were crossed 4.6 and 4.3 times/day respectively. Conventional fences were crossed 2.3 times/day. No livestock escapes occurred during the trial. Fence sections, 15 m long, with 6–9 replicates of each design, were monitored for 21 days in late July–September 1994. Fence crossings were confirmed by presence of tracks and by breaks in a thread above the fence.

(1) Scott M.D. (1992) Buck-and-pole fence crossings by 4 ungulate species. *Wildlife Society Bulletin*, 20, 204–210.

(2) Knight J.E., Swensson E.J. & Sherwood H. (1997) Elk use of modified fence-crossing designs. *Wildlife Society Bulletin*, 25, 819–822.

3.22. Install mammal crossing points along fences on farmland

https://www.conservationevidence.com/actions/2410

- **Four studies** evaluated the effects on mammals of installing mammal crossing points along fences on farmland. Two studies were in Namibia[2,4] and one each was in the USA[1] and the UK[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (4 STUDIES)

- **Use (4 studies):** A study in the USA[1] found that pronghorn antelopes crossed a modified cattle grid which prevented escape of domestic sheep and cows. A controlled, before-and-after study in Namibia[2] found installing swing gates through game fencing reduced the digging of holes by animals under the fence, whilst preventing large predator entry. A study in the UK[3] found that a vertical-sided ditch under an electric fence allowed access by otters. A before-and-after study in Namibia[4] found that tyres installed as crossings through fences were used by wild mammals and reduced fence maintenance requirements.

Background

Fences erected to retain domestic livestock or, in some cases, exclude wild herbivores or carnivores may also act as a barrier to non-target species. Crossings may be installed to retain habitat connectivity for specific species. Crossing designs vary between different situations depending on the nature of the original fence and the species being targeted for continued access.

For wildlife-permeable fencing (as opposed to specific crossing points) see *Use livestock fences that are permeable to wildlife*.

A study in 1965 of grassland at a site in Wyoming, USA (1) found that a modified pass based on a cattle grid design enabled passage by pronghorn antelopes *Antilocapra americana* whilst preventing escape of domestic sheep and cows. A total of 100 antelope were observed jumping across the grills, during five separate crossing events. Antelopes crossed grills at fence corners more than they crossed those along straight fences. A range of designs were trailed, the optimal being a 6-foot-long grill in a 5.5-foot-wide fence opening. The grill consisted of 13 bars at 6 inch-intervals. These were mounted on 10-inch-high timbers with earth ramps running up to both ends.

A controlled, before-and-after study in 2001–2002 on a game and livestock farm in Otjiwarongo district, Namibia (2) found that installing swing gates along animal routes in game fencing reduced the digging of holes by animals under the fence, whilst preventing large predator entry. Fewer holes were dug under a fence section with gates installed on animal routes (12.2 holes/survey) than on sections with evenly spaced gates (20.2 holes/survey) or no gates (19.1 holes/survey). Before gate installation, there was no significant difference in hole numbers between sections (animal route gates: 20.0 holes/survey; evenly spaced gates: 25.7 holes/survey; no gates: 21.7 holes/survey). Warthogs *Phacochoerus aethiopicus* were the most frequent gate users. Jackals *Canis mesomelas*, cheetahs *Acinonyx jubatus* and leopards *Panthera pardus* passed through holes but not the gates. A game fence (4,800 m long) was divided into three equal sections. One had six gates on established animal routes, one had eight evenly spaced gates and one had no gates. Swing gates comprised a metal frame (45 × 30 cm) covered with galvanised fencing (75-mm mesh). Holes were surveyed and filled at 3–15-day intervals, from August 2001 to April 2002. Animals were identified by signs and heat sensitive cameras.

A study in 2005 at a wetland reserve in Cambridgeshire, UK (3) found that a vertical-sided ditch under an electric fence allowed access to the site by otters *Lutra lutra*. Several otter spraints were found within the fenced area. Some were at the edge of the ditch under the fence, indicating probable otter use of that route. No evidence of red foxes *Vulpes vulpes* using the route was identified. The ditch, 1 m deep and 3 m wide, flowed under the boundary of the fenced reserve. Ditch sides were supported by wooden boards, to maintain the banks as vertical, so that entry could only be achieved by swimming. The fence, 1.3 m high and 2 km long, was electrified year-round. It was installed in 2005 to deter entry by foxes, for the purpose of reducing predation on nesting birds.

A before-and-after study in 2010 on a farm in Namibia (4) found that tyres installed as passageways through fences facilitated movements of wild mammals, especially carnivores, and reduced fence maintenance requirements. During 96 days, 11 mammal species, including nine carnivores, used one crossing. The most frequently recorded species were black-backed jackal *Canis mesomelas* (44 occasions), porcupine *Hystrix africaeaustralis* (21 occasions) and cheetah *Acinonyx jubatus* (nine occasions, seven different animals). Fewer fence holes needed mending after tyre installation (13.6 holes/day) than before (31.3 holes/day). Forty-nine discarded car tyres (37 cm radius opening) were installed at ground level into a 19.1-km-long, 2.4-m-high fence. Tyre locations, 35–907 m apart, were prioritised to areas of high warthog *Phacochoerus africanus* digging activity. One tyre was monitored with a camera trap for 96 days from August–December 2010. Holes needing maintenance were counted for 10 days before and 10 days after tyre installation.

(1) Mapston R.D., Zobell R.S., Winter K.B. & Dooley W.D. (1970) A pass for antelope in sheep-tight fences. *Journal of Range Management*, 23, 457–459, https://doi.org/10.2307/3896324

(2) Schumann M., Schumann B., Dickman A., Watson L.H. & Marker L. (2006) Assessing the use of swing gates in game fences as a potential non-lethal predator exclusion technique. *South African Journal of Wildlife Research*, 36, 173–181.

(3) Gulickx M.M.C., Beecroft R.C. & Green A.C. (2007) Creation of a 'water pathway' for otters *Lutra lutra*, under an electric fence at Kingfishers Bridge, Cambridgeshire, England. *Conservation Evidence*, 4, 28–29.

(4) Weise F.J., Wessels Q., Munro S. & Solberg M. (2014) Using artificial passageways to facilitate the movement of wildlife on Namibian farmland. *South African Journal of Wildlife Research*, 44, 161–166, https://doi.org/10.3957/056.044.0213

3.23. Use traditional breeds of livestock

https://www.conservationevidence.com/actions/2411

- **One study** evaluated the effects of using traditional breeds of livestock on wild mammals. This study was carried out in four European countries[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (1 STUDY)

- **Use (1 study):** A replicated, randomized, controlled study in Europe[1] found that European hares did not use areas grazed by traditional livestock breeds more than they used areas grazed by commercial breeds.

Background

Traditional livestock breeds are often suggested to help enhance biodiversity, though motivations for doing so are often little studied and rely on anecdotal evidence (Rook *et al.* 2004).

Rook A.J., Dumont B., Isselstein J., Osoro K., Wallis De Vriese M.F. Parente G. & Mills J. (2004) Matching type of livestock to desired biodiversity outcomes in pastures — a review. *Biological Conservation*, 119, 137–150, https://doi.org/10.1016/j.biocon.2003.11.010

A replicated, randomized, controlled study in 2002–2004 on grassland in France, Germany, Italy and the UK (1) found that areas grazed by traditional livestock breeds did not have more European hares *Lepus europaeus* than did areas grazed by commercial breeds. Too few hares were recorded to enable statistical analyses. At the UK site, where most hares were recorded, numbers were similar between areas grazed by traditional breeds (15 hares) and commercial breeds (14 hares). Traditional cattle breeds were Devon, German Angus and Salers, compared with commercial Charolais × Fresian, Simmental and Charolais, in the UK, Germany and France respectively. In Italy traditional Karst sheep were compared with commercial Finnish Romanovs. There were three traditional breed paddocks and three commercial breed paddocks (paddock size 0.4–3.6 ha) at single sites in each of the four countries. Hares were counted every two weeks in early morning, from May to October of 2002–2004, during seven minutes of observation and by walking a transect in each paddock.

(1) Wallis De Vries M.F., Parkinson A.E., Dulphy J.P., Sayer M. & Diana E. (2007) Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 4. Effects on animal diversity. *Grass and Forage Science*, 62, 185–197, https://doi.org/10.1111/j.1365-2494.2007.00571.x

3.24. Change type of livestock

https://www.conservationevidence.com/actions/2412

- **Two studies** evaluated the effect of changing type of livestock on mammals. One study was in the UK[1] and one was in the Netherlands[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Abundance (2 studies):** One replicated, randomized, paired sites, controlled, before-and-after study in the UK[1] found that sheep and cattle grazing increased field vole abundance relative to sheep-only grazing. One replicated, randomized, paired sites study in the Netherlands[2] found that cattle grazing increased vole abundance relative to horse grazing.

BEHAVIOUR (0 STUDIES)

Background

Domestic herbivores differ in the way that they graze. In particular, some species are more selective than others, and so will concentrate grazing in areas with highly palatable plant species. This may generate different effects on vegetation dynamics than does grazing by more generalist herbivores (Evans *et al*. 2015). Furthermore, large herbivores, such as cattle, may disturb the ground more through their footprints than is the case for smaller grazers, such as sheep. Such effects may produce a vegetation sward and structure than is more or less suited for wild mammals.

Evans D.M., Villar N., Littlewood N.A., Pakeman R.J., Evans S.A., Dennis P., Skartveit J. & Redpath S.M. (2015) The cascading impacts of livestock grazing in upland ecosystems: a 10-year experiment. *Ecosphere*, 6, article 42, https://doi.org/10.1890/ES14-00316.1

A replicated, randomized, paired sites, controlled, before-and-after study in 2002–2004 on an upland grassland site in Scotland, UK (1) found that, after two years, grazing with sheep and cattle increased field vole *Microtus agrestis* abundance relative to sheep-only grazing. In the first year of the experiment, a similar proportion of quadrats had signs of voles in sheep and cattle plots (11%) and sheep only plots (12%). In the second year, the proportion with vole signs was higher in sheep and cattle (16%) than sheep only plots (11%). Before the experiment began, there was no difference in the frequency of vole signs between plots. Plots were grazed similarly up to 2002 (rate not stated). From 2003, there were six replicates (each 3.3 ha) of sheep and cattle grazing (two ewes/plot and, for four weeks/year, two cattle each with a suckling calf) and sheep only grazing (three ewes/plot). Treatments were designed to have similar overall grazing intensity. Five 25 cm × 25 cm quadrats at each of five points in each plot were searched for vole signs in April and October of 2002–2004.

A replicated, randomized, paired sites, controlled study in 2010–2013 on a coastal salt marsh in the Netherlands (2) found that plots grazed by cattle contained more signs of vole *Microtus* spp. presence than did plots grazed by horses. After four years, a greater proportion of surveyed quadrats contained signs of vole presence in plots grazed by cattle than in plots grazed by horses (data not reported). Twelve plots were established (in three sets of four plots) on a grazed salt marsh. From 2010, six plots (two random plots/set) were grazed by each livestock type: cows (600 kg) or horses (700 kg). Grazing occurred in summer (June–October) only. Half of the plots were grazed at high intensity (1.0 animal/ha) and half were grazed at low intensity (0.5 animals/ha). In October 2013, sixty quadrats (2 m^2) were surveyed in the higher elevations of each plot for signs of vole presence (runways, fresh plant fragments or faecal pellets). Some flooded quadrats were excluded from analyses.

(1) Evans D.M., Redpath S.M., Elston D.A., Evans S.A., Mitchell R.J. & Dennis P. (2006) To graze or not to graze? Sheep, voles, forestry and nature conservation in the British uplands. *Journal of Applied Ecology*, 43, 499–505, https://doi.org/10.1111/j.1365-2664.2006.01158.x

(2) van Klink R., Nolte S., Mandema F.S., Lagendijk D.D.G., Wallis De Vries M.F., Bakker J.P., Esselink P. & Smit C. (2016) Effects of grazing management on biodiversity across trophic levels — the importance of livestock species and stocking density in salt marshes. *Agriculture, Ecosystems & Environment*, 235, 329–339, https://doi.org/10.1016/j.agee.2016.11.001

Reduce human-wildlife conflict

3.25. Relocate local pastoralist communities to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2413

- **One study** evaluated the effects on mammals of relocating local pastoralists to reduce human-wildlife conflict. This study was in India[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A study in India[1] found that after most pastoralists were relocated outside of an area, Asiatic lion numbers increased.

BEHAVIOUR (0 STUDIES)

Background

Species conservation can conflict with interests of local communities that own and manage grazing livestock. An intervention occasionally enacted is to relocate pastoralist communities to areas further away from the threatened species.

A study in 1974–2010 of forest and savanna in one area in Gujarat, India (1) found that after most pastoralists were relocated outside of the area, Asiatic lion *Panthera leo persica* numbers increased. The lion population increased during the study period from 180 in 1974 to 411 individuals 36 years later. This coincided with increased abundance of wild ungulates from 5,600 individuals prior to the start of the study, in 1969–1970, to 64,850 individuals in 2010. Scat analysis showed that domestic livestock formed 75% of lions' diets four years before the main study period which fell to 25% at the end of the study. A wildlife sanctuary was created in 1965 and was expanded and declared a National Park in 1975. Four further areas were protected between 1989 and 2007. Three core protected areas covered 1,452 km^2. Over two thirds of indigenous pastoral Maldharis and their livestock were relocated from the area, commencing in 1972. The number of domestic buffalo and cattle in the protected areas fell from 24,250 animals in the 1970s to 12,500 in the mid-1980s but then increased to 23,440 in 2010. Lions were visually surveyed at 5–6-year intervals, from 1974–2010.

(1) Singh H.S. & Gibson L. (2011) A conservation success story in the otherwise dire megafauna extinction crisis: The Asiatic lion (*Panthera leo persica*) of Gir forest. *Biological Conservation*, 144, 1753–1757, https://doi.org/10.1016/j.biocon.2011.02.009

3.26. Pay farmers to compensate for losses due to predators/wild herbivores to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2414

- **Five studies** evaluated the effects on mammals of paying farmers compensation for losses due to predators or wild herbivores to reduce human-wildlife conflict. Three studies were in Kenya[1,3,5] and one each was in Italy[2] and Sweden[4].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (5 STUDIES)

- **Abundance (2 studies):** Two studies, in Italy[2] and Sweden[4], found that compensating livestock owners for losses to predators led to increasing populations of wolves[2] and wolverines[4].
- **Survival (3 studies):** Three before-and-after studies (including two replicated studies), in Kenya[1,3,5], found that when pastoralists were compensated for livestock killings by predators, fewer lions were killed.

BEHAVIOUR (0 STUDIES)

Background

Where farmers suffer losses to wild mammals, either through predation of livestock or damage to crops, they may carry out lethal control of those mammals. Compensation schemes provide payments for losses to wild mammals and can have certain conditions, such as cessation of using lethal control or improving animal husbandry to reduce losses. The intervention includes schemes that make payments linked directly to losses (e.g. paying for each animal predated) and schemes that where payment is not linked directly to losses but instead to other mechanism that reduce incentives for killing wild mammals.

A before-and-after, site comparison study in 2001–2006 on a group ranch in Kajiado District, Kenya (1) found that compensating pastoralists for livestock predated by lions *Panthera leo* reduced the number of lions that pastoralists killed. Fewer lions were killed after the compensation fund commenced (five in 2003–2006) than before the fund commenced (24 in 2001–2002). Across five other group ranches, which lacked compensation funds, lion killings rose from nine in 2003 to 20 in 2004, 17 in 2005 and 32 in 2006. The lion population on the ranch where compensation was paid did not rise during the study period. The scheme was suspended from June 2003 to January 2004, April–June 2005 and in October 2005. At other times, pastoralists were compensated at market values for verified livestock losses to predators. Lower payments were made in cases of suboptimal animal husbandry. Fines were imposed for killing lions or other large predators.

A study in 1999–2009 of pasture and forest in Piedmont, Italy (2) found that when compensation was paid for livestock losses to wolves *Canis lupus* and dogs *Canis lupus familiaris*, an already expanding wolf population continued to grow. Over 11 years, the number of wolf packs increased from five to 20. Over the first five of these years, the annual number of attacks by wolves or dogs on livestock rose from 47 to 156. It then remained between 95 and 154 over the following six years. The scheme was established in 1999 to mitigate farmer-wolf conflict in a region with a recolonizing wolf population. Herders were compensated for livestock losses to wolves or dogs (as it is difficult to differentiate casualties due to these predators) and paid lump sums for indirect damages. From 2006, eligibility required using subsidised predation prevention measures, such as livestock guarding dogs, corrals and night confinement.

A replicated, before-and-after study in 2003–2011 of savanna grassland across three adjacent group ranches in southern Kenya (3) found that compensating for livestock predated by lions *Panthera leo* reduced lion killings by pastoralists. Prior to offering compensation, up to 25 lions/year were killed on two ranches and up to 10/year on the third. After introducing compensation payments, 2–15 lions/year were killed on two ranches and none was recorded killed on the third ranch. Compensating for loses was overall estimated to reduce lion killing by 87–91%. Compensation was paid for verified livestock losses to lions at the three group ranches between 2003 and 2008. Lion mortality data from 2003 to 2011 were collated primarily from community informants and direct interviews with lion hunters.

A study in 1996–2011 on tundra in northern Sweden (4) found that compensating reindeer herders for losses to wolverines *Gulo gulo* by paying for successful wolverine reproduction events was associated with an increase in wolverine abundance. The wolverine population grew at an annual rate of 4%. Male wolverines had a higher annual risk of being illegally killed (21%) than did female wolverines (8%), suggesting that payments were a greater disincentive to illegal killing of females. From 1996, payment rates to reindeer herders changed from being dependent on losses to predation to payment for documented wolverine reproductions (irrespective of predation levels). Population demography data were obtained from 95 wolverines (≥2 years old) radio-tracked in 1996–2011.

A before-and-after study in 2002–2013 in a savanna group ranch in the Amboseli–Tsavo ecosystem, Kenya (5) found that after introduction of a scheme to compensate for livestock killed by predators, fewer lions *Panthera leo* were killed or poisoned by pastoralists. Fewer lions were killed and poisoned during the six years after the scheme started (killed: 6; poisoned: 0) than the six years before (killed: 33; poisoned: 12). The number of livestock killed by lions did not differ significantly between the five years after the scheme commenced (cattle: 47–144/year; sheep and goats: 6–104/year) and the year before (cattle: 109; sheep and goats: 43). The study was conducted in a 1,133-km^2 group ranch, inhabited by 17,000 people and 20–30 lions. A compensation scheme for livestock killed by predators commenced in 2008. Livestock owners could claim between 35% and 70% of the market value of depredated livestock. The number of lions killed directly or poisoned was monitored between 2002 and 2013.

(1) Maclennan S.D., Groom R.J., Macdonald D.W. & Frank L.G. (2009) Evaluation of a compensation scheme to bring about pastoralist tolerance of lions. *Biological Conservation*, 142, 2149–2427, https://doi.org/10.1016/j.biocon.2008.12.003

(2) Dalmasso S., Vesco U., Orlando L., Tropini A. & Passalacqua C. (2012) An integrated program to prevent, mitigate and compensate Wolf (*Canis lupus*) damage in the Piedmont region (northern Italy). *Hystrix, the Italian Journal of Mammology*, 23, 54–61, https://doi.org/10.4404/hystrix-23.1-4560

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3.27. Install non-electric fencing to exclude predators or herbivores and reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2415

- **Eight studies** evaluated the effects on mammals of installing non-electric fencing to exclude predators or herbivores and reduce human-wildlife conflict. Two studies were in the USA[1,2] and one each was in Germany[3], the UK[4], Spain[5], China[6], Tanzania[7] and Kenya[8].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (8 STUDIES)

- **Human-wildlife conflict (8 studies):** Four replicated studies (including three before-and-after studies), in USA[1], China[6], Tanzania[7] and Kenya[8], found that non-electric fencing reduced livestock predation by coyotes[1], Tibetan brown bears[6], and a range of mammalian predators[7,8]. A replicated, controlled study in USA[2] found that a high woven wire fence with small mesh, an overhang and an apron (to deter burrowing) was the most effective design at deterring crossings by coyotes. A replicated, controlled study in Germany[3] found that fencing with phosphorescent tape was more effective than fencing with normal yellow tape for deterring red deer and roe deer, but had no effect on crossings by wild boar or brown hare. Two studies (one replicated, before-and-after, site comparison and one controlled study) in the UK[4] and Spain[5] found that fences reduced European rabbit numbers[4] on or damage to[5] crops.

Background

Wild mammals can compete with domestic herbivores for food, can predate domestic herbivores or can damage crops. Human-wildlife conflict can be reduced if wild mammals can be effectively excluded from fields or other areas of crops or livestock. Non-electric fences are extensively used and can reduce the risk of wild mammal incursions into such sites. If successful, this could reduce incentives for carrying out lethal control of such mammals. Non-electric fences may be more suited to more extensive farming situations than are electric fences, as they may require less maintenance. This intervention also includes fortification of bomas (traditional livestock enclosures constructed by pastoralists) using conventional fencing materials such as fence wires.

A replicated, before-and-after, site comparison study in 1972–1977 in two pasture ranches in Oregon, USA (1) found that following erection of a fence to protect sheep, the number killed by coyotes *Canis latrans* was reduced to zero. Results were not tested for statistical significance. Over one year after fencing, no sheep were lost to coyotes in two fenced pastures. During the five years before fences were installed, 2% of sheep/pasture/year were killed by coyotes across one ranch and 24% across the other. On unfenced pastures on one of the ranches, 1% of sheep were lost to coyotes in the year that the fenced pasture was monitored, with 10% lost to coyotes on unfenced pastures on the other ranch. Two 5-ha pastures were fenced in November–December 1976. Fences were 1.8 m tall, made of wire, had a 41-cm overhang at a 60° angle from the fenced poles and an apron of old fence wire extending 61 cm out from the bottom, to inhibit digging under the fence. Ranchers monitored sheep kills by coyotes.

A replicated, controlled study in 1975–1976 in a captive facility in Oregon, USA (2) found that a high woven wire fence with small mesh, an overhang and an wire apron projecting out from the fence base (to deter burrowing) was the most effective of 34 fence designs at deterring crossings by coyotes *Canis latrans*. Fence performance varied from 0 to 71% of coyotes failing to cross fences. The best-performing non-electric fence prevented more crossings (14 of 15 trials) than did the best-performing electric fence (11 of 15 trials) or a standard sheep fence (6 of 15 trials). One of two coyotes, which had already crossed a standard sheep fence, crossed the best-performing fence during each of two tests whilst the other failed to cross it during four tests. Best-performing fence measurements were not stated explicitly but the paper recommends fences are ≥168 cm high, with mesh ≤15.2 × 10.2 cm and with an overhang and apron of ≥38 cm. Initial tests involved 10 coyotes, conditioned to walk a route, with 34 fence designs sequentially installed on the route. Subsequent trials, with five new coyotes, tested their ability to cross fences to reach a tethered rabbit. In final trials, coyotes that crossed a standard sheep fence and killed a tethered rabbit were tested using the best-performing fence design. Coyotes were wild caught. Trials were conducted from April 1975 to March 1976.

A replicated, controlled study in 1997 of four grassland fields and one cultivated field in central Germany (3) found that fencing with phosphorescent tape was more effective than fencing with normal yellow tape for deterring red deer *Cervus elaphus* and roe deer *Capreolus capreolus*, but had no effect on crossings by wild boar *Sus scrofa* or brown hare *Lepus europaeus*. At four grazing sites, areas surrounded by phosphorescent tape were avoided by red deer for four months and by roe deer for three weeks. Red deer entered areas fenced with yellow non-phosphorescent tape after one week and roe deer after one day. All deer species kept out of an area of willow fenced with phosphorescent strips for three weeks. After that, roe deer (but not red deer) tracks were found within the area. Wild boar and brown hare movements were not affected by tapes. PVC tape (4 cm wide) was attached 1 m high on 1.3-m iron posts. Four game grazing fields each had two 300-m^2 areas fenced off using phosphorescent strips and two with non-phosphorescent tape. After two months, all four areas were mown and the type of fencing was swapped. Mammal presence was assessed from droppings and tracks.

A replicated, before-and-after, site comparison study in 1980–1983 on 23 arable sites in southern UK (4) found that wire netting fences reduced European rabbit *Oryctolagus cuniculus* numbers on crops. Rabbit numbers on plots protected by fences with a buried fence base were lower 0–4 weeks after erection (7 rabbits/count) and 5–20 weeks after erection (7 rabbits/count) than before erection (41 rabbits/count). Numbers were also lower on plots protected by fences with the base folded horizontally along the ground 0–4 weeks after erection (11 rabbits/count) and 5–20 weeks after erection (7 rabbits/count) than they were before erection (45 rabbits/count). Rabbit numbers in unfenced plots remained constant throughout (0–4 weeks after erection: 16 rabbits/count; 5–20 weeks after erection: 13 rabbits/count; before erection: 14 rabbits/count). Fences (0.9 m high) were erected along one side of winter barley fields. Fences had bases buried 150 mm deep and then projecting horizontally underground for 150 mm (six sites), or laid out horizontally for 150 mm at ground level (seven sites). Ten unfenced sites were also monitored. Adult rabbits were counted using spotlights and binoculars in November–April between 1980 and 1983.

A controlled study in 2008 at three vineyards in Córdoba province, Spain (5) found that fencing reduced damage by European rabbits *Oryctolagus cuniculus* to common grape vines *Vitis vinifera* and resulted in greater grape vine yields. Grape vines within fenced plots had a lower percentage of buds and shoots removed by rabbits (0.5%) and greater yields (7 kg/vine) than unfenced plots (21%; 4.7 kg/vine). Each of three vineyard sites had a fenced plot and an unfenced plot. Fences were checked weekly. No details are provided about the fencing design. The proportion of buds and shoots removed by rabbits on 15–20 vines/plot was recorded throughout the growing season in 2008. Grape vine yields were estimated during harvest from the number and size of grape clusters on each vine.

A replicated, before-and-after study in 2008–2009 of 19 households in Tibetan Autonomous Region, China (6) found that households fenced to exclude predators experienced fewer visits and lower rates of livestock predation by Tibetan brown bears *Ursus arctos pruinosus*. Results were not tested for statistical significance. In the year after fence installation, there were fewer bear visits (2.4/household) than in the year before (5.3/household). In the year after fence installation, fewer livestock were lost to bears (0.2/household) than in the year before (11.6/household). Fourteen fences were constructed around 19 households (some fences enclosed >1 household) and associated livestock in 2008. Fences were constructed of wire mesh (with mesh diagonal dimensions of ≤30 cm) and barbed wire, set on a steel frame. Each fence enclosed 120–1,000 sheep and goats. Bear visits and predation events were recorded by householders.

A replicated, before-and-after, site comparison study in 2003–2013 around two villages and associated pasture in Tanzania (7) found that fortifying bomas with trees and chain link fencing resulted in reduced predation of livestock by large mammalian predators. There was a lower rate of attacks by large predators on livestock in bomas after fortification (0.001 attacks/boma/month) than before (0.012 attacks/boma/month). Including bomas that remained unfortified throughout the study, the attack rate was lower overall on fortified bomas (0.001 attacks/boma/month) than on unfortified bomas (0.009 attacks/boma/month). Between 2008 and 2013, 62 of 146 traditional bomas (built mainly from thorny branches) were fortified with 'living walls' (which combined fast-growing, thorny trees *Commiphora* sp. as fence posts at 0.5-m intervals, connected with chain link fencing). The average cost of the chain link was US$500/boma. Bomas were monitored for predator attacks from September 2003 to August 2013 (excluding January–February of 2006 and 2010).

A replicated, site comparison study in 2013–2015 of 308 savanna households in Narok County, Kenya (8) found that fewer livestock were lost to mammalian predators from fortified fenced areas than from traditional thorn-bush-fenced areas. Households holding their livestock in fortified fences lost fewer on average to predators (0.35 animal/month) than did households with livestock in traditional fenced areas (0.96 animals/month). The proportion of households not losing any livestock to mammalian predators over a year was higher for those using fortified fences (67%) than for those using traditional fences (15%). Mammalian predators included lions *Panthera leo*, leopards *Panthera pardus*, wild dogs *Lycaon pictus*, spotted hyenas *Crocuta crocuta*, honey badgers *Mellivora capensis*, cheetahs *Acinonyx jubatus* and baboons *Papio* sp. The study was based on 375 interviews, carried out from April 2013 to July 2015, with 308 Maasai households that housed livestock in fenced areas (bomas). Including some that were upgraded during the study, 179 households used fences fortified with posts, chain link wire and galvanized wire and 164 households used traditional fences made of thorny plants and branches during some or all of the period.

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3.28. Install electric fencing to reduce predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2417

- **Eleven studies** evaluated the effects of installing electric fencing to reduce predation of livestock by mammals to reduce human-wildlife conflict. Six studies were in the USA[2,4a,4b,4c,6,7] (and a further one was presumed to be in the USA[1]) and one each was in Canada[3], South Africa[5], Brazil[8] and Spain[9].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (11 STUDIES)

- **Human-wildlife conflict (11 studies):** Six out of 10 randomized and/or controlled or before-and-after studies (including eight replicated studies), in the USA[2,4a,4b,4c,6,7] (and a further one presumed to be in the USA[1]), Canada[3], Brazil[8] and Spain[9], found that electric fences reduced or prevented entry to livestock enclosures or predation of livestock by carnivores[1,3,4c,6,7,9]. Two studies[4a,4b] found that some designs of electric fencing prevented coyotes from entering enclosures and killing or wounding lambs. The other two studies found electric fencing did not reduce livestock predation or prevent fence crossings by carnivores[2,8]. A before-and-after study in South Africa[5] found that electrifying a fence reduced digging of burrows under the fence that black-backed jackals could pass through.

Background

Wild predatory mammals can come into conflict with humans if they predate domestic livestock. This conflict can be reduced if wild mammals can be effectively excluded from livestock enclosures. Electric fences are one means of doing this. If successful at reducing predation of livestock by carnivores, this could reduce incentives for carrying out lethal control of such species.

A replicated, controlled study (year not stated) of pasture at an undisclosed location, presumed to be in the USA (1) found that electric fencing prevented coyotes *Canis latrans* from entering an enclosure and killing lambs. During three trials, coyotes did not kill any of eight lambs in an enclosure surrounded by electric fencing but, in each trial, all eight lambs in an enclosure with conventional fencing were killed in 8–9 days. Two sheep enclosures (each 8,000 m^2) were constructed within a coyote-proof 64-ha pasture. One enclosure had a 12-wire electric fence, 1.5 m high, with an additional electrified wire 20 cm outside the enclosure and 15 cm above the ground. The other enclosure had conventional wire fencing (81-cm woven wire with two strands of barbed wire, 15 cm apart, above the woven wire). For each of three trials, each lasting two weeks, a pair of wild-born captive coyotes was released into the pasture and eight lambs were placed in each of the two enclosures and observed daily. A different coyote pair was used for each trial.

A replicated, controlled study in 1975–1976 in a captive facility in Oregon, USA (2) found that most coyotes *Canis latrans* crossed electric fences and all 18 electric fence designs trialled were crossed by at least some coyotes. Coyotes crossed fences in 48–100% of the 20–30 tests/design. The most successful design (crossed in 13 of 27 tests) included three low-down electric wires laid out horizontally from the main vertical conventional fence (99-cm-high woven wire with two barbed wires above and one at the base). See paper for further details of fence designs. Tests involved 10 coyotes, conditioned to walk a route. Electric fences of 18 designs were sequentially placed along this route and

20–30 tests were conducted for each to see if coyotes would cross. The 18 designs represented modifications of standard fences used to house livestock in the study area, supplemented with wires charged by a 12-V battery. Trials were conducted from April 1975 to March 1976 and lasted each time for 10–15 minutes.

A replicated, before-and-after study in 1974–1978 on five farms in an area of boreal mixed-wood forest of Alberta, Canada (3) found that installing electric fences reduced the numbers of sheep killed by coyotes *Canis latrans*. These results were not tested for statistical significance. During the three years after electric fences were installed at five farms, fewer sheep were killed by coyotes (26) than during the three years before the electric fences were installed (147). The study was conducted in five farms, each covering 6–65 ha. An annual average of 44–550 sheep grazed at each farm in May–October. Between 0.8 and 3.2 km of electric fences were installed at each farm in 1976–1977. At two farms, fences had one or two strands of barbed wire spaced 15 cm apart above 81-cm-high woven wire, with a charged wire placed 15 cm above the ground and another 12 cm from the fence around the outside perimeter. At three farms, the fence was made of seven 2.7-mm wires alternating charged and grounded. Predation losses were reported by farmers.

A replicated, controlled study in 1977 at two sheep ranches in North Dakota, USA (4a) found that 12-wire electric fencing prevented coyotes *Canis latrans* from entering enclosures and killing lambs, but 6-wire electric fencing did not. At both ranches, 12-wire electric fencing prevented coyotes from killing lambs for at least 60 days, but 16–17 lambs were killed in 22–68 days in enclosures with conventional fencing. At one ranch, lambs were also killed in enclosures with 6–wire electric fencing (nine lambs killed in 20 days) and 6–wire electric fencing with a 'trip' wire (four lambs killed in four days). Two sheep ranches each had one enclosure with electric fencing (wires alternately charged) and one enclosure with conventional fencing (five strands of barbed wire, 104 cm high). Both ranches tested 12-wire electric fencing (168 cm high) for 60 days and conventional fencing for 22–68 days. One ranch tested 6-wire electric fencing (78 cm high) with and without an additional 'trip' wire (25 cm high, 51 cm from the fence) for four and 20 days respectively. All enclosures (1–1.5 ha) were kept stocked with 10 lambs and checked every other day for coyote kills during each of the six trials.

A replicated, before-and-after study in 1978 at two sheep ranches in Kansas, USA (4b) found that adding five electric wires to the outside of conventional fencing prevented coyotes *Canis latrans* from entering enclosures and killing or wounding lambs, but results varied when fewer wires were used. At one ranch, lambs were killed by coyotes in an enclosure with no electric wires (five lambs killed in 105 days) and four electric wires (one lamb killed in 17 days), but after adding a fifth wire no lambs were killed for at least 60 days. At the other ranch, lambs were killed or wounded in an enclosure with no electric wires (11 lambs killed in 11 days) and two electric wires (nine lambs killed or wounded in 14 days), but after adding two additional wires (total of four) no lambs were killed for at least 60 days. Two sheep ranches each had one enclosure (0.9–1.8 ha) with conventional fencing (woven wire and 1–2 strands of barbed wire, 110 cm high). At each ranch, enclosures were kept stocked with 10–20 lambs and checked for coyote kills during one trial (11–105 days) with conventional fencing only and two trials (11–60 days) with 2–5 electric wires added.

A replicated, before-and-after study in 1979 of 14 sheep producers in the USA (4c) found that installing electric fences or electric wires reduced predation of sheep by coyotes *Canis latrans*. Overall, the total number of sheep killed by coyotes was lower during a total of 228 months and 22 lambing seasons after electric fences or wires were installed (51 sheep) compared to during a total of 271 months and 27 lambing seasons before (1,064 sheep). However, the difference was not tested for statistical significance. In 1979, a total of 37 sheep producers using electric fencing or electric wires offset from existing conventional fencing were interviewed with a questionnaire. Fourteen responded with adequate information to compare sheep losses before and after electric fencing or wires were installed. Most respondents were reported to check their sheep at least once/day. Two-thirds answered questions from memory rather than written records.

A before-and-after study in 1983–1985 in a dry shrubland site in Cape Province, South Africa (5) found that electrifying a fence reduced digging of burrows under the fence that could then be used by black-backed jackals *Canis mesomelas* to enter and predate livestock. Fewer holes were dug under the fence after it was electrified (0–11 holes/week) than before (17–87 holes/week). Where the digger could be identified, holes were dug by black-backed jackals, warthogs *Phacochoerus africanus*, porcupines *Hystrix africaeaustralis*, bushpigs *Potamochoerus larvatus* and antbears *Orycteropus afer*. A 13.75-km-long game fence, that shared a boundary with five farms, was electrified by adding electric wires 250 mm away from both sides of the fence, 200 mm above the ground. The fence was monitored weekly for burrows for 33 weeks before electrification (September 1983 to May 1984) and for 44 weeks after (August 1984 to June 1985).

A replicated, before-and-after study in 1984–1985 of 51 sheep producers in Oregon, Washington and California, USA (6) found that installing electric fencing reduced predation of sheep by coyotes *Canis latrans*. The number of sheep killed by coyotes each year was lower during two or more years after electric fencing was installed (average 3.5 sheep/year; 0.3%) than during 1–7 years before (average 41 sheep/year; 3.9%). Results were similar when sheep losses were included for producers that had electric fencing installed for one year only (before: 4.3% of sheep killed; after 0.7% killed; numbers not reported). More producers lost no sheep to coyotes after electric fencing was installed (28 of 51, 55%) than before (5 of 51, 10%). In 1984–1985, a total of 51 sheep producers that used electric fencing were interviewed. Electric fences enclosed areas of 1–1,550 ha containing 20–20,000 sheep. Sheep losses to coyotes were recorded during 1–7 years before electric fencing was installed and during one year (five producers) or two or more years (46 producers) after.

A randomized, replicated, controlled, before-and-after study in 2006 in a captive centre in Minnesota, USA and a replicated, controlled study in 2007 at 12 pastures in Montana, USA (7) found that electric fences with flags attached delayed grey wolf *Canis lupus* and red wolf *Canis rufus* entry. In the captive study, grey wolves and red wolves took longer (10 days) to cross electric fences with flags than non-electric fences with flags (1 day) or unfenced areas (<5 minutes). In the pasture study, wolves never entered pastures with electric fences and flags but twice entered pastures without electric fences and flags. The captive study ran for two weeks, using 45 wolves in 15 packs. Each pack (1–7 animals) was housed in a 105–925-m^2 enclosure. Five packs were offered food (white-tailed deer *Odocoileus virginianus*) positioned within an 18-m^2 electric fence (2,000 V) enclosure with red plastic flags (50 × 10 cm, 50 cm apart), five packs were offered food inside a non-electric fence with flags and five packs were offered food that was not protected by a fence or flags. Animals were monitored 24 hours/day with infra-red cameras. The pasture study was conducted in 12 cattle-grazed pastures (each 16–122 ha) enclosed with conventional barbed wire fences. Six pastures were further protected with electric fences with flags and six were not. Wolf tracks were monitored twice each week for three months.

A before-and-after study in 2006–2008 in a grassland-dominated cattle ranch in Mato Grosso do Sul, Brazil (8) found that after upgrading non-electric fences to become electric fences, a smaller percentage (but larger overall quantity) of cattle losses was due to killings by jaguars *Panthera onca*. These results were not tested for statistical significance. One year after upgrading fences to electric, 10% (50 of 504) of cattle losses were attributed to killings by jaguars. During the two years before non-electric fences were replaced by electric fences 24–85% (11 of 46 in one year and 24 of 28 in the other) of losses were attributed to killings by jaguars. The study was conducted on a 900-ha farm, fenced with five non-electrified wires at heights of 25, 50, 75, 100 and 125 cm. In February 2008, a 13,745-m perimeter fence was supplemented with two electrified wires (5,000–7,000 V), 25 and 50 cm above the ground. About 630 m of the fence was not electrified. Predation losses in the two years before the electric fence was installed were reported by farmers. After the electric fence was installed, losses were recorded by researchers.

A replicated, before-and-after study in 2012–2014 of two sheep flocks in Mediterranean forests and scrubland in Andalusia, Spain (9) found that electric fences prevented night-time predation by Iberian lynx *Lynx pardinus*. Over one winter and two spring lambing seasons following fence installation, no lynx or other predator attacks occurred inside fences. During the winter lambing season before fence installation, there were seven night-time predation events, involving 13 lambs. Electric fences (75 m perimeter, 106 cm high) were installed in early March 2013 (before the spring lambing season) for two sheep flocks. Fences contained a live braided plastic rope. Above the mesh were two 4-cm-wide conductor strips, giving a total height of 160 cm. Fences were powered from a solar rechargeable battery. Sheep were contained at night, but roamed freely, and suffered attacks, during daytime. All predator attacks on the two flocks were documented from December 2012 to May 2014.

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3.29. Exclude wild mammals using ditches, moats, walls or other barricades to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2420

- **Two studies** evaluated the effects of excluding wild mammals using ditches, moats, walls or other barricades to reduce human-wildlife conflict. One study was in Cameroon and Benin[1] and one was in Cameroon[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** Two studies (including one before-and-after study and one site comparison), in Cameroon and Benin[1] and in Cameroon[2], found that fewer livestock were predated when they were kept in enclosures[2], especially when these were reinforced[1].

Background

This intervention includes the use of a range of barriers to prevent access to livestock by mammalian predators. If successful, this could reduce incentives for carrying out lethal control of predators.

A replicated, before-and-after study in 2004–2006 at a national park in Cameroon and a national park in Benin (1) found that when livestock enclosures were reinforced, fewer livestock were predated. In Cameroon, no cattle or pigs were predated from reinforced enclosures compared to six cattle predated (by lions *Panthera leo*) and 20 pigs predated (three by lions, 17 by hyenas *Crocuta crocuta*) from non-reinforced enclosures. In Benin, four cattle were predated (by lions) and 16 pigs (2 by lions, 14 by hyenas) from reinforced enclosures compared to 13 cattle predated (12 by lions, one by hyenas) and 53 pigs (28 by lions, 25 by hyenas) before reinforcements were added. In Cameroon, 75% of pastoralists across six villages in a national park buffer zone upgraded livestock enclosures. Enclosures comprised a thick layer of thorny shrubs and/or earth walls, with a safe gate (wood, or a complete tree *Acacia seyal* crown as a 'gate-plug'). Their performance was compared with that of non-reinforced enclosures over an unspecified period. In Benin, 13 enclosures were improved in 10 villages around a national park. The improved enclosures comprised sundried clay bricks covered with a clay/cement mixture ('banco'), similar to local houses. Livestock predation figures before (2004) and after (2005–2006) improvements were collated.

A site comparison study in 2008 of savanna around a national park in Cameroon (2) found that barricading livestock inside enclosures overnight reduced losses through predation by lions *Panthera leo*. Households owning enclosures lost an average of one animal/year to lion predation compared to two animals/year for households not owning enclosures. Owning enclosures did not reduce overall numbers of livestock predated by all mammalian predators (lions, spotted hyaenas *Crocuta crocuta* and jackals *Canis aureus*) (with enclosure: 4 animals predated/year; without enclosure: 5). However, fewer animals were lost by households that owned solid enclosures (2 animals/year) than those that owned enclosures made of thorny bushes (7 animals/year). In total, 207 resident pastoralists were interviewed for this study. Pastoralists reported the incidence of predation on livestock by large carnivores as well as whether their livestock were confined in enclosures at night. Villages were selected based on the tracking of movements of radio-collared lions.

(1) Bauer H., de Iongh H.H. & Sogbohossou E. (2010) Assessment and mitigation of human-lion conflict in West and Central Africa. *Mammalia*, 74, 363–367, https://doi.org/10.4404/hystrix-26.1-10957

(2) Tumenta P.N., de Iongh H.H., Funston P.J. & Udo de Haes H.A. (2013) Livestock depredation and mitigation methods practised by resident and nomadic pastoralists around Waza National Park, Cameroon. *Oryx*, 47, 237–242, https://doi.org/10.1017/s0030605311001621

3.30. Use flags to reduce predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2421

- **Five studies** evaluated the effects on mammals of using flags to reduce predation of livestock by mammals to reduce human-wildlife conflict. Three studies were in the USA[2,3,4], one was in Italy[1] and one was in Canada[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (5 STUDIES)

- **Human-wildlife conflict (5 studies):** Three studies (including two before-and-after studies and a controlled study), in Italy[1], Canada[2] and the USA[4], found that flags hanging from fence lines (fladry) deterred crossings by wolves[1,2,4] but not by coyotes[4]. A further replicated, controlled study in the USA[5] found that electric fences with fladry were not crossed by wolves. A replicated, controlled, before-and-after study in the USA[3] found that fladry did not reduce total deer carcass consumption by a range of carnivores.

Background

Coloured flags (fladry) hung from fences are thought to deter crossings by wolves *Canis lupus* and potentially other predatory mammals. Thus, the intervention has potential for reducing predation on enclosed livestock. If successful, this could reduce incentives for carrying out lethal control of predatory mammals. The studies include both wild carnivores and captive wolves in experimental trials.

A before-and-after study in 1998 of captive animals in Italy (1) found that installing lines of flags (known as fladry) 50 cm high and ≤ 50 cm apart, deterred passage by gray wolves *Canis lupus*. Of 18 barrier designs trialled, four of five that were not crossed at all by two wolves involved lines of flags 50 cm high, with flags ≤50 cm apart. Three wolves in a larger enclosure made no crossings of a 50-cm-high flag line put in place to prevent access to one sixth, half and five sixths of the enclosure, even when the flag line split the enclosure in half with food placed at the opposite side. Flag lines comprised 50 × 10-cm red or grey flags. Two wolves, in a 120-m^2 enclosure, regularly paced along a fence line and barriers were set along this route. Three wolves, in an 850-m^2 enclosure, were excluded from varying proportions by flag lines. In all trials, wolves were observed for 30 minutes before and 30 minutes after each flag line was installed.

A replicated, before-and-after study in 2001–2002 on two pastures in Alberta, Canada (2) found that installing flags along fences (known as fladry) deterred wolves *Canis lupus* from entering pastures and predating livestock. Results were not tested for statistical significance. Before flags were installed, wolves approached pastures 2–7 times and predated livestock 2–5 times. With flags installed, wolves approached pastures 6–17 times but did not enter or predate livestock. After flags were removed, wolves approached twice and predated livestock 0–2 times. Plastic flags were placed at 50-cm intervals, suspended 50 cm above the ground on rope, 2 m out from the livestock fence. Two pastures (c.25 ha, 150 km apart) were studied. Each contained 100 cattle. Wolves were monitored by tracking signs in the snow, in winters of 2001 and 2002. Monitoring covered 60 days before flag installation, 60 days with flags installed and 60 days after flag removal.

A replicated, controlled, before-and-after study in 2002 of forest at six sites in Wisconsin, USA (3) found that installing lines of coloured flags (known as fladry) did not reduce overall deer carcass consumption by carnivores. Before installation, average consumption did not differ between carcasses assigned to treatments (flags: 2.0 kg/day; no flags: 1.6 kg/day). After flags were installed, consumption at these plots (2.5 kg/day) did not differ significantly from that at plots with no deterrent (3.3 kg/day). Wolves *Canis lupus*, black bears *Ursus americanus*, fishers *Martes pennanti* and foxes *Vulpes vulpes* visited plots. Study plots (30-m circumference) were established within territories of each of six wolf packs. A fresh deer carcass was placed in each plot. Plots were maintained for 9–35 days pre-treatment and 16–29 days during the treatment phase. The study ran during April–June 2002. Red flagging (100 × 7.5 cm) was suspended from perimeter ropes and was used at one plot in each territory and one plot had no deterrent. Carcasses were weighed every 2–3 days and replaced as required. Camera traps at three territories identified species visiting plots.

A replicated, randomized, controlled study in 2004–2005 in eight pasture and forest sites in Michigan, USA (4) found that tying coloured flags to a fence (known as fladry) reduced visits to pastures by gray wolves *Canis lupus* but not by coyotes *Canis latrans.* Fewer wolves were found in pastures where flags were used (0.3 visits/day) than outside pastures at the same sites (1.4 visits/day). There was no significant difference in wolf visitation rates where flags were not used (inside pasture: 0.7 visits/day; outside pasture: 0.3 visits/day). With flags, there was no significant difference in frequency of coyote visits in pastures (0.4 visits/day) and outside pastures at the same site (0.7 visits/day), and the same was true when flags were not used (inside pasture: 0 visits/day; outside pasture: 0.3 visits/day). In May 2004, red nylon flags were attached to fences at four randomly selected farms. At four other farms, no flags were used. One bait station, containing sand with sheep or cattle faeces, was placed inside each pasture and one outside each pasture fence. In May–August 2004 and 2005, each bait station was checked for wolf and coyote tracks.

A replicated, randomized, controlled study in 2007 at 12 pasture sites in Montana, USA (5) found that wolves *Canis lupus* did not visit sites with flags hanging from an electrified fence. The result was not tested for statistical significance. Relative effects of flags and electric fences cannot be separated in this study. Grey wolves *Canis lupus* did not visit any pastures with flags on electrified fences but twice visited pastures with conventional barbed wire fences. However, no livestock were killed by wolves in the pastures. The study was conducted in 12 pastures (16–122 ha), each with 40–200 cows. Pastures were contained within barbed wire fences. Six pastures (randomly selected) had electrified fences with red flags (50 × 10 cm) suspended from them, positioned outside existing fences and six did not. Wolf tracks were monitored twice weekly, for three months, in 2007.

(1) Musiani M. & Visalberghi E. (2001) Effectiveness of fladry on wolves in captivity. *Wildlife Society Bulletin*, 29, 91–98.

(2) Musiani M., Mamo C., Boitani L., Callaghan C., Gates C.C., Mattei L., Visalberghi E., Breck S. & Volpi G. (2003) Wolf depredation trends and the use of fladry barriers to protect livestock in western North America. *Conservation Biology*, 17, 1538–1547, https://doi.org/10.1111/j.1523-1739.2003.00063.x

(3) Shivik J.A., Treves A. & Callahan P. (2003) Nonlethal techniques for managing predation: primary and secondary repellents. *Conservation Biology*, 17, 1531–1537, https://doi.org/10.1111/j.1523-1739.2003.00062.x

(4) Davidson-Nelson S.J. & Gehring T.M. (2010) Testing fladry as a nonlethal management tool for wolves and coyotes in Michigan. *Human–Wildlife Interactions*, 4, 87–94, https://doi.org/10.26077/mdky-bs63

(5) Lance N.J., Breck S.W., Sime C., Callahan P. & Shivik J.A. (2010) Biological, technical, and social aspects of applying electrified fladry for livestock protection from wolves (*Canis lupus*). *Wildlife Research*, 37, 708–714, https://doi.org/10.1071/wr10022

3.31. Use visual deterrents (e.g. scarecrows) to deter predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2427

- **Two studies** evaluated the effects of using visual deterrents, such as scarecrows, to deter predation of livestock by mammals to reduce human-wildlife conflict. One study was in Kenya[1] and one was in Mexico[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** A study in Kenya[1] recorded more livestock predation at bomas with scarecrows than those without scarecrows whereas a replicated, controlled study in Mexico[2] found that a combination of visual and sound deterrents reduced livestock predation.

Background

A range of visual deterrents, including scarecrows, may be used to deter carnivores from approaching livestock. If successful, such deterrents could reduce incentives for carrying out lethal control of carnivores.

A study in 2001–2005 of bushland and savanna in Laikipia and neighbouring districts, Kenya (1) found that at bomas with scarecrows positioned to deter predators, there were more, rather than fewer, carnivore attacks on livestock than at bomas without scarecrows. Scarecrows at bomas were associated with an increased risk of livestock attack by carnivores (results presented as odds ratio). The effect was strongest for leopards *Panthera pardus*. Scarecrows comprised cloth hung on trees or boma walls. They were present at 44% of 483 bomas (average 2.4/boma). Combining attacks on bomas with attacks on livestock herds grazing by day, the study documented 105 attacks by spotted hyenas *Crocuta crocuta*, 96 by leopards, 44 by African wild dogs *Lycaon pictus*, 35 by lions *Panthera leo* and 19 by cheetahs *Acinonyx jubatus*. From January 2001 to June 2005, eighteen local staff verified reports of livestock lost to predation and gathered data on animal husbandry practices used. Attacked bomas were compared to nearby bomas (median 323 m away) that had not been attacked.

A replicated, controlled study in 2010 of six farms in a forested area in central Mexico (2) found that visual and sound deterrents reduced predation of livestock on ranches. The relative effects of the two deterrent types were not assessed individually. No large predators (puma *Puma concolor* or jaguar *Panthera onca*) were detected on ranches that used deterrents compared with 2 detections/ranch and 2–4 livestock attacks/ranch where deterrents were not used. Out of six ranches (44–195 ha extent, ≥6 km apart), two cattle ranches and two goat ranches deployed deterrents whilst no deterrents were deployed on one cattle ranch and one goat ranch. Visual deterrents were shirts worn by livestock owners, hung around paddocks. Sound deterrents were recordings of voices, motors, pyrotechnics, barking dogs and bells, played twice daily for 40 min, between 06:00–08:00 and 20:00–22:00 h. Deterrents alternated weekly between visual and sound, through July–August 2010. Large predators were monitored using two camera traps/ranch and by searching for tracks and other signs.

(1) Woodroffe R., Frank L.G., Lindsey P.A., ole Ranah S.M.K. & Romañach S. (2007) Livestock husbandry as a tool for carnivore conservation in Africa's community rangelands: a case-control study. *Biodiversity and Conservation*, 16, 1245–1260, https://doi.org/10.1007/s10531-006-9124-8

(2) Zarco-González M.M. & Monroy-Vilchis O. (2014) Effectiveness of low-cost deterrents in decreasing livestock predation by felids: a case in Central Mexico. *Animal Conservation*, 17, 371–378, https://doi.org/10.1111/acv.12104

3.32. Use pheromones to deter predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2428

- We found no studies that evaluated the effects of using pheromones to deter predation of livestock by mammals to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Pheromones are chemical substances released into the environment by an animal that can affect the behaviour or physiology of other animals of the same species. If pheromones can be synthesised that deter wild mammalian predators from approaching and predating livestock, this could reduce the motivation among farmers for carrying out lethal control of such predators.

3.33. Use taste-aversion to reduce predation of livestock by mammals to deter human-wildlife conflict

https://www.conservationevidence.com/actions/2429

- **Nine studies** evaluated the effects of using taste-aversion to reduce predation of livestock by mammals to deter human-wildlife conflict. Six studies were in the USA[1,3,5,6,8a,8b], two were in Canada[4,7] and one was at an unnamed location[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (9 STUDIES)

- **Human-wildlife conflict (9 studies):** Three of seven replicated studies (including three controlled studies), in the USA[1,3,5,6], Canada[4,7] and at an unnamed location[2], found that coyotes killed fewer sheep[1,3,7], rabbits[1] or turkeys[3] after taste-aversion treatment. The other four studies found that taste-aversion treatment did not reduce killing by coyotes of chickens[2], sheep[4,5] or rabbits[6]. A replicated, before-and-after study in the USA[8a] found that taste-aversion treatment reduced egg predation by mammalian predators whilst a replicated, controlled, paired sites study in the USA[8b] found no such effect.

Background

Wild mammalian predators can cause unacceptable levels of livestock losses. Human-wildlife conflict can be reduced if wild mammals can be effectively deterred from attacking livestock. This intervention covers the use of substances that cause unpleasant effects in mammals, such as gastrointestinal discomfort, but at a dose not intended to cause long-term harm to the animal. Most studies are trials using captive animals, especially coyotes *Canis latrans*. One study included here is a trial of using the same approach to deter predation of bird eggs. This would most likely find application in poultry or game rearing operations, and so is included here given that the intention could be to reduce economic losses caused by wild mammals. If the intervention is effective at reducing predation, it could reduce incentives for carrying out lethal control of mammalian predators.

A replicated, controlled, before-and-after study (year not stated) on captive animals in the USA (1) found that after conditioned taste-aversion treatment, coyotes *Canis latrans* did not catch and eat live lambs or rabbits. After one or two meals of lamb or rabbit meat containing lithium chloride (which causes gastrointestinal discomfort), six coyotes did not attack either lambs or rabbits. Three coyotes were held in individual pens. Over a 13-day period, coyotes alternated between being let into an enclosure with a live lamb or rabbit or with lamb meat containing lithium chloride. A similar experimental procedure was carried out with three different coyotes, which received rabbit meat containing lithium chloride.

A replicated study in 1975–1976 on captive animals (location not stated) (2) found that feeding dead chickens injected with lithium chloride to coyotes *Canis latrans* did not induce taste-aversive against taking live chickens. After eating dead chickens laced with lithium chloride (which causes gastrointestinal discomfort), two coyotes each killed and ate the single live chickens that they were offered. Three different coyotes between them killed and ate 25 of 31 live chickens offered. The five coyotes were offered 79 dead lithium chloride-laced chickens, from which 39 were uneaten, 23 were entirely eaten and 17 were partially eaten. Prior to lacing trials, each coyote was offered five live and five dead chickens (unlaced), all of which were eaten. Coyotes were then offered four to eight dead chickens, laced with lithium chloride. Following this, in daily trials, they were offered, in random order, a recently killed laced chicken or a live chicken. Two coyotes were offered single live chickens at this stage, and three were offered from three to nine live chickens each.

A replicated study in 1976–1977 of six livestock farms in a desert area of California, USA (3) found that after taste-aversion treatment, the number of sheep and turkeys killed by coyotes *Canis latrans* declined over time. In the second year that baits containing lithium chloride (which causes gastrointestinal discomfort) were used, the number of sheep killed by coyotes was lower (59 kills) than in the first year that baits were used (186 kills). The same pattern was true for the numbers of turkeys killed (data not presented). From August 1976 to April 1977, sheep carcasses containing lithium chloride were laid as bait, adjacent to areas where four sheep herds were grazing. Sheep herds were at least 12 km apart. From November 1976 to April 1977, turkey carcasses containing lithium chloride were laid as bait adjacent to two turkey farms. Turkey farms were 27 km apart. Methods used to monitor the numbers of animals killed were unclear.

A replicated, randomized, controlled, before-and-after study in 1978 on pastures in four areas in Alberta, Canada (4) found that lacing sheep meat baits with lithium chloride did not induce taste-aversive in coyotes *Canis latrans* against taking lambs. Average lamb predation rates on farms where baits were laced with lithium chloride (which causes gastrointestinal discomfort) (5.7/farm) did not significantly differ from those on farms without baits (7.5/farm). Over each of the previous two years, there was also no difference in predation rates between treatment farms (7.4 and 9.4/farm respectively) and control farms (6.1 and 9.5/farm respectively). Four areas were studied, with five to eight sheep farms (≥8 km apart) in each. Half of farms had lithium chloride baits, half had baits without lithium chloride. Six to 10 baits (sheep meat, wrapped in sheep hide) were placed on each treatment farm in April 1978. Baits were replaced at least every three weeks. Baiting continued to September (to July on two farms). Few baits were consumed in one area, so predation data there were excluded from analyses. Predation rates were supplied by farmers for 1976–1978. Lethal control of coyotes was carried out when predation was confirmed.

A replicated, controlled study (year unspecified) in a research facility in Utah, USA (5) found that lithium chloride-injected bait did not induce taste aversion that prevented coyotes *Canis latrans* from killing lambs *Ovis aries.* Coyotes fed with baits containing lithium chloride (which causes gastrointestinal discomfort) took a similar length of time to kill a lamb after feeding (2.7 days) than did coyotes that had eaten bait without lithium chloride (2.7 days). Eight coyotes were held in separate kennels. At 08:00 each day, an individual animal was let into a 250-m^2 pen containing food. If a coyote consumed the food within 10 minutes on three consecutive days, then on the following day bait, in the form of sheep meat contained within sheep hide, was placed in the pen. For four coyotes, the baits contained lithium chloride (which induced gastrointestinal discomfort) and, for the other four, they did not. Coyotes were left in pens until they had eaten at least one bait. Following this, coyotes were let back into the pen along with a live lamb and the time it took for the coyote to kill the lamb was monitored.

A replicated, before-and-after study in 1983 in a research facility in Colorado, USA (6) found that feeding domestic European rabbits *Oryctolagus cuniculus* baited with an illness-inducing agent to coyotes *Canis latrans* did not change their predation rate on live rabbits. Coyotes killed all live rabbits presented to them both before and after being fed with rabbit meat and rabbit carcases baited with an illness-inducing agent. The study was conducted in a 6,400-m^2 enclosure of unspecified habitat. Three wild-caught adult coyotes were each presented with a series of live rabbits and made 10 consecutive kills. Each then received a control bait package (rabbit meat with an empty gelatin capsule) followed by five further live rabbits. Coyotes then received a bait package with a gelatin capsule containing lithium chloride, followed a day later by a live white rabbit. The next day, they received another lithium chloride-laced bait package followed by another live rabbit. Three days later, they received a lithium chloride-treated rabbit carcass and then live rabbits the following day. Bait packages were 227 g of rabbit meat containing 7 g of illness-inducing lithium chloride in a gelatin capsule. Baited rabbit carcasses were injected with 10 g of dissolved lithium chloride. No additional food was provided between trials.

A replicated, before-and-after study in 1975–1976 on 16 pastures in Saskatchewan, Canada (7) found that use of lithium chloride-treated baits to induce taste-aversion, was associated with reduced predation of sheep by coyotes *Canis latrans*. Losses of sheep and lambs to coyotes fell from 4% (892 predated out of 22,407 animals) in 1975 (before baits used) to 1.5% (301 predated out of 20,574 animals) in 1976. Factors such as animal husbandry and use of other coyote control methods were not controlled for. Sixteen sheep pastures (mix of private ownership and community cooperatives), holding 101–4,543 sheep, on which predation by coyotes was previously reported, were studied. Baseline predation data were collected in 1975. In 1976, lithium chloride baits (which induce gastrointestinal discomfort) were used at all sites (bait application methods not detailed in paper).

A replicated, before-and-after study in 1986 in three deciduous forest sites in Connecticut, USA (8a) found that dosing chicken eggs with emetine dihydrochloride reduced egg predation by inducing conditioned taste aversion in mammalian predators. The proportion of eggs predated daily was 85% at the end of the pre-treatment period (eggs not dosed), 10% at the end of the treatment period (eggs dosed with emetine) and remained low (17%) at the end of the post-treatment period (eggs not dosed). Mammals (mostly raccoons *Procyon lotor*, opossums *Didelphis virginia* and striped skunks *Mephitis mephitis*) predated 66% of eggs taken. At each of three sites (>4 km apart) 10 chicken eggs were placed >75 m apart. Pre-treatment, treatment and post-treatment each lasted three weeks. Eggs were placed for four days/week and checked (and replaced if predated) daily. During the treatment period, eggs were injected with 20–25 mg of emetine, which causes gastrointestinal discomfort. The study ran in June–September 1986.

A replicated, controlled, paired sites study in 1987 in eight deciduous forest sites in Connecticut, USA (8b) found that dosing chicken eggs with emetine dihydrochloride did not reduce egg predation by inducing conditioned taste aversion in mammalian predators. At treatment sites, the number of eggs predated that were dosed (5.0–8.7/week) or undosed (2.3–3.5/week) was not lower than the number predated at untreated sites (0.8–3.3). Racoons *Procyon lotor* were the main mammalian predator in this study. Four treatment sites each had 10 undosed eggs and 10 dosed eggs placed >75 m apart. Four further untreated sites each had 10 undosed eggs placed >75 m apart. Dosed eggs were injected with 20–25 mg of emetine, which causes gastrointestinal discomfort. Eggs were checked twice weekly in July–September 1987, and predated eggs were replaced.

(1) Gustavson C.R., Garcia J., Hankins W.G. & Rusiniak K.W. (1974) Coyote predation control by aversive conditioning. *Science*, 184, 581–583, https://doi.org/10.1126/science.184.4136.581

(2) Conover M.R., Francik J.G. & Miller D.E. (1977) An experimental evaluation of aversive conditioning for controlling coyote predation. *The Journal of Wildlife Management*, 41, 775–779, https://doi.org/10.2307/3800006

(3) Ellins S.R. & Catalano S.M. (1980) Field application of the conditioned taste aversion paradigm to the control of coyote predation on sheep and turkeys. *Behavioral and Neural Biology*, 29, 532–536, https://doi.org/10.1016/s0163-1047(80)92882-4

(4) Bourne J. (1982) A field test of lithium chloride aversion to reduce coyote predation on domestic sheep. *The Journal of Wildlife Management*, 46, 235–239, https://doi.org/10.2307/3808426

(5) Burns, R. J. (1983) Microencapsulated lithium chloride bait aversion did not stop coyote predation on sheep. *The Journal of Wildlife Management*, 47, 1010–1017, https://doi.org/10.2307/3808159

(6) Horn S.W. (1983) An evaluation of predatory suppression in coyotes using lithium chloride-induced illness. *The Journal of Wildlife Management*, 47, 999–1009, https://doi.org/10.2307/3808158

(7) Jelinski D.E., Rounds R.C. & Jowsey J.R. (1983) Coyote predation on sheep, and control by aversive conditioning in Saskatchewan. *Journal of Range Management*, 36, 16–19, https://doi.org/10.2307/3897972

(8) Conover M.R. (1990) Reducing mammalian predation on eggs by using a conditioned taste aversion to deceive predators. *The Journal of Wildlife Management*, 54, 360–365, https://doi.org/10.2307/3809055

3.34. Dispose of livestock carcasses to deter predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2432

- **One study** evaluated the effects of disposing of livestock carcasses to deter predation of livestock by mammals to reduce human-wildlife conflict. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One site comparison study in the USA[1] found that burying or removing sheep carcasses reduced predation on livestock by coyotes, but burning carcasses did not alter livestock predation rates.

Background

Leaving livestock carcasses in place on farms after death may attract mammalian carnivores that may also attack live farm animals. Carcasses can be removed to eliminate this form of attraction for predators. If this results in fewer predators being attracted to farms and, consequently, less predation on livestock, this could reduce incentives for carrying out lethal control of such predators.

A site comparison study in 1975–1976 of 97 sheep farms in Kansas, USA (1) found that when sheep carcasses were buried or removed, sheep losses to coyotes *Canis latrans* and dogs *Canis lupus familiaris* were reduced compared to leaving them on the pasture, but burning carcasses did not reduce predation. The proportion of sheep lost to coyotes or dogs each month was lower when carcasses were buried (0.05%) or removed (0.08%) than when they were left in place (0.14%). The rate when carcasses were burned (0.17%) did not differ from that of leaving them in place. Ninety-seven farms were studied, on which total sheep numbers varied through the study period from 14,578 to 17,023. Farmers recorded monthly sheep losses and husbandry methods for 15 months.

(1) Robel R.J., Dayton A.D., Henderson F.R., Meduna, R.L. & Spaeth, C.W. (1981) Relationships between husbandry methods and sheep losses to canine predators. *The Journal of Wildlife Management*, 45, 894–911, https://doi.org/10.2307/3808098

3.35. Use guardian animals (e.g. dogs, llamas, donkeys) bonded to livestock to deter predators to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2433

- **Twelve studies** evaluated the effects of using guardian animals (e.g. dogs, llamas, donkeys) bonded to livestock to deter mammals from predating these livestock to reduce human-wildlife conflict. Four studies were in the USA[1,2,3,6], two were in Kenya[4,5] and one each was in Solvakia[7], Argentina[8], Australia[9], Cameroon[10], South Africa[11], and Namibia[12].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (12 STUDIES)

- **Human-wildlife conflict (12 studies):** Four of seven studies, (including four site comparison studies), in the USA[1,2], Kenya[4,5], Solvakia[7], Australia[9] and Cameroon[10], found that guardian animals reduced attacks on livestock by predators. The other three studies reported mixed results with reductions in attacks on some but not all age groups[2] or livestock species[4] and reductions for nomadic but not resident pastoralists[10]. Two studies, (including one site comparison study and one before-and-after study), in Argentina[8] and Namibia[12], found that using dogs to guard livestock reduced the killing of predators by farmers[8,12] but the number of black-backed jackals killed by farmers and dogs combined increased[12]. A replicated, controlled study in the USA[3] found that fewer sheep guarded by llamas were predated by carnivores in one of two summers whilst a replicated, before-and-after study in South Africa[11] found that using dogs or alpacas to guard livestock reduced attacks by predators. A randomized, replicated, controlled study in USA[6] found that dogs bonded with livestock reduced contact between white-tailed deer and domestic cattle.

Background

Using animals to guard livestock is a long-established practice. Usually dogs *Canis lupus familiaris* are used but occasionally other animals (e.g. llamas *Lama glama*) may be used. In most cases, guardian animals are raised among livestock and bond to them. If guardian animals can reduce losses of livestock to predators, this may reduce motivations for lethal control of such predators.

A replicated study in 1981 of 36 ranches in North Dakota, USA (1) found that guard dogs *Canis lupus familiaris* reduced sheep losses to predation by coyotes *Canis latrans*. The average annual predation rate after commencing use of guard dogs (0.4% of the sheep flock) was lower than that before guard-dog use commenced (6%). In 1981, thirty-six ranchers were interviewed about livestock management and losses to predation in the 1976–1981 period. Between them, ranchers had 52 great Pyrenees dogs (44 working and eight training) and two working komondor dogs. All ranchers commenced using guardian dogs during the period. Guarded pastures were 4–486 ha in extent and guarded sheep flocks contained 10–1,300 animals. Dogs were raised with the sheep flock and remained with them most of the time.

A replicated, site comparison study in 1986 of 134 sheep producers in Colorado, USA (2) found that using livestock-guarding dogs *Canis lupus familiaris* reduced coyote *Canis latrans* predation of lambs in fenced pastures and some open ranges, but predation of ewes was not reduced in either. A lower percentage of lambs was killed by coyotes in fenced pastures with livestock-guarding dogs (0%) than without dogs (2–5%). In open ranges, a lower percentage of lambs was killed compared to 20 of 25 producers without dogs (with dogs: 1.2%; without dogs: 16%), this was not the case compared to the five producers without dogs that responded by telephone rather than post (without dogs: 3%). The percentage of ewes killed by coyotes did not differ significantly with dogs (fenced pastures: 0%; open ranges: 0.4%) or without dogs (fences pastures: 0.5–1%; open ranges: 1.1–1.5%). Sheep producers kept ewes and lambs with or without livestock-guarding dogs in fenced pastures (with dogs: 6–7 producers; without dogs: 87–92 producers) or open ranges (with dogs: 10 producers; without dogs: 25 producers). Average flock sizes were 90–321 lambs or ewes in fenced pastures and 910–2,440 lambs or ewes in open ranges. Seven breeds (or mixed breeds) of livestock-guarding dog were used (see original paper for details). The 134 sheep producers responded to postal or telephone surveys in 1986.

A replicated, controlled study in 1996–1997 on pasture in Utah, USA (3) found that using llamas *Lama glama* to guard sheep flocks reduced canine predation on lambs in one of two summers. Sheep flocks guarded by a llama lost a lower proportion of lambs to predators in the first summer season than did flocks without llamas. There was no significant difference in losses during the second summer season. Actual loss rates were not presented. Predation rates of ewes and predation in the winter season were very low across all flocks. Coyotes *Canis latrans*, domestic dogs *Canis lupus familiaris* and red foxes *Vulpes vulpes* accounted for 92% of losses to predators. Flocks with llamas averaged 301 sheep (including lambs). Flocks without llamas averaged 333 sheep and lambs. Twenty flocks were each guarded by a single llama. The number of flocks without llamas varied through the study, due to splitting and merging of flocks, from 8 to 29. Sheep producers reported fortnightly, from May 1996 to December 1997, on predation events and flock sizes.

A replicated, site comparison study in 1999–2000 of savanna across 10 ranches in Laikipia District, Kenya (4) found that at bomas with domestic dogs *Canis lupus familiaris* in attendance, fewer cattle were killed by predators, though there was no effect on predation of sheep or goats. Fewer cattle were killed by lions *Panthera leo*, leopards *Panthera pardus* and hyenas *Crocuta crocuta* and *Hyaena hyaena* combined when dogs were present at bomas (0.03 cattle/month) than at bomas without dogs (0.28 cattle/month). There was no significant relationship between dog presence and predation on sheep or goats (data not presented). Livestock were housed in bomas overnight, when 75% of recorded kills occurred. Data on livestock predation and predator deterrence activities at 84 bomas on 10 ranches (nine commercial ranches, one community area) were gathered from ranch managers. Ranches were monitored for 2–17 months, between January 1999 and May 2000.

A study in 2001–2005 of bushland and savanna in Laikipia and neighbouring districts of Kenya (5) found that when livestock were accompanied by one or more domestic dogs *Canis lupus familiaris*, fewer were attacked by carnivores. Livestock herds grazing by day and those held overnight in thornbrush bomas were less likely to be attacked by carnivores if accompanied by domestic dogs (results presented as odds ratios). Of 502 grazing herds, 24% were accompanied by one or more dogs (average 1.3 dogs/accompanied herd). Of 491 bomas, dogs were present at 71% (average 2.0 dogs/boma). The study documented 105 attacks by spotted hyenas *Crocuta crocuta*, 96 by leopards *Panthera pardus*, 44 by African wild dogs *Lycaon pictus*, 35 by lions *Panthera leo* and 19 by cheetahs *Acinonyx jubatus*. From January 2001 to June 2005, eighteen local staff verified reports of livestock lost to predation and gathered data on animal husbandry practices used. Attacked herds or bomas were compared to nearby herds (median 656 m away) or bomas (median 323 m away) that had not been attacked.

A randomized, replicated, controlled study in 2003 at two forest sites in Michigan, USA (6) found that dogs *Canis lupus familiaris* bonded with livestock reduced levels of contact (and potential for disease transmission) between white-tailed deer *Odocoileus virginianus* and domestic cattle. In dog-guarded pastures, deer came within 5 m of cattle fewer times (three instances) than in non-guarded pastures (79 instances). No deer were within 5 m of cattle when dogs were present, while 114 events occurred with dogs absent. Deer consumed hay less frequently in dog-guarded pastures (two instances) compared to pastures without dogs (303 instances). At each site, four 1.2-ha pastures, >200 m apart, were enclosed by electric fencing. Deer were baited into pastures with corn and alfalfa. Each pasture contained four calves while two pastures at each site also had a dog. Livestock guarding dogs were great Pyrenees, raised from eight-week-old pups, following standard training procedures. Visits of deer into pastures were monitored by direct observation and video surveillance, in March–August 2003.

A replicated, site comparison study in 2002 on 58 farms in Solvakia (7) found that farms using livestock-guarding dogs *Canis lupus familiaris* lost fewer livestock to predation than did farms without dogs. The number of livestock lost to predators (mainly grey wolf *Canis lupus*) in flocks with livestock-guarding dogs (1.1 sheep/flock) was not significantly different to that in unguarded flocks (3.3 sheep/flock). However, dog placement was prioritised at flocks with previously high predation rates. On farms where predation occurred, fewer livestock were lost in guarded (1.5 sheep/flock) than in unguarded flocks (5.0 sheep/flock). Pups (Slovenský čuvač and Caucasian shepherd dog) were reared alongside livestock. Of 34 pups placed on farms in 2000–2004, seventeen were successfully integrated into livestock flocks during the first full grazing season. Reported losses for 2002 were compared between 13 flocks with successfully integrated 1–2-year-old livestock-guarding dogs and 45 farms in the same regions without dogs.

A replicated, site comparison study in 2005–2011 on a grass-shrub steppe area in Patagonia, Argentina (8) found that use of dogs *Canis lupus familiaris* by goat herders to guard livestock reduced the killing of predators by herders. Results were not tested for statistical significance. Six of eight herders with working guard dogs reported that they no longer killed predators, one had never done so and one did so less frequently than previously. Nine herders who did not have working dogs all continued to kill predators. Most reported predation was by cougar *Puma concolor* and culpeo fox *Lycalopex culpaeus*. Thirty-seven puppies were placed with herders, of which 11 became successful livestock guarding dogs. Herders were interviewed monthly or bimonthly during the dog training period. Nine neighbouring herders without dogs were also interviewed. Interviews included questions about predator control activities carried out by the herders.

A before-and-after study in 1997–2010 on a grassland-dominated ranch in Queensland, Australia (9) found that when guardian dogs *Canis lupus familiaris* were used to protect livestock from dingoes *Canis dingo* and other predators, sheep mortality declined. By three years after the guardian dog programme commenced, annual sheep losses had fallen to 4% of the flock and remained at 4–7% over the following five years. In the six years before the programme commenced, there was 7–15% annual mortality of the sheep flock. Sheep mortality figures included all causes of death, not only predation. The study was conducted on a 47,000-ha ranch, hosting approximately 12,000–22,000 sheep and 4,000 cattle. Dingoes and feral dogs were the main livestock predators in the area. In 2002, twenty-four Maremma sheepdogs were integrated with the sheep. The sheepdogs worked unsupervised in groups of 1–4. They had access to self-feeders with dry dog food. Dingoes and wild dogs were also baited with poison and wild dogs were shot opportunistically.

A site comparison study in 2008 of savanna around a national park in Cameroon (10) found that using dogs *Canis lupus familiaris* to guard livestock reduced losses through predation among nomadic pastoralists but not among resident pastoralists. Among nomadic pastoralists that owned dogs (53% of all nomadic pastoralists), fewer livestock were lost to carnivores (six animals/year) than among those that did not own dogs (10 animals/year). Among resident pastoralists that owned dogs (33% of all resident pastoralists), there was no significant difference in the number lost to predators (five animals/year) compared to those that did not own dogs (four animals/year). Two hundred and seven resident pastoralists and 174 nomadic pastoralists were interviewed. Subjects reported the incidence of predation on livestock by large carnivores and details of animal husbandry techniques used. Villages were selected based on the tracking of movements of radio-collared lions.

A replicated, before-and-after study in 2007–2009 of four livestock farms in savanna and shrubland in Eastern Cape, South Africa (11) found that using dogs *Canis lupus familiaris* and alpacas *Vicugna pacos* to guard livestock reduced attacks by carnivores on livestock, compared to using lethal control of predators. Results were not tested for statistical significance. When guard animals were used, 0–15% of livestock were killed each year by predators, but when lethal predator-control methods were used 5–45% of livestock were killed. Costs of using non-lethal control were lower (0.73–6.02 USD/livestock animal) than were those of lethal control (0.95–7.94 USD/livestock animal). In August 2006–August 2007, all four farms used lethal methods, including trapping and shooting, to control black-backed jackals *Canis mesomelas,* caracals *Caracal caracal* and leopards *Panthera pardus.* In September 2007–September 2009, farms either used guard dogs (three farms) or alpacas (one farm) to protect animals. Farmers reported the number of livestock killed by predators and associated costs, each September, in 2007–2009.

A before-and-after study in 2009–2010 of 73 livestock farms in Namibia (12) found that placing dogs *Canis lupus familiaris* with farmers to guard livestock reduced the overall number of farmers that killed predators, but increased the numbers of black-backed jackals *Canis mesomelas* killed by farmers and dogs combined. Eighteen percent of farmers killed livestock predators in the year after dog placement compared to 31% in the previous year. The reduction was larger among subsistence farmers (0% after dog placement; 30% before) than commercial farmers (26% after dog placement; 32% before). However, the number of black-backed jackals killed by farmers and dogs combined in the year following dog placement (3.4/farm) was greater than the number killed by farmers alone the previous year (1.7/farm). There were no significant differences for killings of caracal *Caracal caracal* (farmer and dog: 0.19; farmer: 0.10), cheetah *Acinonyx jubatus* (farmer and dog: 0.02; farmer: 0.11) or leopard *Panthera pardus* (farmer and dog: 0; farmer: 0.02). Anatolian shepherd dogs were placed on 53 commercial farms and 20 subsistence farms. Farmers were interviewed between March 2009 and September 2010. Dogs were placed with a livestock flock at eight weeks old and averaged 39 months old at time of the study.

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3.36. Use loud noises to deter predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2435

- **Three studies** evaluated the effects of using loud noises to deter predation of livestock by mammals to reduce human-wildlife conflict. Two studies were in the USA[1,2] and one was in Mexico[3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (3 STUDIES)

- **Human-wildlife conflict (3 studies):** Three replicated studies (including two controlled studies), in the USA[1,2] and Mexico[3], found that loud noises at least temporarily deterred sheep predation[1] or food consumption[2] by coyotes and (combined with visual deterrents) deterred livestock predation by large predators[3].

Background

This intervention specifically refers to use of sound, from various sources, to deter predation on livestock by wild mammalian carnivores. If successful, such an intervention could reduce livestock losses and, thus, reduce motivation for carrying out lethal control of predators.

A replicated study in 1979–1980 of three ranches in North Dakota, USA (1) found that gas exploders temporarily deterred sheep predation by coyotes *Canis latrans*. Installation and use of gas exploders stopped predation for 17–102 days. Sites selected for the study had suffered ≥5 sheep losses to predation by coyotes in the previous two weeks. Following this, propane gas exploders were installed in the pastures. Exploders were operated until the grazing season was over or until ≥2 verified coyote kills occurred. Two to three exploders/site fired at 8–20-minute intervals overnight and were moved every 4–5 days. Sheep farmers were compensated for losses to coyotes provided that exploders were used as the sole means of control. The trial operated on three sites, with pastures extending over 56–255 ha, and containing 190–1,000 sheep.

A replicated, controlled study on captive animals in Utah, USA (2) found that playing loud noises deterred consumption of food by coyotes *Canis latrans*. Six of 14 coyote pairs did not eat food while loud noises were playing repeatedly, whilst all seven coyote pairs not played loud noises ate their food. Food consumption was reduced if loud noises were activated solely when coyotes approached food. Twenty-one pairs of coyotes were held in 0.1-ha pens. An alarm was suspended 2 m above the door to the pen, where 100 g of food was positioned. For seven coyote pairs, the alarm sounded every 7–9 seconds for 1 hour. For seven more pairs, it activated solely when they approached the food. For seven further coyote pairs, it was not activated. Behaviour of coyotes was observed for 1 hour.

A replicated, controlled study in 2010 of six farms in a forested area in central Mexico (3) found that sound and visual deterrents reduced predation of livestock on ranches. The relative effects of the two deterrent types were not assessed individually. No large predators (puma *Puma concolor* or jaguar *Panthera onca*) were detected on ranches that used deterrents compared with 2 detections/ranch and 2–4 livestock attacks/ranch where deterrents were not used. Out of six ranches (44–195 ha extent, ≥6 km apart), two cattle ranches and two goat ranches deployed deterrents, whilst no deterrents were deployed on one cattle ranch and one goat ranch. Sound deterrents were recordings of voices, motors, pyrotechnics, barking dogs and bells, played twice daily for 40 minutes, between 06:00–08:00 h and 20:00–22:00 h. Visual deterrents were shirts worn by livestock owners, hung around paddocks. Deterrents alternated weekly between sound and visual, through July–August 2010. Large predators were monitored using two camera traps/ranch and by searching for tracks and other signs.

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3.37. Translocate predators away from livestock to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2436

- **Eleven studies** evaluated the effects on mammals of translocating predators away from livestock to reduce human-wildlife conflict. Four studies were in the USA[1,2,3,7] two were in Botswana[9,11], one each was in Canada[4], Zimbabwe[6] and Namibia[10], one was in Venezuela and Brazil[8] and one covered multiple locations in North and Central America and Africa[5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (8 STUDIES)

- **Reproductive success (2 studies):** Two studies, in Zimbabwe[6] and Namibia[10], found that predators translocated away from livestock bred in the wild after release.
- **Survival (8 studies):** Four of eight studies (including three replicated studies and a systematic review), in the USA[2,7], Canada[4], Zimbabwe[6], South America[8], Botswana[9,11] and Namibia[10], found that translocating predators reduced their survival[7] or that most did not survive more than 6–12 months after release[4,9,11]. Three studies found that translocated predators had similar survival to that of established animals[2,10] or persisted in the wild[6] and one study could not determine the effect of translocation on survival[8].

BEHAVIOUR (0 STUDIES)

OTHER (6 STUDIES)

- **Human-wildlife conflict (6 studies):** Four of six studies (including a review and a systematic review), in the USA[1,2,3,7], South America[8] and in North and Central America and Africa[5], found that some translocated predators continued to predate livestock or returned to their capture sites[1,2,5,7]. One study found that translocated predators were not subsequently involved in livestock predation[3] and one study could not determine the effect of translocation on livestock predation[5].

Background

Where mammalian predators cause unacceptable losses to farmers, through predation on livestock, they may be translocated from their point of capture and released some distance away. The release site may be an area away from where livestock are kept. The intervention can fail if translocated animals continue to predate livestock or if survival of translocated animals is low. If the intervention is successful, it can reduce incentives for carrying out lethal control of such animals. Several other interventions cover translocations that are primarily for conservation of rare or threatened species, such as *Translocate to re-establish or boost populations in native range*.

A study in 1975–1978 of an extensive primarily forested area in Minnesota, USA (1; same experimental set-up as 2) found that gray wolves *Canis lupus* translocated away from sites of livestock predation or harassment were less likely to return to capture sites if moved when younger or across greater distances. Of 15 translocations of <64 km, nine endpoints (sites of mortality, recapture or last radiolocation) were at original capture sites. Of 20 translocations of >64 km, no endpoints were at original capture sites. None of nine pups, whose endpoints were determined (following translocation of 64 km (two pups) or 111–321 km (seven pups), returned to original capture locations. Between February 1975 and May 1978, 62 adult wolves and 45 four-to seven-month-old pups were caught in an area of livestock predation and harassment by wolves. Wolves were ear-tagged and released into forests, 50–331 km from capture sites. Forty-one wolves were released individually. Sixty-six were released in groups of 2–6. Fifteen adults and four pups were fitted with radio-collars. Seventeen of these were tracked from an aircraft for 1–588 days. Thirty-five endpoints in total were determined from 32 wolves (23 adults and nine pups — second endpoints were determined for three recaptured wolves that were translocated twice).

A study in 1975–1978 of an extensive primarily forested area in Minnesota, USA (2; same experimental set-up as 1) found that gray wolves *Canis lupus* translocated away from sites of livestock predation or harassment had similar survival to that of established wolves. Annual survival for 17 radio-collared wolves (60%) was similar to survival in three studies of established wolves in the region (65%, 66% and 21–100%). Between February 1975 and May 1978, sixty-two adult wolves and 45 four-to seven-month-old pups were caught in an area of livestock predation or harassment by wolves. Wolves were ear-tagged and released into forests, 50–331 km from capture sites. Forty-one wolves were released individually. Sixty-six were released in groups of 2–6. Fifteen adults and four pups were fitted with radio-collars. Seventeen of these were tracked from an aircraft for 1–588 days.

A study in 1989–1992 of forest and meadow in an area of Oregon, USA (3) found that black bears *Ursus americanus* translocated away from areas with histories of bear attacks on sheep were not subsequently involved in livestock predation. None of five radio-collared, translocated bears was involved in sheep predation during the monitoring period (≤1 year). However, four of the bears died during that period (three were shot and one found dead) and one either moved away or its radio-collar malfunctioned. Sixteen bears were translocated in 1990 and five in 1991 from areas where five bears had been killed in 1989 to protect livestock. Bears were released ≤20 miles from capture sites. Bears translocated in 1991 were radio-collared. One was monitored for approximately one year. The others were monitored for shorter, unspecified, periods.

A replicated study in 1988–1990 across parts of Alberta, Canada (4) found that three cougars *Felis concolor* translocated following predation of livestock survived for between 3.5 months and at least one year after release. An adult female (4.3 years old) was translocated 51 km following sheep predation. She was found dead, from a bacterial infection, 3.5 months later. A 20-month-old male was translocated 51 km. One year later he was recaptured, 79 km from the release site, following reports of goat killings. He was released 43 km away but not subsequently monitored. A 15-month-old male was translocated 63 km after having killed a dog *Canis lupus familiaris*, and was shot by a licensed hunter, 20 km from the release site, nine months later. All three cougars had been previously caught and either ear-tagged or radio-collared for monitoring and research. In this study, the adult female was radio-tracked from an airplane.

A review published in 1997 of translocation studies in North and Central America and southern Africa (5) found that many carnivores translocated to prevent livestock conflict or 'nuisance' behaviours returned to capture sites and/or resumed predation or nuisance behaviour. Ten of 11 studies of brown bears *Ursus arctos* and black bears *Ursus americanus* found that 45–100% of translocated bears returned up to 229 km to their capture site. Eight leopards *Panthera pardus* translocated to a national park immediately left the park and some (number not specified) resumed livestock predation. A further animal returned and resumed livestock predation following an 80-km translocation. Two further animals did likewise following translocation over an unspecified distance. Of 25 lions *Panthera leo* translocated 5–300 km (pooled from two studies), at least six resumed livestock killing. Of two jaguars *Panthera onca* translocated 160 km, at least one resumed livestock killing. Relevant studies on translocations to reduce livestock predation or nuisance behaviours were gathered for black bear (seven studies), brown bear (four studies), leopard (three studies), lion (two studies) and jaguar (two studies).

A study in 1994–1998 in a woodland savanna protected area in northern Zimbabwe (6) found that a population of cheetahs *Acinonyx jubatus* translocated to reduce livestock losses, persisted over four years and that translocated animals reproduced in the wild. At least 13 adult cheetahs and four cubs, were alive four years after the translocation of 17 individuals. Translocated cheetahs bred at least five times and at least two cubs survived to adulthood. In 1993–1994, fourteen adult cheetahs and three cubs were released into Matusadona National Park. Cheetahs had been captured in commercial ranches where they were causing livestock losses. At the time of release, the park had no resident cheetahs but had a high density of lions (0.31/ km^2) and hyenas (0.13/ km^2). Cheetah numbers were estimated until July 1998, from sightings by visitors and park workers.

A study in 1982–2002 in 25 temperate forest sites in Montana, Idaho, and Wyoming, USA (7) found that some wolves *Canis lupus* translocated away from areas of livestock predation continued to prey on livestock, some returned to their capture location and that translocation reduced wolf survival. Out of 63 translocated individual wolves and nine wolf groups, 19 wolves preyed on livestock following release. Of 81 wolves or wolf groups, 16 returned to their capture site, from 74–316 km away. Annual survival of translocated wolves (60%) was lower than that of non-translocated, resident wolves (73%). Eighty-eight individual wolves were translocated 74–515 km in 1989–2001, in response to livestock predation (75 wolves) or pre-emptively to avoid such conflict (13 wolves). Seven translocated wolves were moved twice and five were moved three times. Translocated wolves were radio-collared, and were monitored to the end of 2002. Survival data were also compiled over 1982–2002 from 399 non-translocated, resident wolves in the same general area.

A systematic review published in 2010 of studies in forest and savanna areas in Venezuela and Brazil (8) found insufficient evidence to determine whether or not translocating jaguars *Panthera onca* reduced livestock predation by jaguars, or hunting of jaguars or whether it increased survival of translocated individuals. Ten studies met review criteria. Of these, seven provided only qualitative data, whilst the three quantitative studies had methodological limitations. No evidence was identified for effectiveness of translocation in reducing livestock predation by jaguars or reducing hunting of jaguars. Of 14 translocated jaguars, four survived translocation and the follow-up monitoring period of three weeks to eight months, four died during capture or post-release monitoring and six further animals were insufficiently monitored to determine post-release survival. Keyword and database searches were used to collect 3,200 articles evaluating jaguar translocation. Of these, 10 met pre-defined criteria for inclusion in the review.

A replicated study in 2001–2008 on two savanna game reserves in Botswana (9) found that following translocation of four leopards *Panthera pardus* involved in livestock predation, three did not survive more than six months after release. Of four stock-raiding leopards translocated to a protected area, three were shot within six months, having left the release area and resumed livestock predation. The fourth animal returned to, and settled back within, its initial capture area. By comparison, four leopards resident within the protected area had stable home ranges. Four leopards (three male and one female), which were suspected of predating livestock, were released in a protected area, 33–158 km from capture sites. These animals, and four leopards resident in the protected area (one male, three female), were monitored by a combination of radio-and satellite-tracking between April 2001 and March 2008, for between 23 days and 53 months.

A controlled study in 2004–2014 across five regions of Namibia (10) found that following translocation (mostly of animals moved from sites of livestock predation), survival rates and home range sizes of leopards *Panthera pardus* did not differ significantly from those of resident leopards and that translocated females reproduced in the wild. The average annual survival rate of the six translocated leopards (93%) was not significantly different to that of 12 resident leopards (85%). The same applied for home range sizes (translocated: 54–481 km^2; resident: 36–580 km^2). Two of three translocated females reproduced in the wild, with conception occurring from eight months post-release. Livestock predation ceased for 16–29 months or entirely at pre-translocation capture sites, and was then lower (1–3 calves/year) than before translocation (5 calves in one year). Only one of six translocated leopards killed livestock (herded into range) at release sites. Eighteen leopards were trapped and fitted with GPS (14) or VHF (5) transmitter collars. Twelve were released at or close to their capture sites and six (4 'problem' animals) were released at an average distance of 403 km (47–754 km) from their capture site. Translocated animals spent an average of 203 days in captivity before release. VHF-tagged leopards were monitored at least weekly and GPS-tagged individuals were monitored daily, for an average of 718 days for translocated animals and 465 days for resident animals.

A replicated study in 2003–2011 of savanna and farmland at several sites across Botswana (11) found that nine of 11 cheetahs *Acinonyx jubatus* translocated away from farms, for livestock protection reasons, survived for less than one year. Eight translocated male cheetahs survived for 46 to at least 981 days (average 106) after release. Three females survived for 21–95 days (average 31) after release. Nine of the 11 cheetahs were known to have died (three were shot and for six, the cause of death was unknown). On one animal, the GPS-collar failed after 981 days and the outcome for one animal was unknown. Twenty-one cheetah social groups, involving 39 animals, were translocated. They were held for 0–16 days and then released 28–278 km from capture sites. Eleven translocated animals were monitored using satellite-or GPS-collars.

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(2) Fritts S.H., Paul W.J. & Mech L.D. (1985) Can relocated wolves survive? *Wildlife Society Bulletin*, 13, 459–463.

(3) Armistead A.R., Mitchell K. & Connolly G.E. (1994) Bear relocations to avoid bear/sheep conflicts. *Proceedings of the 16th Vertebrate Pest Conference*, 31–35.

(4) Ross P.I. & Jalkotzy M.G. (1995) Fates of translocated cougars, *Felis concolor*, in Alberta. *The Canadian Field-Naturalist*, 109, 475–476.

(5) Linnell J.D.C., Aanes R., Swenson J.E., Odden J. & Smith M.E. (1997) Translocation of carnivores as a method for managing problem animals: a review. *Biodiversity and Conservation*, 6, 1245–1257.

(6) Purchase G.K. (1998) The Matusadona cheetah project: lessons from a wild-to-wild translocation. *Proceedings of a Symposium on Cheetahs as Game Ranch Animals*, Onderstepoort, 83–89.

(7) Bradley E.H., Pletscher D.H., Bangs E.E., Kunkel K.E., Smith D.W., Mack C.M., Meier T.J., Fontaine J.A., Niemeyer C.C. & Jimenez M.D. (2005) Evaluating wolf translocation as a nonlethal method to reduce livestock conflicts in the Northwestern United States. *Conservation Biology*, 19, 1498–1508.

(8) Isasi-Catala E. (2010) Is translocation of problematic jaguars (*Panthera onca*) an effective strategy to resolve human-predator conflicts? *CEE review* 8-018, SR55.

(9) Weilenmann M., Gusset M., Mills D.R., Gabanapelo T. & Schiess-Meier M. (2010) Is translocation of stock-raiding leopards into a protected area with resident conspecifics an effective management tool? *Wildlife Research*, 37, 702–707, https://doi.org/10.1071/WR10013

(10) Weise F.J., Lemeris J., Stratford K.J., van Vuuren R.J., Munro S.J., Crawford S.J., Marker L.L. & Stein A.B. (2015) A home away from home: insights from successful leopard (*Panthera pardus*) translocations. *Biodiversity and Conservation*, 24, 1755–1774.

(11) Boast L.K., Good L. & Klein R. (2016) Translocation of problem predators: is it an effective way to mitigate conflict between farmers and cheetahs *Acinonyx jubatus* in Botswana? *Oryx*, 50, 537–544, https://doi.org/10.1017/S0030605315000241

3.38. Provide diversionary feeding to reduce predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2437

- **Two studies** evaluated the effects of providing diversionary feeding to reduce predation of livestock by mammals to reduce human-wildlife conflict. One study was in the USA[1] and one was in Canada[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Reproductive success (1 study):** A controlled study in the USA[1] found that diversionary feeding of predators did not increase overall nest success rates for ducks.

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** One of two studies (one controlled, one before-and-after study) in the USA[1] and Canada[2] found that diversionary feeding reduced striped skunk predation on duck nests. The other study found that diversionary feeding of grizzly bears did not reduce predation on livestock[2].

Background

Mammalian predators can cause unacceptable losses to farmers, through predation on livestock. If diversionary feeding can reduce the extent to which animals exhibit nuisance behaviour, this may reduce motivations for carrying out lethal control or other intensive management. See also: *Provide diversionary feeding to reduce crop damage by mammals to reduce human-wildlife conflict* and *Residential and commercial development — Provide diversionary feeding for mammals to reduce nuisance behaviour and human-wildlife conflict.*

A controlled study in 1993–1994 of 24 upland prairie areas in North Dakota, USA (1) found that diversionary feeding of predators reduced striped skunk *Mephitis mephitis* predation on duck *Anas* spp. nests, but overall nest success rates did not increase significantly. The proportion of predation events on large-clutch duck nests by striped skunks was lower in areas with diversionary feeding (11%) than in areas without feeding (24%). However, the proportion of duck nests in which at least one egg hatched did not differ significantly between feeding areas (41%) and areas without food provision (29%). In April–July 1993 and 1994, supplementary food (90–100 kg of fish offal and sunflower seeds) was distributed within 1–2 plots (50 x 200–300 m) in each of 12 areas every 3–4 days. Twelve control areas had no supplementary food. Each area contained 33–83 ha of upland nesting cover and was managed for duck production. In May–July 1993 and 1994, three searches for duck nests were conducted in each of the 24 areas using a vehicle-towed chain drag. A total of 1,008 nests (609 in feeding areas; 399 in areas without supplementary food) were marked and checked every 6–21 days or until abandoned/destroyed.

A before-and-after study in 1982–2013 in a forested and agricultural area of southwestern Alberta, Canada (2) found that diversionary feeding of grizzly bears *Ursus arctos* did not reduce predation on livestock. The frequency of grizzly bear-livestock incidents during the spring did not differ significantly during 14 years before (average 0.8 incidents/year) and 15 years after (average 3.3 incidents/year) diversionary feeding commenced. Road-killed ungulate carcasses were dropped by helicopter at sites close to grizzly bear dens each spring during 1998–2013. In 2012 and 2013, 149–160 carcasses were dropped at 14–15 sites in March–April (details for earlier years are not reported). All sites were within a 3,600-km^2 area comprising forested mountains adjacent to agricultural land. Remote trail cameras at feeding sites recorded grizzly bears. Complaint data (reports of grizzly bears harassing, mauling or killing livestock) were analysed for March–June in each year before (1982–1995) and after (1998–2013) diversionary feeding commenced.

(1) Greenwood R.J., Pietruszewski D.G. & Crawford R.D. (1998) Effects of food supplementation on depredation of duck nests in upland habitat. *Wildlife Society Bulletin*, 26, 219–226.

(2) Morehouse A.T. & Boyce M.S. (2017) Evaluation of intercept feeding to reduce livestock depredation by grizzly bears. *Ursus*, 28, 66–80, https://doi.org/10.2192/URSU-D-16-00026.1

3.39. Keep livestock in enclosures to reduce predation by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2438

- **One study** evaluated the effects of keeping livestock in enclosures to reduce predation by mammals to reduce human-wildlife conflict. This study was in Portugal[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated study in Portugal[1] found fewer wolf attacks on cattle on farms where cattle were confined for at least some of the time compared to those with free-ranging cattle.

Background

Free-ranging livestock may be more vulnerable to attacks by predators than those contained indoors or in enclosures close to farm buildings. Here we consider the effectiveness of such methods of animal husbandry. If successful, this intervention could reduce incentives for carrying out lethal control of predators.

See also *Exclude wild mammals using ditches, moats, walls or other barricades to reduce human-wildlife conflict*.

A replicated, site comparison study in 2012–2014 of 68 cattle farms in a mountainous region dominated by agricultural land, forests and shrubs in northern Portugal (1) found that farms that often kept cattle in barns or enclosures suffered fewer wolf *Canis lupus* attacks than did farms with free-ranging cattle. The average annual number of wolf attacks was lower on farms that often confined cattle (2.4 attacks/year) than on farms with free-ranging cattle (9.0 attacks/year). Eighteen farms suffered no wolf attacks, 42 had 1–9 wolf attacks and eight had >9 wolf attacks. The study was conducted in an area of approximately 20,000 km^2. Semi-structured interviews were conducted in 2013–2014 with 68 cattle farmers reporting high or low levels of wolf-attacks during 2012–2013. Interview responses were used to classify farms as those that often confined cattle within fences or in barns year-round, or those using a free-ranging system, in which animals were rarely confined with fences or in barns (except at night during winter).

(1) Pimenta V., Barros I., Boitani L. & Beja P. (2017) Wolf predation on cattle in Portugal: Assessing the effects of husbandry systems. *Biological Conservation*, 207, 17–26, https://doi.org/10.1016/j.biocon.2017.01.008

3.40. Install electric fencing to protect crops from mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2439

- **Eleven studies** evaluated the effects of installing electric fencing to protect crops from mammals to reduce human-wildlife conflict. Three studies were in Japan[4,7,9], three were in the USA[1,6,10], two were in the UK[2,3] and one each was in Namibia[5], India[8] and Guinea-Bissau[11].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (11 studies)

- **Human-wildlife conflict (11 studies):** Nine of 11 studies (including three before-and-after studies and three controlled studies), in the USA[1,6,10], the UK[2,3], Japan[4,7,9], Namibia[5], India[8] and Guinea-Bissau[11], found that electric fences deterred crossings by mammals, ranging in size from European rabbits[2] to elephants[8]. Two studies had mixed results, with some fence designs deterring elephants[5] and black bears[10].

Background

Wild mammals can compete with domestic herbivores for food, can predate domestic herbivores or can damage crops. Human-wildlife conflict can be reduced if wild mammals can be effectively excluded from fields. Electric fences are extensively used and can reduce the risk of wild mammal incursions into such fields. If successful, they may reduce incentives for carrying out lethal control of such mammals.

A before-and-after study in 1961–1965 in a forest in New York State, USA (1) found that an electric fence reduced browsing on hardwood trees by white-tailed deer *Odocoileus virginanus*. Three years after fence erection, there were more unbrowsed stems inside the fence (43 unbrowsed stem/plot) than outside (16 unbrowsed stems/plot). There had been no difference in browsing rates before fence erection (inside fence line: 22 unbrowsed stems/plot; outside fence line: 22 unbrowsed stems/plot). The fence (2.5 miles perimeter) consisted of five wires, with the lower three electrified from November 1961. Browsing intensity was measured in plots measuring one rod-square (approximately 25 m^2). Twenty plots inside and 20 outside the fence were surveyed in 1961 and 1964.

A replicated, before-and-after, site comparison study in 1980–1983 on 24 arable sites in southern UK (2) found that electric fences reduced European rabbit *Oryctolagus cuniculus* numbers on crops. Rabbit numbers fell on plots protected by a Flexinet® fence (0–4 weeks after erection: 6.7 rabbits/count; 5–20 weeks after erection: 7.6 rabbits/count; before erection: 42.7 rabbits/count) and a Livestok® fence (0–4 weeks after erection: 10.1 rabbits/count; 5–20 weeks after erection: 17.6 rabbits/count; before erection: 48.0 rabbits/count). Rabbit numbers in unfenced plots remained constant throughout (0–4 weeks after erection: 15.9 rabbits/count; 5–20 weeks after erection: 13.3 rabbits/count; before erection: 13.6 rabbits/count). Electric fences (0.5 m high) were erected along one side of winter barley fields. Flexinet® (seven sites) had 80 ×

80-mm mesh and Livestok® (seven sites) had 500 × 50-mm mesh. Ten unfenced sites were also monitored. Adult rabbits were counted using spotlights and binoculars in November–April between 1980 and 1983.

A controlled study in 1988–1989 on an arable farm in Devon, UK (3) found that electric fencing reduced damage to an oat *Avena sativa* crop by badgers *Meles meles* in one of two years. Results were not tested for statistical significance. In the first year, 1.8–2.6% of crop area in fields protected by electric fencing was damaged by badgers, compared to 9.6% in an unfenced field. In the second year, 2.2–4.3% of fenced crop was damaged compared to 1% of unfenced crop. Electric fences around two fields had parallel wires at 10 cm and 20 cm above the ground. Wires were connected to a fence energiser, powered from a 12-volt battery. A third field was unfenced. Vegetation short circuited the fence, especially in 1988. In 1989, dry conditions may have reduced soil conductivity, thus reducing fence voltage. Damage (mostly flattened stalks) was assessed by walking crops in August 1988 and 1989. Additionally, 1988 data were verified using aerial photographs.

A replicated study in 1997–1998 of 24 crop fields and two areas of beehives adjacent to woodlands in Nagano prefecture, Japan (4) found that electric fences prevented raids by Asiatic black bears *Ursus thibetanus*. No bears got through any of the electric fences. Bear activity near fences was documented 23 times, including three bears departing after touching the fence, one trying unsuccessfully to dig under the fence and eight raids on unprotected fields within 13–120 m of fences. In July–October of 1997 and 1998, twenty-four sweetcorn fields and two areas of beehives (area enclosed 0.001–0.75 ha) with recent history of bear-raids were fenced using Gallagher power fence systems for 2–65 nights/fence. Fences comprised four wires at 24 cm intervals with a further wire 30 cm outside the fence and 30 cm above the ground.

A replicated, before-and-after study in 1991–1995 on farmland and grassland at four sites in East Caprivi, Namibia (5) found that some electric fences reduced crop losses to elephants *Loxodonta africana*. At one village, where 31 farms were enclosed within a 9.5-km-long permanent electric fence, there were no compensation claims for losses to elephants over two years following installation, compared to 30 claims over the previous three years. A 4-km-long permanent electric fence at another site was unsuccessful, due to inadequate installation or maintenance. At a third site, temporary electric fences kept out elephants at one village in one year. In the second year, the fence was effective but elephants were able to walk around the side. At a fourth temporary fence site, no elephants returned after electric fence installation, so its effectiveness was untested. The two, 2 m-high, permanent steel wire electric fences comprised two strands of 2-mm steel wire attached to trees or poles. The temporary fences (<2 km long) at two villages comprised polyurethane cords which were threaded with wire strands and strung between trees. Fences were powered by 12-volt batteries. Data were collated from questionnaire surveys in 1991–1995.

A randomized, replicated, controlled study in 2002–2004 at a woodland and grassland site in Ohio, USA (6) found that electric fencing deterred white-tailed deer *Odocoileus virginianus* when turned on. Significantly fewer deer entered enclosures with electric fencing (0–1 deer/day) than entered enclosures without fencing (72–86 deer/day). When power was applied to fencing in week two, deer entries decreased 88–99%. When power was delayed 10 weeks, entries decreased 90%. When power was turned on and off within a 4-week period, entries decreased 57%. Corn consumption was lower in powered (<2–6.4 kg/day) than in unpowered sites (15–32 kg/day). Ten sites (> 1 km apart) each had two 5 × 5 m enclosures (9 m apart), fenced on three sides, each containing a feed trough that measured food (corn) consumption. Infra-red cameras monitored enclosures. In February 2002, 1.3-m-high electric fencing (7 kV; ElectroBraid™) was installed around one enclosure in each pair. After one week, the treatment and control were swapped. In March 2002, one feed trough was removed from each pair, leaving five sites with troughs, surrounded by electric fencing and five unfenced troughs, for three weeks. In December 2002, all sites had electric fencing but five had it turned on and five off for one week. Power was then off for two weeks and then the same repeated. Treatment and control sites were then swapped (10 weeks since start) with the power on for three weeks at treatment sites. In January 2004, five were fenced and five were controls without fencing, for six weeks. Before each trial there was a week with no treatments.

A study in 2007–2008 of three fences in Japan (7) found that electric fencing was effective at excluding a range of large and medium-sized wild mammals. No mammals were recorded inside any fences. Outside the lowest fence, there were 157 occurrences of eight species. Outside the intermediate-height fence, there were 96 occurrences of eight species. Outside the highest fence, there were 117 occurrences of three species. Japanese macaques *Macaca fuscata*, which can climb non-electrified fences, were among animals excluded at the highest fence. Fences enclosed areas of 100–930 m^2. They comprised metallic 15 × 29 mm mesh in 0.6-m-high × 1.8-m-wide sections. The lowest fence (0.6 m high) was a single section high. The intermediate fence (1.6 m high) comprised a single wire between two mesh sections. The highest fence (1.8 m high) comprised three wires and nylon netting between two mesh sections, with two ground wires above. A current (2,000–6,500 V) ran through metallic parts. A corrugated polyvinyl chloride sheet insulated the fence bottom from the ground.

A study in 2006–2009 in two areas of Assam, India (8) found that electric or chili fences reduced the probability of Asian elephants *Elephas maximus* damaging crops. The effectiveness specifically of electric fences was not analysed. The chance of crop damage occurring was lower when fences provided a barrier to crop-raiding elephants, compared to a range of other interventions or to no intervention (results presented as statistic model coefficients). However, loud noises alongside fences reduced their effectiveness. Within two study areas, 33 community members trained as monitors recorded 1,761 crop-raiding incidents, from 1 March 2006 to 28 February 2009. A range of deterrent methods, used singly or in combination, included two-strand electric fences, chili fencing (engine grease and ground chili paste, on a jute or coconut rope), chili smoke (from burning dried chilies, tobacco, and straw), spotlights, elephant drives (repelling wild elephants using domesticated elephants), fire and noise.

A replicated study in 2010 at four arable sites in Japan (9) found that a modified electric fence design was effective at excluding large and medium-sized mammals from crops. Fewer animals were recorded inside fences (0–3) than outside fences (60–327). Raccoon dog *Nyctereutes procyonoides* (one occurrence), sika deer *Cervus nippon* (two) and wild boar *Sus scrofa* (one) crossed fences. The most frequently recorded mammals outside fences were wild boar (112 occurrences), sika deer (373) and Japanese macaque *Macaca fuscata* (117). Four fences enclosed cops covering 100–1,700 m^2. They comprised insulated fiberglass poles

(8.5 mm diameter, 2.1 m long) at 2.5-m intervals. Nine electrified wires (0.9 mm diameter) were attached, up to 1.7 m high. Nylon net (45-mm mesh) was attached to the full fence height. Poles were flexible, so animals attempting to climb would retain ground contact and hence be shocked. Measured voltages were 3,600–6,800 V. Fences were checked at least weekly. Animals were monitored inside and outside fences using infrared-triggered cameras for ≥5 months from April–November 2010.

A site comparison study in 2010 in a forested area in Michigan, USA (10) found that two of four electric fence designs successfully excluded black bears *Ursus americanus*. Two of four electric fence designs excluded 100% of black bears from accessing bait within fenced enclosures during a total of 30–38 fence interactions. Bears breached the other two fence designs and accessed bait on three occasions during a total of 48–52 fence interactions. Each of four electric fence designs was tested at 2–3 baited sites within a 17-km^2 forested area. The fences enclosed a 13-m^2 area filled with 4–13 l of bait/day (including bread, cookies, trail mix, honey, bacon, sardines etc.). Fences were constructed with 2–3 rows of white polytape (1.3 cm) at different spacings (23–58 cm from the ground) and charged with 5,000 V (see original paper for details). Each site was baited for an average of three nights prior to fencing and was visited by bears during this time. Infrared cameras recorded bears interacting with the fences during 2–5 nights/site in June–August 2010.

A replicated, controlled study in 2008–2012 of 100 rice fields in the Bijagos archipelago and Oio and Gabau regions, Guinea Bissau (11) found that electric fences deterred hippopotamus *Hippopotamus amphibius* entry into fields. The proportion of fenced fields where hippopotamuses were detected (1.3%) was lower that of unfenced fields (80.0%). Hippopotamuses were monitored in 100 rice fields in 2008–2011 in Orango Islands National Park and Uno Island and, in 2012–2013, in Cacheu National Park. Seventy-five rice fields had electric fences and 25 were unfenced. Fences were 80 cm high, were made out of 2.5-mm-diameter aluminium wire, connected to an energizer unit. Fences also comprised rope between wooden stakes, with strips of red and white striped plastic at 1-m intervals. Vegetation was cut from within 2–3 m around the wires twice each week. Fenced and unfenced fields were surveyed every 3–4 days for hippopotamus footprints.

(1) Tierson W.C. (1969) Controlling deer use of forest vegetation with electric fences. *The Journal of Wildlife Management*, 33, 922–926, https://www.jstor.org/10.2307/3799326

(2) McKillop I.G. & Wilson C.J. (1987) Effectiveness of fences to exclude European rabbits from crops. *Wildlife Society Bulletin*, 15, 394–401.

(3) Wilson C.J. (1993) Badger damage to growing oats and an assessment of electric fencing as a means of its reduction. *Journal of Zoology*, 231, 668–675, https://doi.org/10.1111/j.1469-7998.1993.tb01949.x

(4) Huygens O. & Hayashi H. (1999) Using electric fences to reduce Asiatic black bear depredation in Nagano prefecture, central Japan. *Wildlife Society Bulletin*, 27, 959–964.

(5) O'Connell-Rodwell C.E., Rodwell T., Rice M. & Hart L.A. (2000) Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation*, 93, 381–391, https://doi.org/10.1016/S0006-3207(99)00108-1

(6) Seamans T.W. & VerCauteren K.C. (2006) Evaluation of ElectroBraide™ fencing as a white-tailed deer barrier. *Wildlife Society Bulletin*, 34, 8–15, https://doi.org/10.2193/0091-7648(2006)34[8:EOEFAA]2.0.CO;2

(7) Honda T., Miyagawa Y., Ueda H. & Inoue M. (2009) Effectiveness of newly-designed electric fences in reducing crop damage by medium and large mammals. *Mammal Study*, 34, 13–17, https://doi.org/10.3106/041.034.0103

(8) Davies T.E., Wilson S., Hazarika N., Chakrabarty J., Das D., Hodgson D.J. & Zimmermann A. (2011) Effectiveness of intervention methods against crop-raiding elephants. *Conservation Letters*, 4, 346–354, https://doi.org/10.1111/j.1755-263X.2011.00182.x

(9) Honda T., Kuwata H., Yamasaki S. & Miyagawa Y. (2011) A low-cost, low-labor-intensity electric fence effective against wild boar, sika deer, Japanese macaque and medium-sized mammals. *Mammal Study*, 36, 113–117, https://doi.org/10.3106/041.036.0203

(10) Otto T.E. & Roloff G.J. (2015) Black bear exclusion fences to protect mobile apiaries. *Human–Wildlife Interactions,* 9, 78–86, https://doi.org/10.26077/dn8a-3941

(11) González L.M., Montoto F.G., Mereck T., Alves J., Pereira J., de Larrinoa P.F., Maroto A., Bolonio L. & El-Kadhir N. (2017) Preventing crop raiding by the Vulnerable common hippopotamus *Hippopotamus amphibius* in Guinea-Bissau. *Oryx*, 51, 222–229, https://doi.org/10.1017/S003060531500109X

3.41. Install metal grids at field entrances to prevent mammals entering to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2440

- **Two studies** evaluated the effects on mammal incursions of installing metal grids at field entrances to reduce human-wildlife conflict. Both of these studies were in the USA[1,2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** One of two replicated studies (including one controlled study), in the USA[1,2], found that deer guards (horizontal, ground-level metal grids) reduced entry into enclosures by white-tailed deer[2] whilst the other found that they did not prevent crossings by mule deer or elk[1].

Background

Wild herbivores can compete with domestic herbivores for food and can damage crops. Fencing can exclude wild herbivores from fields but entranceways remain vulnerable to incursions, especially were regular vehicle access is required. Metal grids (sometimes known as cattle grids) fitted across field entrances may be used to exclude wild herbivores. If successful, this could reduce incentives for carrying out lethal control of such species.

See also *Install wildlife exclusion grates/cattle grids* for studies where the intention is to exclude herbivore access to roads rather than into fields.

A replicated study in 1972–1973 of two fences in Colorado, USA (1) found that steel rail deer guards did not prevent crossings through vehicle openings by mule deer *Odocoileus hemionus hemionus* or elk *Cervus canadensis*. In test conditions, 16 of 18 mule deer released adjacent to 12, 18 or 24-foot-wide guards, crossed the guards, in an average time of 173 s. During natural encounters, 11 mule deer and one elk crossed a 24-ft-long guard and four mule deer crossed a 12-ft-long guard. There were at least 11 approaches by mule deer and three by elk in which animals did not then cross. Guards, at vehicle openings in 8-ft-high fences, comprised flat steel rails, 0.5-inch-wide, 4 inches high and 120 inches long, set 4 inches apart. Rails were perpendicular to the traffic direction. Eighteen deer were released in situations where guard crossing providing the only exit. Deer and elk tracks, from natural encounters with two guards, were examined periodically, between 29 June 1972 and 19 April 1973.

A replicated, controlled study in 2006–2007, in three forest and grassland sites in Ohio, Iowa and Wisconsin, USA (2) found that deer guards (ground-level roller grids) reduced white-tailed deer *Odocoileus virginianus* entry into enclosures. Deer guards at two sites excluded more deer than did open enclosures (data not presented). At the third site, deer did not cross one deer guard but there were 2.5 incursions/day at the other compared to 0.4 incursions/day in open enclosures at that site. Deer-resistant enclosures (6 m × 6 m, baited with alfalfa cubes) were constructed at three sites. At each site, two enclosures (one each in forest and grassland) had a deer guard (a grid of rollers over a 1.5 × 3 m pit) and two (one each in forest and grassland) had open gateways. Deer incursions into enclosures were monitored using camera traps from December 2006 to April 2007.

(1) Reed D.F., Pojar T.M. & Woodard T.N. (1974) Mule deer responses to deer guards. *Journal of Range Management*, 27, 111–113.

(2) VerCauteren K.C., Seward N.W., Lavelle M.J., Fischer J.W. &Phillips G.E. (2009) Deer guards and bump gates for excluding white-tailed deer from fenced resources. *Human-Wildlife Conflicts*, 3, 145–153, https://doi.org/10.26077/sb9r-sh17

3.42. Install automatically closing gates at field entrances to prevent mammals entering to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2441

- **One study** evaluated the effects on mammal movements of installing automatically closing gates at field entrances to reduce human-wildlife conflict. This study was in USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, controlled study, in the USA[1] found that vehicle-activated bump gates prevented white-tailed deer from entering enclosures.

Background

Wild mammals can compete with domestic herbivores for food, can predate domestic herbivores or can damage crops. Human-wildlife conflict can be reduced if wild mammals can be effectively excluded from fields. Gates through fences can provide crossing points if there is a risk of the gate being left open. Gates that close automatically may reduce the risk of wild mammals entering such fields. If successful, this may reduce incentives for carrying out lethal control of such mammals.

A replicated, controlled study, in 2006–2007, in three forest and grassland sites in Ohio, Iowa and Wisconsin, USA (1) found that vehicle-activated bump gates prevented white-tailed deer *Odocoileus virginianus* entry into enclosures. Bump gates excluded deer from all enclosures. At enclosures without bump gates, there were averages across the three sites of 0.4, 33.0 and 49.0 deer entries/day. However, supplementary tests on a separate bump gate revealed that it did not always close securely following vehicle passage. Deer-resistant enclosures (6 × 6 m, baited with alfalfa cubes) were constructed at three sites. At each site, two enclosures (one each in forest and grassland) had bump gates installed (designed to open upon low-speed vehicle contact and close after vehicle passage) and two (one each in forest and grassland) had open gateways. Deer movements into enclosures were monitored using camera traps from December 2006 to April 2007.

(1) VerCauteren K.C., Seward N.W., Lavelle M.J., Fischer J.W. & Phillips G.E. (2009) Deer guards and bump gates for excluding white-tailed deer from fenced resources. *Human-Wildlife Conflicts*, 3, 145–153, https://doi.org/10.26077/sb9r-sh17

3.43. Use tree nets to deter wild mammals from fruit crops to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2442

- We found no studies that evaluated the effects of using tree nets to deter mammals from fruit crops to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Tree nets can be used to close off tree canopy pathways or other access in order to protect fruit crops from being accessed by mammals. Netting is cheap to install but can be labour intensive for subsistence farmers. If successful in protecting fruit crops, use of nets could reduce incentives for carrying out lethal control of mammals.

3.44. Deter predation of livestock by mammals by having people close by to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2444

- **One study** evaluated the effects of deterring predation of livestock by mammals by having people close by to reduce human-wildlife conflict. This study was in Kenya[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One study in Kenya[1] recorded fewer attacks by predators on livestock in bomas when people were also present but the presence of people did not reduce predator attacks on grazing herds.

Background

Domestic livestock may be vulnerable to mammalian predators. Livestock can be guarded by animals, especially dogs *Canis lupus familiaris*, or by people (or both). This intervention involves people remaining close to livestock, either actively guarding or simply as a passive deterrent, such as by bringing livestock in at night to an area adjacent to human habitation. If the intervention results in fewer livestock being predated, this could reduce incentives for carrying out lethal control of predators.

A study in 2001–2005 of bushland and savanna across Laikipia and neighbouring districts, Kenya (1) found that when livestock in bomas were accompanied by people, fewer animals were attacked by carnivores, but there was no similar effect for grazing herds. Livestock kept in bomas overnight were less likely to be attacked when more herders were present. Presence of herders did not reduce the risk of attack for herds grazing away from bomas in the daytime (results presented as odds ratios). The 502 grazing herds were accompanied by an average of 2.1 herders. At 491 bomas, an average of 11.3 people were present. The study documented 105 attacks by spotted hyenas *Crocuta crocuta*, 96 by leopards *Panthera pardus*, 44 by African wild dogs *Lycaon pictus*, 35 by lions *Panthera leo* and 19 by cheetahs *Acinonyx jubatus*. From January 2001 to June 2005, eighteen local staff verified reports of livestock lost to predation and gathered data on animal husbandry practices used. Attacked herds or bomas were compared to nearby herds (median 656 m away) or bomas (median 323 m away) that had not been attacked.

(1) Woodroffe R., Frank L.G., Lindsey P.A., ole Ranah S.M.K. & Romañach S. (2007) Livestock husbandry as a tool for carnivore conservation in Africa's community rangelands: a case-control study. *Biodiversity and Conservation*, 16, 1245–1260, https://doi.org/10.1007/978-1-4020-6320-6_28

3.45. Deter predation of livestock by herding livestock using adults instead of children to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2445

- **One study** evaluated the effects on predatory mammal activities of herding livestock using adults instead of children to reduce human-wildlife conflict. This study was in Cameroon[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A site comparison study in Cameroon[1] found that using adults to herd livestock reduced losses through predation relative to that of livestock herded solely by children.

Background

Domestic livestock may be vulnerable to mammalian predators. Livestock may be guarded by people to deter predators. In some areas, guarding is routinely carried out by children. This intervention refers to guarding by adults instead of children.

A site comparison study in 2008 of savanna around a national park in Cameroon (1) found that using adults to herd livestock reduced losses through predation relative to livestock herded by children. Among resident pastoralist households, fewer livestock were lost to carnivores when the livestock were herded by adults (two animals/year) than by children (eight animals/year). Among nomadic pastoralist households, there were also fewer livestock lost to carnivores when herded by adults (five animals/year) than by children (16 animals/year). Among resident pastoralists that herded livestock, 42% of herders (60 herders) were adults. Among nomadic pastoralists that herded livestock, 72% (124 herders) were adults. Two hundred and seven resident pastoralists and 174 nomadic pastoralists were interviewed. Pastoralists reported the incidence of predation of livestock by large carnivores and details of animal husbandry techniques used. Villages studied were selected based on tracked movements of radio-collared lions.

(1) Tumenta P.N., de Iongh H.H., Funston P.J. & Udo de Haes H.A. (2013) Livestock depredation and mitigation methods practised by resident and nomadic pastoralists around Waza National Park, Cameroon. *Oryx*, 47, 237–242, https://doi.org/10.1017/s0030605311001621

3.46. Deter predation of livestock by using shock/ electronic dog-training collars to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2446

- **Five studies** evaluated the effects of using shock/electronic dog-training collars to deter predation of livestock to reduce human-wildlife conflict. All five studies were in the USA[1,2,3,4,5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (5 STUDIES)

- **Human-wildlife conflict (5 studies):** Three of four replicated studies (including two controlled studies), in the USA[2,3,4,5], found that electric shock collars reduced livestock predation or bait consumption by wolves, whilst one found that they did not reduce wolf bait consumption. One replicated, controlled study in the USA[1] found that electric shock collars reduced the frequency of attacks by captive coyotes on lambs[1].

Background

Electric shock collars may be used on mammalian predators as a form of aversive conditioning. A shock is administered if the animal approaches or attacks livestock. Some studies summarized below test the potential for aversive conditioning to work on captive animals using non-live food and some others studies look at wild mammals, but using artificial food. Whilst not directly assessing the effectiveness of the intervention in reducing livestock predation, these studies provide evidence as to the potential for shock collars to alter animals' behaviour in a way that could potentially be applied to wild predators in livestock production areas. If using shock collars can reduce livestock predation, this could reduce incentives for carrying out lethal control of predators.

A replicated study in 1997 on pasture at a site in Utah, USA (1) found that electric shock collars reduced the frequency of attacks by captive coyotes *Canis latrans* on lambs. During week 1 (five coyotes each spending 4–6 hours with lambs) there was a total of 10 attempted lamb attacks. During week 2 (five coyotes each spending two hours with lambs) there was one attempted attack. There were no attempted attacks in week 4, one in week 7 and none in weeks 11, 16 or 22 (five coyotes each spending two hours with lambs during each study week). All attempted attacks ceased upon electric shock administration. Five captive male coyotes (aged 5–9 years), which killed lambs in trials, were studied. Each was fitted with a Model 100 Lite electronic dog-training collar, set at maximum shock intensity. During each trial, one coyote and one lamb were held in a 679 m^2 enclosure. Shocks were administered when the coyote actively pursued the lamb.

A replicated, controlled study in 2002 of captive wolves *Canis lupus* in Minnesota, USA (2) found that electronic dog-training collars did not reduce the amount of food consumed by wolves *Canis lupus*. Wolves fitted with dog-training collars, which activated when close to the food, consumed 43% of food offered. This was not significantly different to the 84% of food eaten by wolves where no deterrent was used. Four groups of 1–4 captive wolves were each offered 1 kg of sled-dog chow for 1 hour during June or July 2002. The wolves wore electronic dog-training collars, which emitted an electric shock when ≤2 m from the food. Four further groups of 1–4 wolves were offered the same food, without any deterrent.

A replicated study in 1998–2001 on a cattle farm in Wisconsin, USA (3) found that electric shock collars deterred gray wolves *Canis lupis* from predating livestock. In the first year, one calf was killed (possibly by non-collared wolves) after the alpha-female wolf was fitted with a shock collar, compared to nine killed earlier that year. Two were killed over the following two years (by non-collared wolves). A second wolf, collared in the fourth study year and thought to be the new alpha female of the pack, appeared to stay off the farm while the collars were operational. Other pack members continued predating calves, and the pack was subsequently translocated. A female wolf was fitted with an electric shock-collar on 14 May 1998. This activated when she was ≤300 m from cattle pasture. A replacement collar, operating from 26 April to 15 August 1999, beeped and shocked when she came within 0.4 km. In 2000, the collar operated from 26 April–August with beeping only (no shock). The second female wolf's shock-collar operated from 31 May to 13 August 2001.

A replicated, randomized, controlled, before-and-after study in 2003–2004 in a forested area in Michigan, USA (4) found that wolves *Canis lupus* wearing electric shock collars avoided baited areas where shocks were administered, but aversion did not persist. Shocked wolves made fewer visits to the detection zone when shocked (treatment period: 9 visits/wolf) relative to pre-treatment (19 visits/wolf) and post-treatment (16 visits/wolf) periods. There was no corresponding decrease for non-shocked wolves (treatment: 18 visits/wolf; pre-treatment: 21; post-treatment: 19). Shocked wolves spent less time/visit in detection zones during the treatment period (13 minutes/wolf) relative to pre-treatment (77 minutes/wolf) and post-treatment (20 minutes/wolf) periods. No decrease was detected for non-shocked wolves (treatment: 63 minutes/wolf; pre-treatment: 76; post-treatment: 47). Ten wolves (one per pack) were radio-collared in 2003–2004. Five wolves (randomly selected) also received electric shock collars (Innotek Training Shock Collar). A dead deer was placed in each pack's territory every two to three days. Collared wolves ≤75 m from baits were detected and logged over two weeks (pre-treatment). Treatment wolves, ≤30 m from baits, were shocked (for 13 seconds) over the following two weeks (treatment). For two further weeks (post-treatment), collared wolf visits to the 75 m detection zone were logged.

A replicated study in 2005–2006 in a mostly forested area of Wisconsin, USA (5) found that electric shock collars reduced visits by gray wolves *Canis lupus* to baited zones. Shock-collared wolves spent less time in shock zones when collars were active than did wolves without shock collars (with shock collar: 1 min/day in baited zone; no shock collar: 14 min/day). The pattern continued post-treatment when collars were not activated (shock collar: 1 min/day; no shock collar: 21 min/day). Fourteen adult wolves (one in each pack) were caught. Ten had a radio collar and shock unit fitted. Four had a radio collar only fitted. Each pack was baited with a dead deer every three days. The shock zone was a 70-m radius from the bait. Shock collars were automatically activated within this zone during a 40-day shock period. Bait placement and monitoring continued for a further 40-day non-shock period. Radio data loggers recorded wolf visits to bait sites between May and September of 2005 and 2006.

(1) Andelt W.E., Phillips R.L., Gruver K.S. & Guthrie J.W. (1999) Coyote predation on domestic sheep deterred with electronic dog-training collar. *Wildlife Society Bulletin*, 27, 12–18.

(2) Shivik J.A., Treves A. & Callahan P. (2003) Nonlethal techniques for managing predation: primary and secondary repellents. *Conservation Biology*, 17, 1531–1537, https://doi.org/10.1111/j.1523-1739.2003.00062.x

(3) Schultz R.N., Jonas K.W., Skuldt L.H. & Wydeven A.P. (2005) Experimental use of dog-training shock collars to deter depredation by gray wolves. *Wildlife Society Bulletin*, 33, 142–148, https://doi.org/10.2193/0091-7648(2005)33[142:euodsc]2.0.co;2

(4) Hawley J.E., Gehring T.M., Schultz R.N., Rossler S.T. & Wydeven A.P. (2009) Assessment of shock collars as nonlethal management for wolves in Wisconsin. *The Journal of Wildlife Management*, 73, 518–525, https://doi.org/10.2193/2007-066

(5) Rossler S.T., Gehring T.M., Schultz R.N., Rossler M.T., Wydeven A.P. & Hawley J.E. (2012) Shock collars as a site-aversive conditioning tool for wolves. *Wildlife Society Bulletin*, 36, 176–184, https://doi.org/10.1002/wsb.93

3.47. Fit livestock with protective collars to reduce risk of predation by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2448

- **One study** evaluated the effects of fitting livestock with protective collars to reduce human-wildlife conflict on rates of livestock killings by predators. This study was in South Africa[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, before-and-after study in South Africa[1] found that livestock protection collars reduced predation on livestock by carnivores.

Background

Carnivores typically kill their prey by a fatal bite to the neck. Hard collars can protect animals' necks. This may increase the effort needed by predators to kill livestock and, thus, reduce the likelihood of a fatal bite. If the intervention results in fewer livestock predated, this could reduce incentives for carrying out lethal control of predators.

A replicated, before-and-after study in 2006–2009 of seven livestock farms in savanna and shrubland in Eastern Cape, South Africa (1) found that using livestock protection collars reduced livestock fatalities caused by predators, compared to the rate when predators were controlled by lethal means. Results were not tested for statistical significance. When livestock collars were used, 1–12% of livestock were killed each year by predators. When not using livestock collars but, instead, carrying out lethal predator control, 6–31% of livestock were killed. Costs of using livestock collars (3.5 USD/livestock animal) were comparable to those of lethal control (0.7–6.0 USD/livestock animal). In August 2006–August 2007, all seven farms used lethal methods, including trapping and shooting, to control black-backed jackals *Canis mesomelas,* caracals *Caracal caracal* and leopards *Panthera pardus.* In September 2007–September 2009, all farms fitted animals with epoxy–metal mesh collars that protected the animal's neck from predator bites. Farmers reported numbers of livestock killed by predators, and associated costs, in September in 2007–2009.

(1) McManus J.S., Dickman A.J., Gaynor D., Smuts B.H. & Macdonald, B.W. (2015) Dead or alive? Comparing costs and benefits of lethal and non-lethal human-wildlife conflict mitigation on livestock farms. *Oryx*, 49, 687–695, https://doi.org/10.1017/s0030605313001610

3.48. Use lights and sound to deter predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2449

- **Three studies** evaluated the effects of using lights and sound to deter predation of livestock by mammals to reduce human-wildlife conflict. All three studies were in the USA[1,2,3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (3 STUDIES)

- **Human-wildlife conflict (3 studies):** Three replicated studies (including one controlled study), in the USA[1,2,3], found that devices emitting sounds and lights deterred predators from predating sheep[1] or consuming bait[2,3].

Background

This intervention specifically refers to use of light and sound in combination, often delivered via a commercially-purchased frightening devise, designed to repel wild mammals. If successful, such an intervention could reduce predation of livestock by predators and thus reduce motivations for carrying out lethal control of carnivores. For different applications of similar devices, see *Use lights and sound to deter crop damage by mammals to reduce human-wildlife conflict*.

A replicated study in 1979–1983 on pasture at 20 sites in Colorado, Idaho, South Dakota, and Oregon, USA (1) found that strobe light and siren devices reduced predation of sheep by coyotes *Canis latrans*. Ten trials, using 1–2 strobe light and siren devices per pasture, provided an average 53 nights of protection (≤2 sheep losses) from coyotes. Five trials, using 3–6 devices per pasture, protected sheep for an average 91 nights. Predation rates prior to trials were not stated. During five trials on unfenced range with two siren and two strobe light devices on each site, sheep losses to coyotes were 44–95% lower than those during the previous year. Sheep on pasture were protected by units containing a commercial strobe light or a warbling siren or both. Trials occurred in 1979–1982. On rangeland, sheep were protected, from June/July to late September of 1982–1983, by two warbling-type siren units and two with strobe lights, active at night and operating at intervals of 7 or 13 minutes. Other coyote control ceased during this time.

A replicated, controlled study in 2002 in a captive facility in Minnesota and a replicated, controlled, before-and-after study in 2002 at six forest sites in Wisconsin, USA (2) found that movement-activated guard (MAG) devices (emitting sound and light deterrents) reduced food consumption by carnivores. Captive wolves *Canis lupus* ate less of food protected with MAG devices (14% of available food consumed) than of unprotected food (84% consumed). Wild carnivores consumed less of MAG-protected deer carcasses (1.1 kg/day) than of unprotected carcasses (3.3 kg/day). At the same time in sites with no device, there was no difference in consumption between the later period (1.8 kg/day) and the earlier period (1.6 kg/day). Wolves, black bears *Ursus americanus*, fishers *Martes pennanti* and foxes *Vulpes vulpes* visited plots. Six groups of 1–7 captive wolves were each offered 1 kg of sled-dog chow for 1 hour during June or July 2002. A MAG device activated when animals were ≤2 m from the food. Four groups of 1–4 wolves were offered the same food, without deterrent. Study plots (30-m circumference) were established within territories of six wild wolf packs. A fresh deer carcass was placed in each plot. The study ran during April–June 2002 for 9–35 days (pre-treatment) and 16–29 days (treatment phase). A MAG device was used at one plot in each territory and one plot had no deterrent. Carcasses were weighed every 2–3 days and replaced as required. Camera traps at three territories identified species visiting plots.

A replicated, randomized study in 2005 in a captive facility in Utah, USA (3) found that combined light and sound or using light alone deterred coyotes *Canis latrans* from eating bait more than did sound alone. Fewer coyotes consumed bait with both light and sound deterrents used (none, from five pairs) or with light alone used (one coyote from five pairs) than with sound alone used (four coyotes from five pairs).

Fifteen captive coyote pairs were housed separately in 0.1-ha outdoor pens, each with a frightening device. Devices produced noise (100 dB at 2 m), strobe light (400 cd) or noise and light combined, when motion was detected ≤2 m away. Stimuli lasted 20 s. Five coyote pairs were randomly assigned to each of the three treatments. Pork bait was placed 1 m from the frightening device. For eight days' acclimation, devices were inactive. Then one trial, lasting 1.5 h, was run each evening, over 10 evenings. Trials were conducted from 17 July to 31 August 2005.

(1) Linhart S.B. (1984) Strobe light and siren devices for protecting fenced-pasture and range sheep from coyote predation. *Proceedings of the Eleventh Vertebrate Pest Conference*, 154–156.

(2) Shivik J.A., Treves A. & Callahan P. (2003) Nonlethal techniques for managing predation: primary and secondary repellents. *Conservation Biology*, 17, 1531–1537, https://doi.org/10.1111/j.1523-1739.2003.00062.x

(3) Darrow P.A. & Shivik J.A. (2009) Bold, shy, and persistent: Variable coyote response to light and sound stimuli. *Applied Animal Behaviour Science*, 116, 82–87, https://doi.org/10.1016/j.applanim.2008.06.013

3.49. Use scent to deter predation of livestock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2450

- **Three studies** evaluated the effects of using scent to deter predation of livestock by mammals to reduce human-wildlife conflict. Two studies were in the USA[1,3] and one was in Botswana[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (3 STUDIES)

- **Human-wildlife conflict (3 studies):** Two of three studies (including one replicated, before-and-after study), in the USA[1,3] and Botswana[2], found that applying scent marks from unfamiliar African wild dogs[2] and grey wolves[3] restricted movements of these species. The other study found that applying scent marks from coyotes[1] did not restrict their movements.

Background

Predatory mammals often mark their home ranges with scent, especially by selecting sites for depositing faeces and urine. If artificially placing such scent marks can constrain predators to particular areas and, in particular, to avoid areas where livestock are kept, this might reduce predation of livestock. If effective, this could reduce incentives for carrying out lethal control of these predators.

A study in 2007–2009 of a shrubland and grassland wildlife refuge and a replicated, randomized study in 2006 at a captive facility in Utah, USA (1) found that applying coyote *Canis latrans* scent as a trial of its use in deterring livestock predation did not reduce visits by coyotes. In the wildlife refuge study, wild coyotes visited areas marked with other coyotes' scent more often (average 36 visits/coyote) than they visited non-marked areas (average 11 visits/coyote). In the captive study, coyotes visited areas marked with other coyotes' scent more often than they visited non-marked areas both at territory boundaries (marked: 17 visits; not marked: 6 visits) and within territories (marked: 13 visits; not marked: 7 visits). In the wildlife refuge, GPS-collar data were obtained from three coyotes that had been followed for >10 weeks to define home-ranges. Within each home range, 1–2 clearings (2 ha), >100 m apart, were randomly selected and either marked with coyote urine (1–2 ml every 1–2 m) or left unmarked. Coyotes were monitored for four weeks. The captive study was conducted over two 13–14-day periods in October–November 2006. Two from four coyote pairs, housed in 1-ha pens, were randomly selected to have the boundary of 7% of their pen area marked with urine and scats from other coyotes. Two pairs did not have their pens marked. The behaviour of each coyote was monitored for eight hours through direct observation.

A study in 2008–2010 at a savanna reserve in Botswana (2) found that applying scent marks from other African wild dogs *Lycaon pictus* at the reserve boundary caused resident wild dogs to return towards the centre of their range. Seven of eight scent mark applications were followed by wild dogs moving closer to the centre of their range within the reserve. An additional application, 24 h after initial applying scents, generated the same response on the eighth occasion. Wild dogs moved further in the day after application (average 7.2 km) than when no marks were applied (3.4 km). This response reduced movements onto neighbouring farmland and potential livestock depredation. Eighteen wild dogs were translocated to the reserve and released in April 2008. When they moved to the reserve boundary, 3–26 wild dog urine and faeces marks, brought from a different site, were applied 50–200 m from the pack. The pack was monitored, using GPS collars or visual observation, from September 2008 to February 2010.

A replicated, before-and-after study in 2008–2011 in three forest-dominated sites in Idaho, USA (3) found that marking grey wolf *Canis lupus* territories with lines of scent from other wolf packs restricted wolf movements in some but not all cases. Results were not tested for statistical significance. Overall, the proportion of location fixes indicating that wolves had crossed scent lines was variable after scents were deployed (0–23%) and before scent deployment (1–12%). No incursions across scent lines were recorded in single years for two wolf packs (out of five pack/year combinations). In other cases, there was less evidence of scent lines reducing incursions. Two parallel 10–36-km lines were marked across wolf pack territories in 2010 (two packs) and 2011 (three packs). Lines were marked with 3 ml of urine from a different wolf pack, every 500 m and with 6 ml of urine every 750 m, and scats every km. Scent marks were refreshed every 10–14 days in June–August. Wolf packs (8–14 wolves) were monitored by satellite tracking of 2–4 wolves in each pack for 3–4 years during May–September of 2008–2011.

(1) Shivik J.A., Wilson R.R. & Gilbert-Norton L. (2011) Will an artificial scent boundary prevent coyote intrusion? *Wildlife Society Bulletin*, 35, 494–497, https://doi.org/10.1002/wsb.68

(2) Jackson, C.R., McNutt, J.W. & Apps, P.J. (2012) Managing the ranging behaviour of African wild dogs (*Lycaon pictus*) using translocated scent marks. *Wildlife Research*, 39, 31–34, https://doi.org/10.1071/WR11070

(3) Ausband D.E., Mitchell M.S., Bassing, S.B. & White, C. (2013) No trespassing: using a biofence to manipulate wolf movements. *Wildlife Research*, 40, 207–216, https://doi.org/10.1071/WR12176

3.50. Use watchmen to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2451

- We found no studies that evaluated the effects of using watchmen to deter crop damage by mammals to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Damage to agricultural crops by mammalian herbivores may cause substantial losses for some farmers. Although labour-intensive, farmers in some areas may directly guard crops. If this can reduce crop losses to mammals, it could reduce incentive for carrying out lethal control of such species.

3.51. Use mobile phone communications to warn farmers of problematic mammals (e.g. elephants)

https://www.conservationevidence.com/actions/2452

- We found no studies that evaluated the effects of using mobile phone communications to warn farmers of problematic mammals (e.g. elephants).

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Farmers may be vulnerable to loss of crops from raids by wild herbivores or to loss of livestock to mammalian predators. The large growth in use of mobile phones makes it easier for farmers to communicate the presence of problem animals to others in the general area. This may allow faster responses in deployment of prevention measures (Lewis *et al*. 2016). If this reduces crop damage or livestock predation, it might also reduce incentives for lethal control of wild herbivores or predators.

Lewis A.L., Baird T.D. & Sorice M.G. (2016) Mobile phone use and human-wildlife conflict in Northern Tanzania. *Environmental Management*, 58, 117–129, https://doi.org/10.1007/s00267-016-0694-2

3.52. Use fencing/netting to reduce predation of fish stock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2454

- We found no studies that evaluated the effects of using fencing or netting to reduce predation of fish stock by mammals to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Fish farms can attract a range of mammalian predators, causing human-wildlife conflict. For example, questionnaire respondents from among fish farm operators and anglers in the Czech Republic reported between 7% and 17% of fish losses being due to predation by Eurasian otters *Lutra lutra* (Václavíková *et al*. 2011). If barriers, such as netting or fencing, can keep predators from accessing fish, this may reduce incentives for carrying out lethal control of such animals.

Václavíková M., Václavík T & Kostkan V. (2011) Otters vs. fishermen: Stakeholders' perceptions of otter predation and damage compensation in the Czech Republic. *Journal for Nature Conservation*, 19, 95–102, https://doi.org/10.1016/j.jnc.2010.07.001

3.53. Establish deviation ponds in fish farms to reduce predation of fish stock by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2455

- We found no studies that evaluated the effects on mammals of establishing deviation ponds in fish farms to reduce predation of fish stock by mammals to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Some mammals can become significant predators of fish being reared in fish farms. For example, one study found that rainbow trout *Onchorhynchus mykiss* from a fish farm formed 87% of biomass of prey consumed by otters *Lutra lutra* in the vicinity (Marques *et al*. 2007). Deviation ponds are sites where fish are made easily accessible to predators in order to keep them away from other, more valuable, fish kept elsewhere on the site. If effective, this intervention could reduce incentives for carrying out lethal control of mammalian predators of fish.

Marques C., Rosalino LM. & Santos-Reis M. (2007) Otter predation in a trout fish farm of Central-east Portugal: Preference for 'fast-food'? *River Research and Applications*, 23, 1147–1153, https://doi.org/10.1002/rra.1037

3.54. Use lights and sound to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2456

- **Two studies** evaluated the effects of using both lights and sound to deter crop damage by mammals to reduce human-wildlife conflict. Both studies were in the USA[1,2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** Two replicated paired sites, controlled studies (one also randomized), in the USA[1,2], found that frightening devices, emitting lights and sound, did not reduce crop intrusions by white-tailed deer[1] or food consumption by elk and mule deer[2].

Background

This intervention specifically refers to use of light and sound in combination, typically delivered via a commercially-produced product designed to deter visits by wild mammals. If successful, such an intervention could reduce crop damage and, thus, reduce motivation for carrying out lethal control of herbivores.

See also: *Use light/lasers to deter crop damage by mammals to reduce human-wildlife conflict*, *Use loud noises to deter crop damage (e.g. banger sticks, drums, tins, iron sheets) by mammals to reduce human-wildlife conflict* and *Use noise aversive conditioning to deter crop damage by mammals to reduce human-wildlife conflict*.

A replicated, paired sites, controlled study in 1999 of corn fields at two sites in Nebraska, USA (1) found that a device emitting lights and sound (Electronic Guard) did not reduce crop visits by white-tailed deer

Odocoileus virginianus. The number of deer visits/km of field boundary did not differ between treatment fields protected by Electronic Guards (38–46/day) and unprotected control fields (40–56/day). Similarly, there was no difference between fields before devices operated (treatment fields: 24 visits/km/day; control fields: 21 visits/km/day) or after operations ceased (treatment fields: 47 visits/km/day; control field: 53 visits/km/day). Four groups of fields were studied at each of two sites. Fields were 0.5–2.5 km apart and separated by woodland. In each group, one field was protected by two Electronic Guard devices and one field was unguarded. Electronic Guards comprised a strobe light (60 flashes/minute) and siren (116 dB at 1 m). They operated at night, from when corn crops became susceptible to damage (13 July 1999 at one site and 25 July 1999 at the second site), for 18 days. Deer activity was assessed by counting tracks twice while devices operated, once during the two weeks before devices operated and once during the week after they operated.

A replicated, randomized, paired sites, controlled study in 2001 of pastures on a ranch in Colorado, USA (2) found that a device emitting lights and sound (Critter Gitter™) did not reduce combined elk *Cervus canadensis* and mule deer *Odocoileus hemionus* food consumption. Daily alfalfa consumption at bales protected by Critter Gitters™ (3.1–6.0 kg/day) did not differ from that at unprotected bales (2.8–7.3 kg/day). The Critter Gitter™ activated when infrared sensors detected movement and heat. When activated, an alarm (approaching 120 decibels) sounded for five seconds and a pair of red LEDs flashed. Five sites (>300 m apart) on private ranchland, adjacent to residential areas, were studied. Each site had two alfalfa bales, 60 m apart. One or two devices were positioned by one bale (selected randomly). The other bale was unprotected. Devices detected animals ≤2 m away. Alfalfa consumption was estimated visually, every two or three days, on 10 occasions.

(1) Gilsdorf J.M., Hygnstrom S.E., VerCauteren K.C. Blankenship E.E. & Engeman R.M. (2004) Propane exploders and Electronic Guards were ineffective at reducing deer damage in cornfields. *Wildlife Society Bulletin*, 32, 524–531, https://doi.org/10.2193/0091-7648(2004)32[524:PEAEGW]2.0.CO;2

(2) VerCauteren K.C., Shivik J.A. & Lavelle M.J. (2005) Efficacy of an animal-activated frightening device on urban elk and mule deer. *Wildlife Society Bulletin*, 33, 1282–1287, https://doi.org/10.2193/0091-7648(2005)33[1282:eoaafd]2.0.co;2

3.55. Provide diversionary feeding to reduce crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2457

- **Six studies** evaluated the effects of providing diversionary feeding to reduce crop damage by mammals to reduce human-wildlife conflict. Three studies were in Canada[1a,1b,2] and one was in each of France[3], Spain[4] and Austria[5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (6 STUDIES)

- **Human-wildlife conflict (6 studies):** Three of six studies (including four controlled and one before-and-after study) in Canada[1a,1b,2], France[3], Spain[4] and Austria[5] found that diversionary feeding reduced damage by red squirrels[2] to pine trees and European rabbits[4] to grape vines, and resulted in fewer red deer[5] using vulnerable forest stands. Two studies found that diversionary feeding did not reduce damage by voles[1a] to apple trees or wild boar[3] to grape vines. One study[1b] found mixed results on damage by voles to crabapple trees depending on the food provided.

Background

Mammals can cause unacceptable losses to farmers, through feeding on crops. If diversionary feeding can reduce the extent to which animals exhibit nuisance behaviour, this may reduce motivations for carrying out lethal control or other intensive management.

See also: *Provide diversionary feeding to reduce predation of livestock by mammals to reduce human-wildlife conflict* and *Residential and commercial development — Provide diversionary feeding for mammals to reduce nuisance behaviour and human-wildlife conflict*.

A randomized, controlled study in 1983–1984 at an orchard in British Columbia, Canada (1a) found that diversionary feeding with treated plywood sticks did not reduce damage by voles *Microtus* spp. to spartan apple *Malus domestica* trees. The percentage of apple trees damaged by voles did not differ significantly in orchard blocks with treated plywood sticks (32%) or those without sticks (36%). Trees with treated plywood sticks around them had more bark and tissues removed by voles (average 20–27 cm^2/tree) than trees without sticks (5 cm^2/tree), although the difference was not tested for statistical significance. In November 1983, three treatments (plywood sticks treated with sucrose, soybean oil or sorbitol) were randomly assigned to each of three orchard blocks of 100 spartan apple trees (15 and 30 years old). Three plywood sticks (5 x 37.5 cm, 9 mm thick kiln-dried Douglas fir *Pseudotsuga menziesii*) were placed in a triangle around each tree, 1–2 cm from the base. One control orchard block had no plywood sticks. The area of bark and vascular tissues removed by voles was measured on each of the 400 trees in March 1984.

A randomized, controlled study in 1984–1985 at a newly planted orchard in British Columbia, Canada (1b) found that diversionary feeding with bark-mulch logs treated with soybean oil reduced damage by montane voles *Microtus montanus* to crabapple *Malus* spp. trees, but logs treated with apple or apple and soybean oil did not. Orchard blocks with logs treated with soybean oil had a lower percentage of trees damaged by voles (25%) and trees with stem or root girdling (4%) than those without logs (63% damaged; 25% girdling). The difference was not significant between orchards with logs treated with apple (46% damaged; 17% with girdling) or apple and soybean oil (58% damaged; 33% with girdling) and those without logs. In November 1984, logs made from sifted Douglas fir *Pseudotsuga menziesii* bark mulch mixed with wax and one of three treatments (soybean oil, apple powder or apple powder and soybean oil mixed together) were randomly assigned to each of three orchard blocks of 24 one-year-old crabapple trees. Three logs were placed around each tree, 8–10 cm from the base. Additional logs were added as required in December 1984–February 1985. One control orchard block had no logs. Numbers of trees with vole damage and stem or root girdling in each of the four orchard blocks were recorded in March 1985.

A controlled study in 1989–1990 of managed forest in British Columbia, Canada (2) found that diversionary feeding reduced damage by red squirrels *Tamiasciurus hudsonicus* to lodgepole pine *Pinus contorta* crop trees. In each of three years, lodgepole pine blocks with diversionary feeding had a lower percentage of trees damaged by squirrels (average 5–11%) and fewer damage wounds (average 0.02–0.13 wounds/tree) than control blocks without diversionary feeding (average 26–61% of trees damaged; 0.5–2 wounds/tree). In May and June 1989, sunflower seeds were manually distributed in piles (45 kg/ha) within a 20-ha lodgepole pine block, and one 20-ha control block had no seeds. In 1990, two 15-ha blocks had seeds manually distributed in piles (22.7 kg/ha), two 20-ha blocks had seeds distributed by helicopter (22.7 kg/ha), and two 15-ha control blocks had no seeds. In 1991, seeds were distributed across three areas of 131–200 ha by helicopter (20 kg/ha), and three control areas had no seeds. Squirrel damage was recorded within 16–24 circular plots located every 50 or 100 m in a grid pattern within each treatment and control block or area in 1989, 1990 and 1991.

A before-and-after study in 1990–1993 of 283 vineyards in Puechabon, France (3) found that diversionary feeding did not reduce damage by wild boar *Sus scrofa* to grape vines. Average grape vine losses caused by wild boar did not differ significantly during two years before diversionary feeding (193 kg/ha) and one year with diversionary feeding (151 kg/ha). In July–September 1993, a total of 4.7 tons of grain maize (25 kg/day) was distributed along a 4.5 km trail through woodland located 500–1,000 m from 283 vineyards. The 50 owners of the vineyards were questioned on the estimated amount of damage to grape vines caused by wild boar in 1990–1992 (before diversionary feeding) and 1993 (with diversionary feeding).

A controlled study in 2008 at three vineyards in Córdoba province, Spain (4) found that diversionary feeding reduced damage by European rabbits *Oryctolagus cuniculus* to common grape vines *Vitis vinifera*. Grape vines within plots with diversionary feeding had a lower percentage of buds and shoots removed by rabbits (11%) than those without diversionary feeding (21%). However, grape vine yield did not differ between vineyard plots with or without diversionary feeding (both 4.7 kg/vine). At each of three vineyard sites, one plot had diversionary feeding (50 kg fresh alfalfa placed in strips along the edge of the plot each week during the growing season), and a second plot did not. All plots were unfenced. The proportion of buds and shoots removed by rabbits on 15–20 vines/plot was recorded throughout the growing season in 2008. Grape vine yields were estimated during harvest from the number and size of grape clusters on each vine.

A study in 2009–2011 in a mixed timber forest in Austria (5) found that diversionary feeding of red deer *Cervus elaphus* resulted in fewer deer using forest stands vulnerable to deer damage. Forest stands vulnerable to deer browsing and bark-stripping (young and mid-aged stands) were used less by red deer in areas 1.3–1.5 km from winter feeding stations compared to areas further away (data reported as statistical model results). Supplementary food (mainly apple pomace and hay) was provided during winter (October–May) at seven feeding stations (1 station/19 km^2) within a 131-km^2 area of mixed forest managed for production of Norway spruce *Picea abies* and European larch *Larix decidua*. In 2009–2011, eleven red deer (seven males, four females) were radio-tracked to a total of 29,799 locations within the forest. Deer damage was not directly measured.

(1) Sullivan T.P. & Sullivan D.S. (1988) Influence of alternative foods on vole population and damage in apple orchards. *Wildlife Society Bulletin*, 16, 170–175.

(2) Sullivan T.P. & Klenner W. (1993) Influence of diversionary food on red squirrel population and damage to crop trees in young lodgepole pine forests. *Ecological Applications*, 3, 708–718, https://doi.org/10.2307/1942102

(3) Calenge C., Maillard D., Fournier P. & Fouque C. (2004) Efficiency of spreading maize in the garrigues to reduce wild boar (*Sus scrofa*) damage to Mediterranean vineyards. *European Journal of Wildlife Research*, 50, 112–120, https://doi.org/10.1007/s10344-004-0047-y

(4) Barrio I.C., Bueno C.G. & Tortosa F.S. (2010) Alternative food and rabbit damage in vineyards of southern Spain. *Agriculture, Ecosystems and Environment*, 138, 51–54, https://doi.org/10.1016/j.agee.2010.03.017

(5) Arnold J.M., Gerhardt P., Steyaert S., Hackländer K. & Hochbichler E. (2018) Diversionary feeding can reduce red deer habitat selection pressure on vulnerable forest stands, but is not a panacea for red deer damage. *Forest Ecology and Management*, 407, 166–173, https://doi.org/10.1016/j.foreco.2017.10.050

3.56. Use scarecrows to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2459

- We found no studies that evaluated the effects of using scarecrows to deter crop damage by mammals to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Scarecrows are generally life-sized models of people that come in various designs, including static scarecrows and those that move, or inflate at intervals, to increase their impact. They are placed in crop fields, usually to deter visits by birds, but they could also be used to deter mammalian crop-raiders. If successful, this could reduce incentives for carrying out lethal control of such mammals.

3.57. Use loud noises to deter crop damage (e.g. banger sticks, drums, tins, iron sheets) by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2460

- **Ten studies** evaluated the effects of using loud noises to deter crop damage by mammals to reduce human-wildlife conflict. Three studies were in the USA[2,6,7], two were in Zimbabwe[4,5] and Kenya[8a,8b] and one each was in the UK[1], Namibia[3], and India[9].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (10 STUDIES)

- **Human-wildlife conflict (10 studies):** Five of six studies (including two controlled, one replicated and two before-and-after studies), in the USA[2,6], Namibia[3], Kenya[8a,8b] and India[9], found that loud noises activated when an animal was in the vicinity reduced or partially reduced crop damage or crop visits by white-tailed deer[2], black-tailed deer (when combined with using electric shock collars)[6] and elephants[3,8a,9]. The other study[8b] found that using loud noises (along with chili fences and chili smoke) did not reduce crop-raiding by African elephants. Three studies (including two controlled studies), in the UK[1] and the USA[2,7], found that regularly sounding loud noises did not repel European rabbits[1] or white-tailed deer[2,7]. Two replicated studies, in Zimbabwe[4,5], found that, from among a range of deterrents, African elephants were repelled faster from crop fields when scared by firecrackers[5] or by a combination of deterrents that included drums[4].

Background

This intervention specifically refers to use of sound, from various sources, to deter visits by wild mammals into crops. If successful, such an intervention could reduce crop damage and, thus, reduce motivation for carrying out lethal control of herbivores.

See also: *Use lights and sound to deter crop damage by mammals to reduce human-wildlife conflict*, *Use noise aversive conditioning to deter crop damage by mammals to reduce human-wildlife conflict* and *Use ultrasonic noises to deter crop damage by mammals to reduce human-wildlife conflict*.

A before-and-after study in 1984 on grassland in Surrey, UK (1) found that an acoustic scaring device did not deter European rabbits *Oryctolagus cuniculus* from consuming bait. Bait consumption after the device was activated (2–361 g/bait pile/day), did not differ from that before the device was activated (7–368 g/bait pile/day). Five wild, adult rabbits were placed in a 50 × 40-m grass enclosure, with wooden hutches at one end. The opposite end housed the scaring device and 400-g piles of chopped carrots at 3, 6, 9, 12 and 15 m from the device. The device emitted 5-s bursts of rapidly pulsed sound, separated by 4-s silences. Bait was deposited on four days/week. Remaining carrots were removed and weighed to establish quantity consumed. Similar bait, in rabbit-proof cages, was used to correct weights for moisture changes. The enclosure contained sufficient grass to sustain rabbits without their need to eat carrots. The trial lasted four weeks, in March 1984, with the scaring device switched on midway through.

A randomized, controlled, before-and-after study in 1994–1995 on a grassland site in Ohio, USA (2) found that motion-activated propane exploders temporarily reduced white-tailed deer *Odocoileus virginianus* visits but regularly firing exploders did not. There were fewer deer visits in the week following deployment of motion-activated exploders, in two out of three seasons (23–94 visits/week) compared to the pre-treatment period (159–313 visits/week). In spring/early-summer and late-summer, visit rates returned to pre-treatment levels after 2–6 weeks. In autumn, exploders did not reduce deer visits. Regularly firing exploders did not reduce deer visit rates compared to pre-treatment levels in any weeks studied and neither did non-functioning exploders. The experiment used different combinations of three out of six feeding sites, during 9 August–12 September 1994, 20 September–24 October 1994 and 27 April–12 July 1995. Each time, a two-week pre-treatment period preceded a 3–9-week treatment period. Feeding sites (>1 km apart) were semi-circular fences around whole kernel corn. Treatments were propane exploders firing eight times in two minutes when motion was detected, exploders firing every 8–10 minutes and non-functioning exploders. Deer visits were monitored with electronic detecting devices.

A replicated study in 1993–1995 of farmland and grassland at 10 villages in East Caprivi, Namibia (3) found that car sirens connected to trip wires around crops were partially successful in reducing crop raiding by elephants *Loxodonta africana*. Sirens at three villages in the first year were all reported to have positive effects of reducing crop-raiding by elephants (actual crop-raiding frequencies not reported). In the second year, a positive effect of sirens was reported from one village, whilst elephants did not approach at three villages (so the system was untested) and at two further villages, the crop area was too large to protect using the system. In the third year, three villages reported positive effects whilst at a fourth, battery failure rendered the system ineffective. Sirens each protected 1–7 farms at 10 villages during one or two years of the trial. Each system comprised a car siren, a 12-V battery and a 10-s timer. Polyethylene cords were mounted on fences or trees to enclose fields. The siren activated for 10 s when the cord was pulled. Data were collated from questionnaire surveys in 1993–1995.

A replicated study in 1995–1996 in crop fields at a site surrounded by savanna in Sebungwe, Zimbabwe (4) found that African elephants *Loxodonta africana* were repelled faster from agricultural fields by groups of people banging drums (alongside a range of other deterrents) than by one person making less noise. Specific effects of banging on drums cannot be separated from those of other scaring tactics. Elephants were repelled faster when scared by people with drums, dogs *Canis lupus familiaris*, whips and large fires (4 minutes) or with drums, dogs, slingshots and burning sticks (10 minutes) than by one person sometimes with a dog and chasing elephants while banging on tins and yelling (14 minutes). When scared by actions that included drums, elephants charged at defenders 12 times out of 26 trials, though only charged two out of nine times when scared by a single person without drums. Elephants raiding crops were scared 15 times by 4–7 people with drums, dogs, whips and large fires, 11 times by 2–3 people with drums, dogs, slingshots, and burning sticks and 15 times by one person (sometimes with a dog, and sometimes hitting tins and yelling to deter elephants). Behavioural responses were monitored through a monocular. Distance between elephants and farmers was 20–40 m. Tests were conducted between 18:30 and 06:30 h. The number of fields was not specified.

A replicated study in 2001 of arable land in seven villages in Guruve District, Zimbabwe (5) found that using loud noises, by throwing firecrackers at crop-raiding elephants *Loxodonta africana*, repelled them faster than did traditional deterrents such as beating drums and throwing rocks. Elephants left faster when firecrackers were activated (average 6 minutes) than they did when traditional repellent methods alone were used (average 65 minutes). Seven villages were studied. At three villages, on 35 occasions, farmers threw locally made firecrackers at elephants that were attempting to raid crops. On 27 occasions, farmers at four villages used traditional methods to ward off elephants that attempted to raid crops, namely banging drums and throwing rocks with catapults. The study was conducted from 1 January to 30 June 2001 and data were collected by a team of observers.

A replicated, controlled study in two pastures in Washington, USA (6) found that playing loud noise, along with using shock collars, reduced damage by black-tailed deer *Odocoileus hemionus* to tree seedlings. The loud noise and electric shock were part of the same treatment, so their relative effects could not be separated. In areas where playing of loud noise was triggered, damage to tree seedlings was lower (0–1 bites) than in areas where loud noises were not triggered (0–25 bites). Three deer, fitted with shock collars, were placed in each of two 1.5-ha pastures. Within each pasture, four 20 × 20 m plots were established. In each plot, 16 red cedar *Thuja plicata* seedlings were planted at 1-m intervals. When deer entered two of the plots, a loud noise was played through a speaker and deer received an electric shock. When they entered the other two plots, no noise was played and they received no shock. Deer activity was measured by counting the number of bites taken from seedlings over a 21-day period.

A replicated, paired sites, controlled study in 1999 of corn fields at two sites in Nebraska, USA (7) found that loud noises from propane exploders did not reduce visits to crops by white-tailed deer *Odocoileus virginianus*. The number of deer visits/km of field boundary was similar in fields protected by propane exploders (31–36/day) and unprotected fields (40–56/day). Similarly, there were no significant difference between fields before devices operated (exploders: 17 visits/km/day; unprotected: 21 visits/km/day) or after (exploders: 37 visits/km/day; unprotected: 53 visits/km/day). Four groups of fields (0.5–2.5 km apart, separated by woodland) were studied at each of two sites. At each site, one field had propane exploders (two/field) and one was unguarded. Propane exploders fired at 15-minute intervals. They operated at night, from when corn crops became susceptible to damage (13 July 1999 at one site and 25 July 1999 at the second site), for 18 days. Deer activity was assessed by counting tracks twice while devices operated and once each in ≤2 weeks before and after this time.

A before-and-after and site comparison study in 2003–2004 of two farming areas in Laikipia, Kenya (8a) found that using loud noises, along with chili fences and chili smoke, reduced raiding and crop damage by African elephants *Loxodonta africana*. The study does not distinguish between the effects of loud noises and chilli deterrents. After farmers began using loud noises, along with chili fences and smoke, the total number of crop-raiding incidents (26) and the average area of crop damage (375 m^2/incident) was lower than before deterrents were used (92 incidents; 585 m^2/incident). However, the difference was not tested for statistical significance. At a control site without deterrents, crop-raiding increased (total 17–166 incidents) as did crop damage (average 328 m^2–421 m^2/incident) during the same time period. A group of farmers within a 0.03-km^2 area were provided with training and materials to deter crop-raiding elephants. Deterrents included loud noises (bangers, banger sticks, cow bells), chili fences (rope and cloth fences with chili and engine grease applied) and chili smoke (chili and dung briquettes burned at night). Some farmers also used watchtowers and torches. A second control area, of equal size and within 1 km, used no deterrents. Crop-raiding incidents and crop damage were recorded in each of the two areas before (June–December 2003) and after (June–December 2004) deterrents were introduced.

A replicated, before-and-after and site comparison study in 2004–2005 at 40 farms in Laikipia, Kenya (8b) found that using loud noises, along with chili fences and chili smoke, did not result in an overall reduction in crop-raiding by African elephants *Loxodonta africana*. The study does not distinguish between the effects of chilli deterrents and loud noises. After farmers began using loud noises, along with chili fences and chili smoke, the average number of crop-raiding incidents across all farms (2) was similar to before deterrents were used (2.5). At 10 control farms without deterrents, crop-raiding decreased (from an average of three incidents to one) during the same time period. Ten farmers in each of two areas were provided with training and materials to deter crop-raiding elephants. Deterrents included loud noises (bangers, banger sticks, cow bells), chili fences (rope and cloth fences with chili and engine grease applied) and chili smoke (chili and dung briquettes burned at night). Some farmers also used watchtowers and torches. Uptake of deterrent types varied between farms (see original paper for details). Ten control farms within each of the two areas used no deterrents. Crop-raiding incidents were recorded at all 40 farms before (February–November 2004) and after (February–November 2005) deterrents were introduced.

A study in 2006–2009 in two areas of Assam, India (9) found that using loud noises to scare Asian elephants *Elephas maximus* reduced the probability of elephants damaging crops. The chance of crop damage occurring was lower when noise was used to deter elephants compared to a range of other interventions or to no intervention (results presented as statistic model coefficients). Only fences and spotlights reduced crop raiding to a greater extent. Within two study areas, 33 community members, trained as monitors, recorded 1,761 crop-raiding incidents, from 1 March 2006 to 28 February 2009. A range of deterrent methods was used, singly or in combination, including noise (shouting, crackers or drums), chili smoke (from burning dried chilies, tobacco, and straw), spotlights, two-strand electric fences, chili fencing (engine grease and ground chili paste, on a jute or coconut rope), elephant drives (repelling wild elephants using domesticated elephants) and fire.

(1) Wilson C.J. & McKillop I.G. (1986) An acoustic scaring device tested against European rabbits. *Wildlife Society Bulletin*, 14, 409–411.

(2) Belant J.L., Seamans T.W. & Dwyer C.P. (1996) Evaluation of propane exploders as white-tailed deer deterrents. *Crop Protection*, 15, 575–578, https://doi.org/10.1016/0261-2194(96)00027-0

(3) O'Connell-Rodwell C.E., Rodwell T., Rice M. & Hart L.A. (2000) Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation*, 93, 381–391, https://doi.org/10.1016/S0006-3207(99)00108-1

(4) Osborn F.V. (2002) Capsicum oleoresin as an elephant repellent: field trials in the communal lands of Zimbabwe. *The Journal of Wildlife Management*, 66, 674–677, https://doi.org/10.2307/3803133

(5) Osborn F.V. & Parker G.E. (2002) Community-based methods to reduce crop loss to elephants: experiments in the communal lands of Zimbabwe. *Pachyderm*, 33, 32–38.

(6) Nolte D.L., VerCauteren K.C., Perry K.R. & Adams S.E. (2003) *Training deer to avoid sites through negative reinforcement*. USDA National Wildlife Research Center-Staff Publications, 264.

(7) Gilsdorf J.M., Hygnstrom S.E., VerCauteren K.C. Blankenship E.E. & Engeman R.M. (2004) Propane exploders and Electronic Guards were ineffective at reducing deer damage in cornfields. *Wildlife Society Bulletin*, 32, 524–531, https://doi.org/10.2193/0091-7648(2004)32[524:peaegw]2.0.co;2

(8) Graham M. & Ochieng T. (2008) Uptake and performance of farm-based measures for reducing crop raiding by elephants *Loxodonta africana* among

smallholder farms in Laikipia District, Kenya. *Oryx*, 42, 76–82, https://doi.org/10.1017/S0030605308000677

(9) Davies T.E., Wilson S., Hazarika N., Chakrabarty J., Das D., Hodgson D.J. & Zimmermann A. (2011) Effectiveness of intervention methods against crop-raiding elephants. *Conservation Letters*, 4, 346–354, https://doi.org/10.1111/j.1755-263x.2011.00182.x

3.58. Use noise aversive conditioning to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2461

- **One study** evaluated the effects of using noise aversive conditioning to deter crop damage by mammals to reduce human-wildlife conflict. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, controlled study in USA[1] found that noise aversive conditioning reduced bait consumption by white-tailed deer.

Background

Aversive conditioning is the process of associating a negative stimulus with a secondary behaviour or outcome. In the case of this intervention, it involves associating a negative stimulus with a neutral one (noise) when carrying out undesirable behaviour (feeding on crops) to the extent that the neutral stimuli alone deters this behaviour. If this reduces crop damage, it may reduce motivations for carrying out lethal control of wild mammalian herbivores.

A replicated, controlled study in 2001 on a pasture site in Georgia, USA (1) found that attempts to condition white-tailed deer *Odocoileus virginianus* to avoid food when a metronome was played, by initially playing the sound alongside an electric wire deterrent, reduced, but did not eliminate, consumption of the food. With the metronome active but the electric wire deactivated, corn consumption (1.4–2.0 kg/day) was generally lower than at unprotected feeders (2.2 kg/day) but was higher than when both the metronome and electric wire deterrent were active (0–0.1 kg/day). Deer were studied in three 13-ha pasture plots, each containing two feeders, 6.5 m apart. Feeders comprised a plastic tray on a toolbox. At one feeder in each plot, the box housed an electric fence charger and an electronic metronome. An electric fence wire on each tray was likely to be touched by deer accessing corn. Each feeder was supplied with 2.3 kg/day of whole corn. Unconsumed corn was weighed and removed. Data were collected during six 5-day periods in April–May 2001. During the first, third and fifth periods, electric chargers and metronomes were activated. In alternate periods, only metronomes remained active.

(1) Gallagher G.R. & Prince R.H. (2003) Negative operant conditioning fails to deter white-tailed deer foraging activity. *Crop Protection*, 22, 893–895, https://doi.org/10.1016/s0261-2194(03)00048-6

3.59. Use ultrasonic noises to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2479

- **One study** evaluated the effects of using ultrasonic noises to deter crop damage by mammals to reduce human-wildlife conflict. This study was in Australia[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, controlled, paired sites study in Australia[1] found that ultrasonic devices did not repel eastern grey kangaroos.

Background

Ultrasonic noise is sound waves at higher frequencies than those audible to humans. Different mammal species can detect sound at different ranges of frequencies, so some ultrasonic noises may be audible to a range of mammal species. If ultrasonic noises can deter animals from damaging crops, this could reduce motivation for carrying out lethal control of such species.

See also: *Use lights and sound to deter crop damage by mammals to reduce human-wildlife conflict*, *Use noise aversive conditioning to deter crop damage by mammals to reduce human-wildlife conflict* and *Use loud noises to deter crop damage (e.g. banger sticks, drums, tins, iron sheets) by mammals to reduce human-wildlife conflict*.

A replicated, controlled, paired sites study in 1995–1996 on a grassland site in Victoria, Australia (1) found that ultrasonic devices (ROO-Guard) did not repel eastern grey kangaroos *Macropus giganteus*. The number of kangaroo faecal pellets counted with the devices running (0.36–0.38 pellets/m^2/day) was not significantly different from the number counted in the presence of dummy devices (0.17–0.20 pellets/m^2/day). ROO-Guards were reported by the manufacturer to emit high frequency noise that is inaudible to humans but which deters kangaroos by masking their ability to hear predators. ROO-Guard Mk II devices were operated in December 1995–January 1996 in five open grassy areas of ≥100 m diameter. Each was paired with a similar area ≥850 m away, where an inactive device was simultaneously placed. Kangaroo use of each area was assessed by counting faecal pellets after 5–10 days.

(1) Bender H. (2003) Deterrence of kangaroos from agricultural areas using ultrasonic frequencies: efficacy of a commercial device. *Wildlife Society Bulletin*, 31, 1037–1046.

3.60. Use drones to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2481

- **One study** evaluated the effects on mammals of using drones to deter crop damage by mammals to reduce human-wildlife conflict. This study was in Tanzania[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated study in Tanzania[1] found that drones repelled African savanna elephants from crops within one minute.

Background

Wild herbivores can cause substantial damage to agricultural crops. Various methods may be used to deter animals from accessing crops or to scare away animals in the area. This intervention covers use of drones for scaring animals away from crop areas. If successful, the intervention could reduce incentives for carrying out lethal control of crop-raiding mammal species.

A replicated study in 2015–2016 in two savanna reserves in Tanzania (1) found that using drones to deter crop damage led to African savanna elephants *Loxodonta africana* leaving sites within one minute on all occasions. On all 38 occasions when drones were deployed to intercept elephants, the animals began to flee within one minute. Elephants were typically herded to an area > 1 km from croplands. Before drone use, rangers were trained during three 4-day workshops. In February–March and May–August 2015, and in March–April 2016, rangers deployed drones in 38 situations when elephants were found close to croplands or villages. Each drone was fitted with a flashlight, to locate elephants at night and, during the day, a live video feed from a camera on the drone was used. Elephant responses were recorded over 60-second intervals, during the first 10 minutes of the drone flight.

(1) Hahn N., Mwakatobe A., Konuche J., de Souza N., Keyyu J., Goss M., Chang'a A., Palminteri S., Dinerstein E. & Olson D. (2017) Unmanned aerial vehicles mitigate human–elephant conflict on the borders of Tanzanian Parks: a case study. *Oryx*, 51, 513–516, https://doi.org/10.1017/s0030605316000946

3.61. Translocate crop raiders away from crops (e.g. elephants) to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2485

- **Two studies** evaluated the effects on mammals of translocating crop-raiding animals away from crops to reduce human-wildlife conflict. One study was in Kenya[1] and one was in the USA[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A controlled study in Kenya[1] found that translocated crop-raiding African elephants had a lower survival rate after release than did non-translocated elephants at the same site.

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A study in the USA[2] found that most American black bears translocated from sites of crop damage were not subsequently recaptured at sites of crop damage.

Background

Where wild mammals cause unacceptable damage to crops, they may be translocated from their point of capture and released some distance away. The release site may be an area away from where agricultural crops are grown. The intervention can fail if translocated animals continue to raid crops or if survival of translocated animals is low. If the intervention succeeds, it may reduce incentives for carrying out lethal control of such animals. Several other interventions cover translocations that are primarily for conservation of rare or threatened species, such as *Translocate to re-establish or boost populations in native range*.

A controlled study in 2005–2006 of savanna in and around a national park in Kenya (1) found that translocated crop-raiding African elephants *Loxodonta africana* had a lower survival rate than non-translocated elephants at the same site. Twenty-four of 150 translocated elephants died within 55 days of translocation; from dying during translocation (six elephants), poaching (one), shooting by problem animal control officers (two) and unknown causes (three), whilst 12 calves went missing and were presumed to have died. Out of 103 elephants that survived this period and were successfully monitored, four (4%) died over year following release, compared to 77 out of 6,395 (1%) during the same time period from the non-translocated population in the same park. One hundred and fifty elephants were translocated 160 km to a national park, in September 2005, to reduce human-elephant conflicts related to crop damage at the source location. Locations of translocated elephants and resident elephants were monitored 4–5 times/week at the receptor site from road transects and 2–3 times/week by aerial surveys.

A study in 2006–2007 across a large portion of northern Wisconsin, USA (2) found that most American black bears *Ursus americanus* translocated away from sites of damage to corn crops were not subsequently recaptured at sites of crop damage. Out of 520 translocated bears, 20 (4%) were recaptured during subsequent capture activities at sites of crop damage (including the original capture site). Average time to recapture was 45 days. Recaptured bears had been moved 40–64 km following initial capture. Of the total of 21 recaptures of 20 recaptured bears (one was recaptured twice), nine (43%) were at the original capture site and 15 (71%) were within 10 km of the original capture site. Bears were captured on 55 farms from 11 August to 9 October 2006 and 50 farms from 3 August to 12 October 2007. Skin samples were taken using a biopsy dart and 541 out of 567 samples produced genetic material that enabled identification of 520 individuals.

(1) Pinter-Wollman N., Isbell L.A. & Hart L.A. (2009) Assessing translocation outcome: Comparing behavioral and physiological aspects of translocated and resident African elephants (*Loxodonta africana*). *Biological Conservation*, 142, 1116–1124, https://doi.org/10.1016/j.biocon.2009.01.027

(2) Shivik J.A., Ruid D., Willging R.C. & Mock K.E. (2011) Are the same bears repeatedly translocated from corn crops in Wisconsin? *Ursus*, 22, 114–119, https://doi.org/10.2192/URSUS-D-10-00031.1

3.62. Use negative stimuli to deter consumption of livestock feed by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2486

- **One study** evaluated the effects of using negative stimuli to deter consumption of livestock feed by mammals to reduce human-wildlife conflict. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, controlled study in the USA[1] found that white-tailed deer presence at cattle feeders was usually reduced by a device that produced a negative stimulus.

Background

Livestock feed might also attract wild herbivores. This could produce a financial cost to farmers, through added feed costs and through transmission of disease, such as bovine tuberculosis, between wild and domestic herbivores (Phillips *et al*. 2003). Disease transmission may be greater where animals share foodstuffs. Hence, if wild herbivores can be effectively deterred from accessing livestock feed, this may reduce motivations for carrying out lethal control of wild herbivores.

Phillips C.J., Foster C.R., Morris P.A. & Teverson R. (2003) The transmission of *Mycobacterium bovis* infection to cattle. *Research in Veterinary Science*, 74, 1–15, https://doi.org/10.1016/s0034-5288(02)00145-5

A replicated, controlled study in 2005 of captive deer on a farm in Michigan, USA (1) found that a deer-resistant cattle feeder device reduced white-tailed deer *Odocoileus virginianus* presence at feeders for the first five of six weeks. Fewer deer were recorded on camera traps within 1 m of feeders with active devices (0–0.2 deer/activation) than of feeders without devices (0.7–1.9 deer/activation) during the first five treatment weeks. There was no significant difference during the sixth week (active device: 0.4 deer/activation; no device: 1.2 deer/activation). During four weeks before device activation, deer number recorded on camera traps were similar between feeders with (2.3–2.9 deer/activation) and without (2.1–2.7 deer/activation) devices. Three feeders each were protected and unprotected by devices. Devices entailed a 3.4-m horizontal bar with a 1.6-m arm hanging on chains at each end, down to 45 cm above the ground. The rig rotated on a central pivot for 45 s, when an animal entered an infra-red-surveillance zone. Hanging arms struck animals within 1 m of feeders, startling, but not hurting, them. Monitoring, using camera traps, spanned 10 February to 10 March 2005 (devices inactive) and 13 May to 23 June 2005 (devices active).

(1) Seward N.W., Phillips G.E., Duquette J.F. & VerCauteren K.C. (2007) A frightening device for deterring deer use of cattle feeders. *The Journal of Wildlife Management*, 71, 271–276, https://doi.org/10.2193/2006-265

3.63. Play predator calls to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2487

- We found no studies that evaluated the effects on mammals of playing predator calls to deter crop damage to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Wild herbivores can cause damage to crops. Calls of predators of these animals can be played in an attempt to deter wild herbivores from the area.

3.64. Use target species distress calls or signals to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2488

- **Five studies** evaluated the effects of using target species distress calls or signals to deter crop damage by these species to reduce human-wildlife conflict. Two studies were in the USA[2,4] and one each was in Namibia[1], Australia[3] and Sri Lanka[5].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (5 STUDIES)

- **Human-wildlife conflict (5 studies):** Two of five replicated studies (including four controlled studies), in the USA[2,4], Namibia[1], Australia[3] and Sri Lanka[5], found that white-tailed deer[4] and Asian elephants[5] were deterred or repelled from areas by playing their respective distress calls. Two studies found that, in most cases, elephants[1] and white-tailed deer[2] were not deterred from entering or remaining at sites when distress calls were played. The fifth study found mixed results but, overall, eastern grey kangaroo foot-thumping noises did not increase numbers leaving a site[3].

Background

Some animals, especially species that routinely form social groups, produce calls or other audible signals when they detect danger. If artificially playing calls or signals from the same species can restrict movements of animals, this may assist in reducing damage to crops. If effective, the intervention could reduce incentives for carrying out lethal control of such species.

A replicated study in 1994 at three water holes in a grassland area in East Caprivi, Namibia (1) found that playing warning calls of elephants *Loxodonta africana* did not, in most cases, deter elephants from remaining at a site. In eight trials at three sites, groups of elephants (5–30 animals) were deterred from the site during three trials and undeterred during five. In six further trials involving 1–3 bull elephants, the animals were not deterred. Trail groups were not independent and some involved the same animals. Elephant warning calls, produced during times of apparent natural distress events, were recorded. They were played back on a portable cassette player at approximately 15-m distance from each herd as they visited water holes. Playback was activated when elephants pushed a tripwire.

A replicated, paired sites, controlled study in 2001 on arable fields alongside woodland at a site in Nebraska, USA (2) found that playing white-tailed deer *Odocoileus virginianus* distress calls did not affect deer intrusions into corn crops or subsequent corn yields. The rate of deer entries into fields was similar at fields protected by frightening devices (48–57 entries/km boundary/day) and unprotected fields (48–52 entries/km boundary/day). Similarly, there was no difference between fields before devices operated (device fields: 69 entries/km/day; unprotected: 56 entries/km/day) or after devices were turned off (device fields: 23–46 entries/km/day; unprotected: 20–47 entries/km/day). Average corn yields did not differ between fields with frightening devices (6,381 kg/ha) and unprotected fields (5,614 kg/ha). Six pairs of fields (6–20 ha, ≥0.5 km apart, matched for size, shape and location) were studied. Frightening devices played deer distress noises for 30 s when activated by deer breaking 50–200-m-long infrared beams. Two devices at each protected field covered 21–48% of the perimeter. Devices operated from 6–24 July 2001, when corn was most vulnerable to deer-damage. Deer activity was assessed by counting tracks twice during the device operating period, once five days before this and three times during 18 days after this time.

A replicated, randomized, controlled study in 1997–1998 at a shrubland site in Victoria, Australia (3) found that playing recordings of foot-thumping kangaroos increased vigilance in eastern grey kangaroos *Macropus giganteus* and caused more kangaroos to flee in the first few second, but did not cause more overall to flee. Where the foot-thumping noise was played, kangaroos increased vigilance more than did those played a background recording (data presented as indices). A higher proportion of kangaroos fled within the first 3 s of hearing foot-thumping (26%) than of hearing background noise (0%). However, in total, 63% of kangaroos fled, and there was no significant difference in the overall average time to fleeing between noise types (combined average time to fleeing of 25 s). Kangaroos were observed from hides alongside three perimeter fence holes (≥850 m apart). Foot-thumping or a background noise were played for 8 s (noise type selected randomly). Responses were assessed from videos of 236 kangaroos, on 15 nights (20.00 to 21.15 hrs), from 11 December 1997 to 5 February 1998. Fleeing time was measured in 112 adult kangaroos, 64 exposed to foot-thumping and 48 with background noise. Individual kangaroos were tested once/session.

A replicated, randomized, controlled, before-and-after study in 2010 in a deciduous forest in Utah, USA (4) found that devices playing deer distress calls reduced white-tailed deer *Odocoileus virginianus* visits and food uptake. Sites with devices had 0 deer visits/day when devices were active (treatment period) compared to 273 visits/day with devices inactive (pre-treatment). Concurrently, sites without devices had 122 visits/day (treatment period) and 169 visits/day (pre-treatment). Food consumption by deer was lower at sites with devices during treatment (0 litres) than pre-treatment phases (2,175 l). At sites without devices, consumption during treatment (1,100 l) and pre-treatment phases (1,585 l) was similar. Six sites, >0.6 km apart, were each enclosed in a U-shaped fence, 18.3 m long. Three sites, selected randomly, had a deer-activated frightening device installed. This played deer distress calls when an infra-red beam was broken. Sites were baited with >38 l of alfalfa cubes in February 2010. Bait was topped up every second day. Deer visits were monitored using camera traps. Pre-treatment (device inactive) ran during 10–22 March 2010 while the treatment phase (device active) ran from 23 March to 4 April 2010.

A replicated, randomized, controlled study (year not stated) in a protected area containing forest, grassland, and wetland in Sri Lanka (5) found that playing recordings of elephant family groups to Asian elephants *Elephas maximus* led to more elephants fleeing the area compared to playing of other sounds. After playing the sound of elephant family groups, 11 of 17 elephants (65%) fled, compared to three of 31 (10%) when other sounds were played. Randomly selected elephants in the protected area were provided with a sugarcane, banana and palm frond mixture. Speakers were placed approximately 15 m from elephants. Sounds were played in a random order for one minute each, with a five-minute interval between sounds. Sounds played were: elephant group vocalizations (17 occasions), Sri Lankan hornets *Vespa affinis affinis* (12 occasions), lone female elephant vocalizations (8 occasions) and a chainsaw (11 occasions). Behaviour of animals was recorded during and after each playback.

(1) O'Connell-Rodwell C.E., Rodwell T., Rice M. & Hart L.A. (2000) Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation*, 93, 381–391, https://doi.org/10.1016/s0006-3207(99)00108-1

(2) Gilsdorf J.M., Hygnstrom S.E., VerCauteren K.C., Clements G.M., Blankenship E.E. & Engeman R.M. (2004) Evaluation of a deer-activated bioacoustic frightening device for reducing deer damage in cornfields. *Wildlife Society Bulletin*, 32, 515–523, https://doi.org/10.2193/0091-7648(2004)32[515:eoadbf]2.0.co;2

(3) Bender H. (2005) Effectiveness of the eastern grey kangaroo foot thump for deterring conspecifics. *Wildlife Research*, 32, 649–655, https://doi.org/10.1071/wr04091

(4) Hildreth A.M., Hygnstrom S.E. & VerCauteren K.C. (2013) Deer-activated bioacoustic frightening device deters white-tailed deer. *Human–Wildlife Interactions* 7, 107–113, https://doi.org/10.26077/12mz-1p38

(5) Wijayagunawardane M.P., Short R.V., Samarakone T.S., Nishany K.B., Harrington H., Perera B.V., Rassool R. & Bittner E.P. (2016) The use of audio playback to deter crop-raiding Asian elephants. *Wildlife Society Bulletin*, 40, 375–379, https://doi.org/10.1002/wsb.652

3.65. Use bees to deter crop damage by mammals (e.g. elephants) to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2489

- **Three studies** evaluated the effects on elephants of using bees to deter crop damage to reduce human-wildlife conflict. All three studies were in Kenya[1,2,3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (3 STUDIES)

- **Human-wildlife conflict (3 studies):** Three replicated studies (including one controlled study), in Kenya[1,2,3], found that beehive fences reduced crop raiding by African elephants.

Background

Conflicts between farmers and free-ranging elephants occur in parts of Africa. Farmers on small plots may lose large proportions of their crops to raids by elephants. Some elephants are said to be wary of foraging near African honeybees *Apis mellifera scutellata* (Vollrath & Douglas-Hamilton 2002). Thus, fences comprising bee hives linked by wires may deter entry to fields by elephants, as well as providing a further potential crop (honey) for farmers. If successful, the intervention could reduce incentives for carrying out lethal control of elephants.

Vollrath F. & Douglas-Hamilton I. (2002) African bees to control African elephants. *Naturwiss*, 89, 508–511, https://doi.org/10.1007/s00114-002-0375-2

A controlled study in 2007 on two farms in Laikipia, Kenya (1) found that a beehive fence (without resident bees) reduced crop-raiding by African elephants *Loxodonta africana*. Results were not tested for statistical significance. There were fewer successful crop raids on the farm protected by the beehive fence (7 raids) than on the unprotected farm (13 raids). Fewer individual elephants raided the protected farm (38) than the unprotected farm (95). The two farms, 466 m apart, each approximately 2 acres, grew similar mixes of maize *Zea mays*, potatoes *Solanum tuberosum*, sorghum *Sorghum* sp. and beans. On one farm, nine hives were suspended under thatch roofs, along a 90-m boundary. A wire between hives connected to the wires suspending hives, so an elephant pushing against it caused the hives to shake, and bees to emerge. However, hives were unoccupied during the trial. The second farm was unprotected. Elephant raids were documented by farmers over six weeks in August–September 2007.

A replicated, controlled study in 2008–2010 on agricultural land around two villages in Kenya (2) found that beehive fences reduced entry onto farmland by elephants *Loxodonta africana*. Elephants entered farmland through a beehive fence less often (1 occasion) than they did through traditional thorn bush barriers (31 occasions). Following entry to farmland, elephants also left less frequently through beehive fences (six occasions) than they did through thorn bush barriers (26 occasions). Thirty-four farms were studied, of which 17 were protected along parts of their perimeters by beehive fences and 17 were protected solely by traditional thorn bush barriers. Beehive fences comprised a total of 149 beehives deployed in June–August 2008 and 21 deployed in April 2009. Hives were positioned 10 m apart. Farms were monitored over three crop seasons, from June 2008 until June 2010.

A replicated study in 2012–2015 of 10 crop fields in an agricultural community in Kenya (3) found that beehive fences deterred crop raiding by African elephants *Loxodonta africana*. Of 238 elephants that approached farms with beehive fences, more turned away (190 elephants) than broke through to raid crops (48). On 65 occasions, elephant groups approached to ≤10 m from beehive fences. Of these, 39 groups (114 elephants) turned back at the fence and 26 groups (50 elephants) broke through fences. Eight farm plots, each 0.4 ha extent, were enclosed by beehive fences, built in June 2012 to February 2013**.** Fences comprised 12 beehives and 12 two-dimensional plywood dummy hives suspended from a wire running continuously between fence posts. Pushing the wire caused hives to rock and bees to emerge. Elephant movements around fences were recorded by farmers.

(1) King L.E., Lawrence A., Douglas-Hamilton I. & Vollrath F. (2009) Beehive fence deters crop-raiding elephants. *African Journal of Ecology*, 47, 131–137, https://doi.org/10.1111/j.1365-2028.2009.01114.x

(2) King L.E., Douglas-Hamilton I. & Vollrath F. (2011) Beehive fences as effective deterrents for crop-raiding elephants: field trials in northern Kenya. *African Journal of Ecology*, 49, 431–439. https://doi.org/10.1111/j.1365-2028.2011.01275.x

(3) King L.E., Lala F., Nzumu H., Mwambingu E. & Douglas-Hamilton I. (2017) Beehive fences as a multidimensional conflict-mitigation tool for farmers coexisting with elephants. *Conservation Biology*, 31, 743–752, https://doi.org/10.1111/cobi.12898

3.66. Grow unattractive crop in buffer zone around crops (e.g. chili peppers) to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2491

- We found no studies that evaluated the effects on mammals of growing unattractive crops (such as chili peppers) in buffer zones around crops to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Some crops are vulnerable to wild herbivores, such as elephants. Some other crops, such as chilli, may have a repellent effect for wild herbivores. Planting them around the perimeter of the main crop may act as a deterrent to approach by such wild herbivores. If successful, this may reduce the incentives for carrying out lethal control of such herbivores.

3.67. Use chili to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2492

- **Seven studies** evaluated the effects on elephants of using chili to deter crop damage to reduce human-wildlife conflict. Four studies were in Zimbabwe[1,2,3,5], two were in Kenya[4a,4b] and one was in India[6].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (7 STUDIES)

- **Human-wildlife conflict (7 studies):** Five of seven studies (including four replicated and two before-and-after studies), in Zimbabwe[1,2,3,5], Kenya[4a,4b] and India[6], found that chill-based deterrents (chili-spray, chili smoke, chili fences and chili extract in a projectile, in some cases along with other deterrents) repelled elephants at least initially[1,2,3,4a,5], whist two studies found that chili smoke (and in one case chili fences) did not reduce crop raiding[4b,6].

Background

This intervention covers use of chili in various forms for deterring crop damage. All studies are of its effectiveness against elephants *Loxodonta africana* and *Elephas maximus*. In some cases, trials were of deterrent effects of chili against elephants that were not actively crop-raiding. Studies in this intervention are all of situations where chili repellents are targeted specifically at potential crop raiding animal, using smoke, aerosol or projectile. If successful, the intervention could reduce incentives for carrying out lethal control of elephants.

See also *Use repellents that taste bad ('contact repellents') to deter crop or property damage by mammals to reduce human-wildlife conflict*, which includes use of Hot Sauce® and other chili-based repellents that are applied directly to crops.

A replicated study in 1993–1994 of savanna and farmland at two sites in Zimbabwe (1) found that a chili-based capsicum spray repelled elephants *Loxodonta africana*. In 19 of 22 tests in a national park, elephants retreated when sprayed with the capsicum aerosol. In three successful tests, elephants reacted to the sound of the spray discharging. Elephants also retreated in 16 of 18 tests carried out on farmland. In two tests, elephants appeared not to inhale the spray. Twenty-two tests were conducted in a national park from 16–22 July 1993, thirteen on bulls and nine on family groups. Capsicum sprays were discharged on foot or from vehicles (average 40 m from elephants) or by remote-control, 250 m from a watering hole. Eighteen tests were conducted on 1–14 elephants on farmland, on moonlit nights, from February–May 1994. Capsicum sprays were administered on foot or by remote-control. In all tests, elephants were settled for 5–20 mins, with staff in place, before testing. This helped to ensure that elephants' responses were not simply a reaction to human presence. A 10% capsicum oleoresin solution was then discharged from an aerosol can, upwind of elephants.

A replicated study in 1995–1996 in crop fields at a site surrounded by savanna in Sebungwe, Zimbabwe (2) found that a chili-based capsicum spray repelled crop-raiding African elephants *Loxodonta africana* faster than did scaring by combinations of people, dogs *Canis lupus familiaris*, slingshots, drums, whips, burning sticks large fires. Elephants were repelled faster when sprayed with capsicum aerosol (2 minutes) than when scared by one person with a small fire (and sometimes with a dog) (14 minutes), by two to three people with dogs and slingshots, drums and burning sticks (10 minutes) or by four to seven people with dogs, drums, whips and large fires (4 minutes). No elephants charged at defenders when sprayed with the capsicum aerosol but defenders were charged on 13–60% of occasions when elephants were scared by other means. Elephants raiding crops were scared 18 times using 10% capsicum oleoresin spray, 15 times by one person with a small fire (and sometimes with a dog), 11 times by 2–3 people with dogs, slingshots, drums and burning sticks and 15 times by 4–7 people with dogs, drums, whips and large fires. Behavioural responses were monitored by watching through a monocular. Distance between elephants and farmers was 20–40 m. Tests were conducted between 18:30 and 06:30 h. The number of fields studied was not specified.

A replicated study in 2001 of arable land in seven villages in Guruve District, Zimbabwe (3) found that burning chilies mixed with elephant *Loxodonta africana* dung, repelled crop-raiding elephants faster than did traditional deterrents of beating drums and throwing rocks. Elephants left faster (average 9 minutes) when chili mixed with dung was burned than they did when traditional repellent methods alone were used (average 65 minutes). Seven villages were studied. At three villages, farmers set fire to bricks made of elephant dung mixed with chili, to deter elephants that were attempting to raid crops, on 34 occasions. Farmers at four villages used traditional methods to scare off elephants that attempted to raid crops, namely banging drums and throwing rocks with catapults, on 27 occasions. The study was conducted from 1 January to 30 June 2001 and data were collected by a team of observers.

A before-and-after and site comparison study in 2003–2004 of two farming areas in Laikipia, Kenya (4a) found that using chili fences and chili smoke, along with loud noises, reduced raiding and crop damage by African elephants *Loxodonta africana*. The study does not distinguish between the effects of chilli deterrents and loud noises. After farmers began using chili fences and chili smoke, along with loud noises, the total number of crop-raiding incidents (26) and the average area of crop damage (375 m^2/incident) was lower than before deterrents were used (92 incidents; 585 m^2/incident). However, the difference was not tested for statistical significance. At a control site without deterrents, crop-raiding increased (total 17–166 incidents) as did crop damage (average 328 m^2–421 m^2/incident) during the same time period. A group of farmers within a 0.03-km^2 area were provided with training and materials to deter crop-raiding elephants. Deterrents included chili fences (rope and cloth fences with chili and engine grease applied), chili smoke (chili and dung briquettes burned at night) and loud noises (bangers, banger sticks, cow bells). Some farmers also used watchtowers and torches. A second control area, of equal size and within 1 km, used no deterrents. Crop-raiding incidents and crop damage were recorded in each of the two areas before (June–December 2003) and after (June–December 2004) deterrents were introduced.

A replicated, before-and-after and site comparison study in 2004–2005 at 40 farms in Laikipia, Kenya (4b) found that using chili fences and chili smoke, along with loud noises, did not result in an overall reduction in crop-raiding by African elephants *Loxodonta africana.* The study does not distinguish between the effects of chilli deterrents and loud noises. After farmers began using chili fences and chili smoke, along with loud noises, the average number of crop-raiding incidents across all farms (2) was similar to before deterrents were used (2.5). At 10 control farms without deterrents, crop-raiding decreased (from an average of three incidents to one) during the same time period. Ten farmers in each of two areas were provided with training and materials to deter crop-raiding elephants. Deterrents included chili fences (rope and cloth fences with chili and engine grease applied), chili smoke (chili and dung briquettes burned at night) and loud noises (bangers, banger sticks, cow bells). Some farmers also used watchtowers and torches. Uptake of deterrent types varied between farms (see original paper for details). Ten control farms within each of the two areas used no deterrents. Crop-raiding incidents were recorded at all 40 farms before (February–November 2004) and after (February–November 2005) deterrents were introduced.

A study in 2007 of grassland, thicket, woodland and water holes in a national park in Zimbabwe (5) found that, after being shot at with chili oil extract, most savanna elephants *Loxodonta africana* either ran away or backed up, but most soon resumed normal behaviour. When shot at, 11 (46%) of 24 elephants ran away, seven (29%) changed their behaviour and walked away and six (25%) did not change their behaviour. After 1 minute, seven (29%) were still running away, one (4%) was walking away and 16 (67%) had resumed normal behaviour. The study was conducted in a remote area of Hwange National Park in October 2007. Between 09:30 and 18:00 h, a professional hunter shot a ping-pong ball filled with chili oil extract at 24 elephants from 15–110 m using a gas-dispenser. Only eight elephants were hit by the balls, of which seven then released chili oil.

A study in 2006–2009, in two areas of Assam, India (6) found that using chili smoke to deter Asian elephants *Elephas maximus* did not reduce the probability of elephants raiding crops. The chance of crop damage occurring was not lower when chili smoke was used to deter crop-raiding elephants compared to a range of other interventions or to no intervention (results presented as statistic model). Within two study areas, 33 community members were trained as monitors to record the 1,761 crop-raiding incidents, from 1 March 2006 to 28 February 2009. A range of deterrents were used, singly or in combination. These included chili smoke (from burning dried chilies, tobacco, and straw), spotlights, two-strand electric fences, chili fencing (engine grease and ground chili paste, on a jute or coconut rope), elephant drives (using domesticated elephants to repel wild elephants), fire and noise.

(1) Osborn F.V. & Rasmussen L.E.L. (1995) Evidence for the effectiveness of an oleo-resin capsicum aerosol as a repellent against wild elephants in Zimbabwe. *Pachyderm*, 20, 55–64.

(2) Osborn F.V. (2002) Capsicum oleoresin as an elephant repellent: field trials in the communal lands of Zimbabwe. *The Journal of Wildlife Management*, 66, 674–677, https://doi.org/10.2307/3803133

(3) Osborn F.V. & Parker G.E. (2002) Community-based methods to reduce crop loss to elephants: experiments in the communal lands of Zimbabwe. *Pachyderm*, 33, 32–38.

(4) Graham M. & Ochieng T. (2008) Uptake and performance of farm-based measures for reducing crop raiding by elephants Loxodonta africana among smallholder farms in Laikipia District, Kenya. *Oryx*, 42, 76–82, https://doi.org/10.1017/S0030605308000677

(5) Le Bel S., Taylor R., Lagrange M., Ndoro O., Barra M. & Madzikanda H. (2010) An easy-to-use capsicum delivery system for crop-raiding elephants

in Zimbabwe: preliminary results of a field test in Hwange National Park. *Pachyderm*, 47, 80–89.

(6) Davies T.E., Wilson S., Hazarika N., Chakrabarty J., Das D., Hodgson D.J. & Zimmermann A. (2011) Effectiveness of intervention methods against crop-raiding elephants. *Conservation Letters*, 4, 346–354, https://doi.org/10.1111/j.1755-263x.2011.00182.x

3.68. Use light/lasers to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2496

- **Two studies** evaluated the effects of using light or lasers to deter crop damage by mammals to reduce human-wildlife conflict. Both studies were in the USA[1,2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** A replicated, randomized, controlled study in the USA[1] found that red lasers did not disperse white-tailed deer from fields at night whilst a study in India[2] found that spotlights directed at the eyes of Asian elephants did reduce the probability of crop damage.

Background

This intervention specifically refers to use of directional light or lasers aimed at animals. If such lights can reduce crop damage by mammals, this may reduce incentives for carrying out lethal control of such species.

See also *Use lights and sound to deter crop damage to reduce human-wildlife conflict*.

A replicated, randomized, controlled study in 2001 in arable fields on two adjacent wildlife refuges straddling Nebraska and Iowa, USA (1) found that red lasers did not disperse white-tailed deer *Odocoileus virginianus* from fields at night. No differences were found in flight response between two different lasers (deer fled in 2–3% of encounters) or between these lasers and the control without lasers (3% fled). Thirty-two crop fields were randomly assigned one of two lasers, shone from a vehicle, or as the control (vehicle without laser). The two red lasers were the Desman® (633 nm, 5 mW, 12 mm beam) and Dissuader™ (650 nm, 68 mW, variable beam). Deer behaviour was monitored using night-vision binoculars on eight consecutive nights in July 2001 (total 177 deer encounters). Deer were initially located with a spotlight. Lasers were used for 2 minutes/deer, first on adjacent vegetation, then in a zig-zag manner, then on the body.

A study in 2006–2009 in two areas of Assam, India (2) found that using spotlights directed at the eyes of Asian elephants *Elephas maximus* reduced the probability of elephants causing crop damage. The chance of crop damage occurring was lower when spotlights were used to deter crop-raiding elephants compared to a range of other interventions or no intervention (results presented as statistical model coefficients). Only installing fences reduced crop raiding to a greater extent. Using loud noises alongside spotlighting reduced its effectiveness. Within two study areas, 33 community members were trained as monitors to record the 1,761 crop-raiding incidents, from 1 March 2006 to 28 February 2009. A range of deterrents were used, singly or in combination, including spotlights, chili smoke (from burning dried chilies, tobacco, and straw), two-strand electric fences, chili fencing (engine grease and ground chili paste, on a jute or coconut rope), elephant drives (using domesticated elephants to repel wild elephants), fire and noise.

(1) VerCauteren K.C., Hygnstrom S.E., Pipas M.J., Fioranelli P.B., Werner S.J. & Blackwell B.F. (2003) Red lasers are ineffective for dispersing deer at night. *Wildlife Society Bulletin*, 31, 247–252.

(2) Davies T.E., Wilson S., Hazarika N., Chakrabarty J., Das D., Hodgson D.J. & Zimmermann A. (2011) Effectiveness of intervention methods against crop-raiding elephants. *Conservation Letters*, 4, 346–354, https://doi.org/10.1111/j.1755-263X.2011.00182.x

3.69. Use fire to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2499

- **Two studies** evaluated the effects on mammals of using fire to deter crop damage by mammals to reduce human-wildlife conflict. One study was in Zimbabwe[1] and one was in India[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (2 STUDIES)

- **Human-wildlife conflict (2 studies):** A replicated study in Zimbabwe[1] found that a combination of large fires and people with drums and dogs repelled African elephants from crops faster than did a combination of people with dogs and slingshots, drums and burning sticks. A study in India[2] found that fire reduced the chance of Asian elephants damaging crops.

Background

Wild herbivores can cause substantial damage to agricultural crops. Various methods may be used to deter animals from accessing crops or to scare away animals in the area. This intervention covers use of fire for scaring animals away from crop areas. If successful, the intervention could reduce incentives for carrying out lethal control of crop-raiding mammals.

A replicated study in 1995–1996 in crop fields at a site surrounded by savanna in Sebungwe, Zimbabwe (1) found that when scared by a combination of large fires and people with dogs *Canis lupus familiaris*, whips and drums, African elephants *Loxodonta africana* were repelled faster from fields than by a combination of people with dogs, slingshots, drums and burning sticks. Elephants were repelled faster when scared with by large fires and people with dogs, whips and drums (4 minutes) than when scared by people with dogs, slingshots, drums and burning sticks (10 minutes). However, when scared by large fires and people with dogs, whips and drums, elephants charged at defenders during 60% of scaring attempts (9 of 15). Elephants raiding crops were scared 15 times by 4–7 people with multiple large fires, several dogs, whips and drums and 11 times by 2–3 people with dogs, slingshots, drums and burning sticks. Behavioural responses were monitored through a monocular. Elephants and farmers were 20–40 m apart. Tests were conducted between 18:30 and 06:30 h. The number of fields was not specified.

A study in 2006–2009, in two areas of Assam, India (2) found that using fire to deter crop-raiding Asian elephants *Elephas maximus* reduced the chance of crop damage occurring. The chance of crop damage occurring was lower when fire was used to deter crop-raiding elephants compared to a range of other interventions or no intervention (results presented as statistic model coefficients). Loud noise, fences and spotlights reduced crop raiding to a greater extent. Using loud noises alongside fire was less effective than using fire alone. Within two study areas, 33 community members trained as monitors, recorded 1,761 crop-raiding incidents, from 1 March 2006 to 28 February 2009. A range of deterrent methods was used, singly or in combination. These were fire (in pits or on hand-held fire torches), chili smoke (from burning dried chilies, tobacco, and straw), spotlights, two-strand electric fences, chili fencing (engine grease and ground chili paste, on a jute or coconut rope), elephant drives (using domesticated elephants to repel wild elephants) and noise.

(1) Osborn F.V. (2002) Capsicum oleoresin as an elephant repellent: field trials in the communal lands of Zimbabwe. *The Journal of Wildlife Management*, 66, 674–677, https://doi.org/10.2307/3803133

(2) Davies T.E., Wilson S., Hazarika N., Chakrabarty J., Das D., Hodgson D.J. & Zimmermann A. (2011) Effectiveness of intervention methods against crop-raiding elephants. *Conservation Letters*, 4, 346–354, https://doi.org/10.1111/j.1755-263X.2011.00182.x

3.70. Use pheromones to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2503

- We found no studies that evaluated the effects of using pheromones to deter crop damage by mammals to reduce human-wildlife conflict.

'We found no studies' means that we have not yet found any studies that have directly evaluated this intervention during our systematic journal and report searches. Therefore, we have no evidence to indicate whether or not the intervention has any desirable or harmful effects.

Background

Pheromones are chemical substances released into the environment by an animal that can affect the behaviour or physiology of other animals of the same species. If pheromones can be synthesised that deter entry to crops by wild herbivores, this could reduce the motivation among farmers for carrying out lethal control of wild herbivores.

3.71. Use predator scent to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2505

- **Three studies** evaluated the effects of using predator scent to deter crop damage by mammals to reduce human-wildlife conflict. All three studies were in the USA[1,2a,2b].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (3 STUDIES)

- **Human-wildlife conflict (3 studies):** Two of three replicated, randomized, controlled studies (including two before-and-after studies), in the USA[1,2a,2b], found that coyote scent reduced food consumption by mountain beavers[1] and white-tailed deer[2a]. The third study found that it did not reduce trail use by white-tailed deer[2b].

Background

Wild herbivores may be sensitive to scents from predators and may alter their behaviour or visitation rates to a site accordingly (Wikenros *et al*. 2015). If scents can be deployed artificially, they could reduce crop damage caused by wild herbivores and, hence, reduce motivations for carrying out lethal control of these animals.

Wikenros C., Kuijper D.P.J., Behnke R. & Schmidt K. (2015) Behavioural responses of ungulates to indirect cues of an ambush predator. *Behaviour*, 152, 1019–1040, https://doi.org/10.1163/1568539X-00003266

A replicated, randomized, controlled study (year not stated) on captive animals from Washington State, USA (1) found that coyote *Canis latrans* urine was more effective at deterring food consumption by mountain beavers *Aplodontia rufa* than were four synthetic compounds. In two-choice feeding trials, the quantity of coyote urine-soaked food removed by male beavers (7 g) was lower than that of water-soaked food removed (14 g). The same pattern held for females (coyote urine: 1 g; water: 7 g). A3-Isopentenyl methyl sulfide (IMS) did not affect food choice when compared to an untreated 'blank' (IMS: 8–11 g; blank: 7 g), nor did 2,2-dimethylthietane (DMT) (DMT: 7–13 g; blank: 10–14 g). A mix of 2-propylthietane and 3-propyl-l,2-dithiolane (PT/PDT) reduced food retrieval (PT/PDT: 14 g; blank: 18 g) but the response was not apparent during longer (5 day) exposure (PT/PDT: 31 g; blank: 35 g). Twelve wild-caught mountain beavers (six male and six female) were held in captivity for several months prior to the experiment. Trials were run as choice tests between bowls 25 cm apart. Food remaining after one or two hours was weighed. Each beaver was used twice for each choice experiment.

A replicated, randomized, controlled, before-and-after study in 2000–2001 in a forest in Ohio, USA (2a) found that coyote *Canis latrans* hair reduced feeding at troughs by white-tailed deer *Odocoileus virginianus*. With one bag of coyote hair/trough, deer consumed less corn (103 kg) than before bag placement (246 kg). With three bags of coyote hair/trough, deer consumed less corn (46–108 kg/week) than in the week before bag placement (323 kg). At control toughs with empty bags, operated concurrently to experimental troughs, consumption (284–425 kg/week) did not differ to that in the week before bag placement (247–265 kg/week). Ten troughs (≥1 km apart) were fenced on three sides and stocked with whole kernel corn. Five were treatment troughs and five were controls. Stage I (January–February 2000) entailed one week with unprotected troughs. The following week, a nylon mesh bag containing 17 g of coyote hair was placed touching the back of treatment troughs. An empty bag was placed at control troughs. Stage II (January–March 2001) had a similar pre-treatment week, then five weeks with three bags, each containing 16 g of coyote hair, in front of each treatment trough. Three empty bags were placed at each control trough.

A replicated, randomized, controlled, before-and-after study in 2000 in a forest in Ohio, USA (2b) found that hanging bags of coyote *Canis latrans* hair did not reduce use of established trails by white-tailed deer *Odocoileus virginianus*. The number of deer using treatment trails did not differ significantly before (2.6 deer/day) or after (3.1 deer/day) placement of coyote hair bags. Similarly, the number of deer using non-treatment trails was not significantly different before (3.4 deer/day) or after (5.1 deer/day) placement of empty bags. Deer passes along 10 active trails (around 1 km apart) were recorded for three weeks (18 August to 8 September 2000) using infra-red monitors. A nylon mesh bag containing 16 g of coyote hair, was then suspended 2 m high from a tree along five randomly selected trails. Empty bags were hung at the other five trails. Monitoring continued for three further weeks (8–29 September 2000).

(1) Epple G., Mason J.R., Aronov E., Nolte D.L., Hartz R.A., Kaloostian R., Campbell D. & Smith A.B. (1995) Feeding responses to predator-based repellents in the mountain beaver (*Aplodontia rufa*). Ecological Applications, 5, 1163–1170.

(2) Seamans T.W., Blackwell B.F. & Cepek J.D. (2002) Coyote hair as an area repellent for white-tailed deer. *International Journal of Pest Management*, 48, 301–306, https://doi.org/10.1080/09670870210149853

3.72. Use target species scent to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2506

- **One study** evaluated the effects on mammals of using target species scent to deter crop damage to reduce human-wildlife conflict. This study was in South Africa[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, controlled study in South Africa[1] found that African elephants were not deterred from feeding by the presence of secretions from elephant temporal glands.

Background

Mammals often mark their territories with scent. If artificially placed scents from the same species can restrict movements of animals, this may assist in reducing damage to crops. If successful, this could reduce incentives for carrying out lethal control of such animals.

A replicated, controlled study in 1985 of shrubland in Limpopo, South Africa (1) found that compounds mimicing secretions from African elephant *Loxodonta africana* temporal glands did not deter feeding or otherwise change elephant behaviour. The rate of sniffing by captive elephants of hardboard pieces into which five scent compounds were absorbed (1–18 times/elephant/hour) did not differ from that for hardboards treated with carboxylic acids (2–15 times/elephant/hour). The rates fell for all boards over the 10-day study. Boards hung directly over feeding troughs did not deter elephants from feeding. Wild elephants exposed to aerosols containing scent compounds or carboxylic acids did not change behaviour. Seven captive elephants, 9–12 months old, held in three pens, were exposed to secretions or carboxylic acid absorbed into hardboards fastened to the sides of pens. Boards were re-treated every two days. Lone wild bull elephants were exposed to scent compounds (18 times) or carboxylic acid (nine times) mixed with water and administered as aerosols. The study was conducted in July–August 1985.

(1) Gorman M.L. (1986) The secretion of the temporal gland of the African elephant *Loxodonta africana* as an elephant repellent. *Journal of Tropical Ecology*, 2, 187–190, https://doi.org/10.1017/S0266467400000766

3.73. Use ‘shock collars’ to deter crop damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2508

- **One study** evaluated the effects on mammals of using ‘shock collars’ to deter crop damage to reduce human-wildlife conflict. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated, controlled study in the USA[1] found that electric shock collars (combined with loud noise) reduced damage caused by black-tailed deer to tree seedlings.

Background

Using electric shock collars on mammalian herbivores is a form of aversive conditioning. A shock is administered if the animal wearing a 'shock collar' approaches a pre-determined area, containing a crop. The potential for the technique to be effective may be assessed using captive animals in controlled experimental settings. Whilst not directly assessing the effectiveness of the intervention in reducing crop damage, such studies may provide evidence as to the potential for shock collars to alter animals' behaviour in a way that could potentially be applied to wild herbivores in crop production areas. If the intervention is successful, it may reduce incentives for carrying out lethal control of such animals.

A replicated, controlled study (year not stated) on two pastures in Washington, USA (1) found that using electric shock collars, along with playing loud noise, reduced damage by black-tailed deer *Odocoileus hemionus* to tree seedlings. As the loud noise and electric shock were part of the same treatment, their relative effects could not be separated. In areas where shock collars were triggered, damage to tree seedlings was lower (0–1 bites) than in areas where shock collars were not triggered (0–25 bites). Three deer, fitted with shock collars, were placed in each of two 1.5-ha pastures. Within each pasture, four 20 × 20-m plots were established. In each plot, 16 red cedar *Thuja plicata* seedlings were planted at 1-m intervals. When deer entered two of the plots, they received an electric shock and a loud noise was played through a speaker. When they entered the other two plots, they received no shock and no noise was played. Deer activity was measured by counting the number of bites taken from seedlings over a 21-day period.

(1) Nolte D.L., VerCauteren K.C., Perry K.R. & Adams S.E. (2003) *Training deer to avoid sites through negative reinforcement*. USDA National Wildlife Research Center-Staff Publications, 264.

3.74. Use repellents that taste bad ('contact repellents') to deter crop or property damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2509

- **Twelve studies** evaluated the effects of using repellents that taste bad ('contact repellents') to deter crop or property damage by mammals to reduce human-wildlife conflict. Nine studies were in the USA[1–4,5a,5b,5c,9,10], two were in the UK[7,8] and one was in Italy[6].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (12 STUDIES)

- **Human-wildlife conflict (12 studies):** Five of 11 controlled studies (including 10 replicated studies), in the USA[1–4,5a,5b,5c,9], Italy[6] and the UK[7,8], of a range of contact repellents, found that they reduced herbivory or consumption of baits. The other six studies reported mixed results with at least some repellents at some concentrations deterring herbivory, sometimes for limited periods. A replicated, controlled study in the USA[10] found that a repellent did not prevent chewing damage by coyotes.

Background

This intervention considers specifically studies that assess effectiveness of repellents that are intended to be distasteful to wild mammals. Although some may produce some element of repellent odour, the main effect is generally when they are tasted, such as through licking or biting off vegetation to which it has been applied. Included here are tests of several repellents that are marketed commercially, especially to reduce browsing by herbivores on planted trees. The intervention also covers use of these repellents to deter damage to property.

See also: *Use repellents that smell bad ('area repellents') to deter crop or property damage by mammals to reduce human-wildlife conflict*.

A replicated, controlled study, in 1962–1964, on shrubland and a forest area of South Dakota, USA (1) found that applying repellents to trees reduced browsing by white-tailed deer *Odocoileus virginianus* and mule deer *Odocoileus hemionus*. Treated aspen *Populus tremuloides* shoots suffered less browsing than untreated shoots (zinc dimethyldithiocarbamate cyclohexylamine (ZAC)-treated: 3% removed; tetramethylthiuram disulfide (TMTD)-treated: 3%; untreated: 12%). The same pattern applied for wild chokeberry *Prunus virginiana* shrubs (ZAC-treated: 0.7% removed; TMDT-treated: 6.8%; untreated: 28.9%). On trees transplanted from nurseries, there was less browsing on ZAC-treated than untreated chokecherry (ZAC-treated: 0.1% removed; untreated: 6%), American plum *Prunus americana* (ZAC-treated removed: 0.1%; untreated: 19.8%) and caragana *Caragana arborescens* (ZAC-treated: 0.8% removed; untreated: 4.5%). Herbivory on naturally growing Aspen and chokeberry was compared between groups of ZAC-treated, TMTD-treated and untreated trees (10 trees in each case). Chokecherry, American plum and caragana were transplanted from nurseries to two sites where they were either treated with ZAC or were untreated (total ≤64 trees/species). Herbivory was assessed as the proportion of shoot lengths removed. Aspen and wild chokeberry trees were assessed over winters of 1962–1963 and 1963–1964. Transplanted chokecherry, American plum and caragana were assessed in winter of 1963–1964.

A replicated, randomized, controlled study in 1982–1985 at three tree nursery sites in Connecticut, USA (2) found that treating Japanese yew trees *Taxus cuspidata* with commercially available repellents reduced subsequent losses to herbivory by white-tailed deer *Odocoileus virginianus*. Results were not tested for statistical significance. The proportion of shoots browsed by white-tailed deer on trees treated with repellents (23%) was lower than the proportion browsed on untreated trees (41%). Over the three winters from 1982 to 1985, a total of 16 blocks of Japanese yew across three sites were studied. Each block was split into three plots (0.2–0.3 ha), which were randomly assigned to Big Game Repellent, Hinder® repellent or no treatment. Repellent was applied once annually, in November, following manufacturer instructions. Herbivory was assessed the following March, by inspecting 500–1,000 branch terminals in each plot.

A replicated, randomized, controlled study in 1989 on captive animals in Colorado, USA (3) found that chicken eggs, MGK® Big Game Repellent and coyote urine, used as repellents on foodstuffs, reduced consumption of that food by mule deer *Odocoileus hemionus* more than did treatment with thiram, Hinder®, soap and Ro·pel®. Deer consumed less food treated with chicken eggs (89 g/day), MGK® Big Game Repellent (94 g/day) and coyote urine (98 g/day) than food treated with thiram (212 g/day), Hinder® (223 g/day), soap (308 g/day) and Ro·pel® (399 g/day). It was not possible to assess which of these feeding rates differed significantly from consumption of food treated just with water (500 g/day). Three female and eight castrated male mule deer were held in individual pens. Repellents and a control (water) were sprayed daily on commercial deer pellets at a rate of 10 ml/500 g. Pellets were dried for 24 hours. The soap treatment involved hanging a bar of soap above the feed container. Food from each treatment was offered in different containers (500 g in each), which were randomized daily, for four days, in May and June 1989.

A replicated, controlled study in 1997 in a forest in Colorado, USA (4) found that aspens *Populus tremuloides* treated with the repellents Deer Away® and the highest concentration of Hot Sauce® were browsed less by elk *Cervus canadensis* than were untreated trees. There was less browsing on aspens treated with Deer Away® (42% of sprouts and terminal leaders browsed) and 6.2% Hot Sauce® (56% browsed) than on untreated aspens (77% browsed). Browsing rates on aspens treated with 0.62% Hot Sauce® (65%) and 0.062% Hot Sauce® (72%) did not differ significantly from those on untreated aspens. Four fenced pasture blocks (each 0.41 ha) each contained 10 strips (1 × 23 m) of sprouting aspen. Treatments were Deer Away® and Hot Sauce® at three concentrations (0.062%, 0.62%, 6.2%). Each treatment was applied to one strip in each pasture, five weeks before exposure to elk and to a further strip two weeks before exposure. Two strips remained untreated. Two captive elk were placed in each pasture block, from 3 August to 5 September 1997. Proportional browsing rates were assessed by examining all aspen sprouts in each pasture.

A replicated, randomized, controlled study in 1997 on captive animals in a forested site in Washington, USA (5a) found that Hot Sauce® repellent reduced most measures of tree browsing by black-tailed deer *Odocoileus hemionus columbi* for four weeks, but not subsequently. There were fewer damaged trees in treated than in untreated plots during the first two weeks but not during the third and fourth weeks. There were fewer damaged terminal buds and lateral bites in treated than in untreated plots across all four weeks. There was no difference in the number of trees stripped of all leaves in treated and untreated plots on day one, but fewer trees were stripped of all leaves in treated than untreated plots through to and including the fourth week. During weeks five and six, there were no differences in these measures between treated and untreated plots. Data were not presented. Three to four deer were held in each of four pens (0.75–2 ha). Two plots (>25 m apart) in each pen each contained three western red cedar *Thuja plicata* trees (0.5–1 m tall, 1 m apart). Plots were randomly assigned to a single application of 6.2% Hot Sauce® or were untreated. Tree damage was assessed between 4 February and 16 March 1997.

A replicated, controlled study (year not stated) on captive animals in Washington, USA (5b) found that treating food with Hot Sauce® repellent (as a trial of its effectiveness at reducing crop consumption) reduced consumption by porcupines *Erethizon dorsatum*, reduced consumption by pocket gophers *Thomomys mazama* at two of four concentrations and did not reduce consumption by mountain beavers *Aplodontia rufa*.

Porcupines consumed fewer treated than untreated apple pieces at all four Hot Sauce® concentrations. Pocket gopher consumption of apple pieces did not differ between treated and untreated food at 0.062% concentration. At 0.62%, fewer treated than untreated pieces were eaten on two of four days. At 3.1% and 6.2%, fewer treated than untreated pieces were eaten. Mountain beaver consumption of apple pieces did not differ between treated and untreated food at any of the four repellent concentrations. See paper for full details of results. Trials were carried out on four porcupines, 12 pocket gophers and 10 mountain beavers. All were held in enclosures and were offered two-choice tests between apple pieces treated with Hot Sauce®, a repellent containing capsaicin, and untreated apple pieces. Solutions containing 0.062%, 0.62%, 3.1% and 6.2% of Hot Sauce® were used. Each concentration was tested for four days with each animal. Tests ran consecutively, from lowest to highest concentrations of Hot Sauce® solution.

A replicated, randomized, controlled study (year not stated) on captive animals in Washington, USA (5c) found that treating cottonwood *Populus* spp. stems with Hot Sauce® repellent reduced the extent to which they were chewed by beavers *Castor canadensis*. At all three Hot Sauce® concentrations applied, chewing damage was lower in treated stems than in untreated stems (results expressed as damage indices). Eight adult beavers were housed in pens that contained 1-m-long cottonwood stems of 7–10 cm diameter. Adjacent pairs of stems were randomly assigned for treatment by Hot Sauce® at 0.062%, 0.62% and 6.2% concentrations and untreated stems were available. Beavers also had free access to apples, carrots, pelleted food and water. The test was run for six days, then repeated. Damage to cottonwood stems was assessed at the end of each six-day period.

A replicated, controlled study in 2001 on a site in Italy (6) found that two of three repellents significantly reduced browsing of olive trees *Olea europaea* by fallow deer *Dama dama* for three weeks following application. A lower proportion of plants treated with Eutrofit® was browsed, relative to untreated plants, at one, two and three weeks after application (reductions relative to untreated plants of 100%, 71% and 41% respectively). Tree Guard® similarly reduced the proportions of plants browsed relative to untreated plants (by 82%, 82% and 55% after one, two and three weeks respectively). Reductions in the proportions of plants treated with Hot Sauce® that were browsed relative to untreated plants (64%, 12% and 9% after one, two and three weeks respectively) were not significant. From four weeks onwards, no repellent reduced browsing relative to untreated trees. Olive cuttings, 1 year old and about 20 cm high, were planted in five blocks of 20 plants. In each block, five plants each were treated each with the commercially available repellents, Eutrofit®, Tree Guard® and Hot Sauce®, following manufacturer instructions. Browsing damage was assessed weekly, for eight weeks.

A controlled, before-and-after study in 1996 in a woodland in Oxfordshire, UK (7) found that European badgers *Meles meles* ate less food treated with the repellent, ziram, than untreated food, but cinnamamide and capsaicin treatments did not affect consumption rates. Badgers consumed 31–100% of ziran-treated bait over the first eight treatment nights, 0–10% over the ninth to sixteenth treatment nights and 0–3% from the seventeenth to twenty-eighth treatment nights. All untreated baits, and baits treated with cinnamamide and capsaicin, were consumed throughout the trial. A hexagon of paving slabs, each separated into four quadrants, was established. Each quadrant was supplied nightly with 20 g of Beta Puppy 1–6 months™ pelleted food. Untreated baits were used for 68 nights, followed by 56 nights during which treatment nights and control nights (untreated food) alternated. On treatment nights, the four quadrants on each slab each received one from pellets treated with ziram in the form of AAprotect™, cinnamamide with methanol, capsaicin with diethyl ether or untreated bait. Uneaten bait was weighed to determine consumption. The study ran from 19 July to 19 November 1996.

A replicated, randomized, controlled study (year not stated) in a woodland in Oxfordshire, UK (8) found that treating corn cobs with the repellent, ziram, reduced the rate of its consumption by European badgers *Meles meles*. Fewer corn cobs treated with ziram were damaged by badgers (39–63% of cobs) than were untreated cobs (82% of cobs). Among badgers that were repeat visitors to feeding stations, treated cobs were fed on (as opposed to rejected) on a lower proportion of occasions (10–34%) than were untreated cobs (60%). At two sites, 450 m apart, feeding stations were established, each offering 12 corn cobs and water. Sites were pre-baited, to encourage attendance, and the experiment ran for five nights. Cobs were treated, in equal numbers, with 5%, 10%, 20%

or 40% ziram in water or with water alone (as an untreated control). Treatments were assigned randomly across cobs.

A replicated, randomized, controlled study in 2006–2008 in two agricultural sites in Connecticut, USA (9) found that 10 commercially available repellents varied in effectiveness at reducing white-tailed deer *Odocoileus virginianus* herbivory on trees. At one site, trees treated with Chew-Not®, Deer-Away® Big Game Repellent, Bobbex®, Liquid Fence® and Hinder® had greater needle mass (140–234 g) than did untreated trees (14 g). Needle mass of trees treated with five other repellents (Repellex®, Deer Solution®, coyote urine, Plantskydd® and Deer-Off ®) (23–81 g) did not differ from that of untreated trees. Trees treated with Bobbex®, and Hinder® were taller (35–36 cm) than untreated trees (25 cm). Tree height when treated with the eight other repellents (23–31 cm) did not differ significantly from that of untreated trees. At the second site, where herbivory was light, there were no significant differences in tree heights and needle mass was not measured. At each of two sites, two blocks were established in May 2006, each with 12 groups of six yew *Taxus cuspidata* trees. Each treatment was applied randomly to one tree group in each block. Additionally, one group was untreated and one fenced. Repellent application followed manufacturer instructions. Trees were harvested in April 2008.

A replicated, controlled study (year not stated) on captive animals in Utah, USA (10) found that applying the repellent, Ropel®, to nylon items similar to those used on military airstrips did not reduce chewing damage caused by coyotes *Canis latrans*. Coyotes repeatedly tasted a lower proportion of Ropel®-treated items (67–75%) than of untreated items (58–83%). However, there was no difference in the proportion destroyed within 24 hours between treated (58–75%) and untreated items (58–83%). Twelve mated coyote pairs each had access to 1-m lengths of nylon strapping (3 cm wide, 3 mm thick) with three 0.2-m loops. Latex stickers aided adhesion of Ropel® and of water (as an untreated control solution) to nylon strapping. Solutions were applied four and one days before one treated and one untreated item were placed in each coyote pen. Coyote behaviour was monitored using camera traps.

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(2) Conover M.R. (1987) Comparison of two repellents for reducing deer damage to Japanese yews during winter. *Wildlife Society Bulletin*, 15, 265–268.

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(4) Baker D.L., Andelt W.F., Burnham K.P. & Shepperd W.D. (1999) Effectiveness of Hot Sauce® and Deer Away® repellents for deterring elk browsing of aspen sprouts. *The Journal of Wildlife Management*, 63, 1327–1336, https://doi.org/10.2307/3802851

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(6) Santilli F., Mori L. & Galardi L. (2004) Evaluation of three repellents for the prevention of damage to olive seedlings by deer. *European Journal of Wildlife Research*, 50, 85–89, https://doi.org/10.1007/s10344-004-0036-1

(7) Baker S.E., Ellwood S.A., Watkins R. & Macdonald D.W. (2005) Non-lethal control of wildlife: using chemical repellents as feeding deterrents for the European badger *Meles meles*. *Journal of Applied Ecology*, 42, 921–931, https://doi.org/10.1111/j.1365-2664.2005.01069.x

(8) Baker S.E., Ellwood S.A., Watkins R.W. & Macdonald D.W. (2005) A dose–response trial with ziram-treated maize and free-ranging European badgers *Meles meles*. *Applied Animal Behaviour Science*, 93, 309–321, https://doi.org/10.1016/j.applanim.2004.11.022

(9) Ward J.S. & Williams S.C. (2010) Effectiveness of deer repellents in Connecticut. *Human–Wildlife Interactions*, 4, 56–66, https://doi.org/10.26077/v0bn-9k23

(10) Miller E.A., Young J.K., Stelting S. & Kimball B.A. (2014) Efficacy of Ropel® as a coyote repellent. *Human-Wildlife Interactions*, 8, 271–278.

3.75. Use repellents that smell bad ('area repellents') to deter crop or property damage by mammals to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2511

- **One study** evaluated the effects of using repellents that smell bad ('area repellents') to deter crop or property damage by mammals to reduce human-wildlife conflict. This study was in the UK[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A randomized, replicated, controlled study in the UK[1] found that a repellent reduced use of treated areas by moles.

Background

This intervention covers use of manufactured repellents that emit a smell that is designed to repel animals from areas of crops or other property that is vulnerable to damage. If such repellents can prevent or reduce crop or property damage by wild mammals, this could reduce motivations for carrying out lethal control of these animals.

See also: *Use predator scent to deter crop damage by mammals to reduce human-wildlife conflict* and *Use pheromones to deter crop damage by mammals to reduce human-wildlife conflict*.

Randomized, replicated, controlled studies in 1989–1990 on three farms in Oxfordshire, UK (1) each found that a bone-oil based repellent (Renardine) reduced use of treated areas by moles *Talpa europaea*. Moles avoided the 25% of their home range that was treated with the repellent for 9–27 days (moles' home ranges treated similarly, but with water, were not avoided). With close to 100% of their home ranges treated, moles avoided reoccupying treated areas for 42 hours to at least nine days. Moles took longer to cross a repellent-treated slit, cut across their home ranges (26 days) than a similar water-treated slit (four hours). The repellent, Renardine [use of which is prohibited in some countries], was soaked into rolled toilet paper and pushed into one mole tunnel/m^2 in the 25% most heavily used part of home ranges (three moles) in spring 1989 or into all identified tunnels in the home range (four moles) in late summer 1989. One site was used in each case. Water-soaked toilet paper acted as a control at the 25% site (two moles). At a third site, 0.5 l/m of Renardine was poured into a 50-cm-deep slit across six home ranges in autumn/winter 1990. The slit was filled with peat, and a further 0.5 l/m of Renardine poured on top. One further home range was treated similarly, but with water. Mole movements were monitored by radio-tracking.

(1) Atkinson R.P.D. & MacDonald D.W. (1994) Can repellents function as a non-lethal means of controlling moles (*Talpa europaea*)? *Journal of Applied Ecology*, 31, 731–736, https://doi.org/10.2307/2404163

3.76. Use dogs to guard crops to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2512

- **One study** evaluated the effects on mammals of using dogs to guard crops to reduce human-wildlife conflict. This study was in Zimbabwe[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** A replicated study in Zimbabwe[1] found that people with dogs took longer to repel African elephants from crops compared to scaring them by using combinations of people, dogs, slingshots, drums, burning sticks, large fires and spraying with capsicum.

Background

Dogs *Canis lupus familiaris* are frequently used to guard livestock but this intervention covers the use of dogs to deter herbivores from damaging crops. If successful, this could reduce incentives for carrying out lethal control on crop-raiding mammal species.

A replicated study in 1995–1996 in agricultural fields surrounded by savanna in Sebungwe, Zimbabwe (1) found that African elephants *Loxodonta africana* took longer to be repelled from agricultural fields when scared only by people with dogs *Canis lupus familiaris* than by combinations of people, dogs, slingshots, drums, burning sticks, large fires and when sprayed with capsicum. Relative effects of the individual deterrents cannot be separated. Elephants were repelled more slowly when scared by one person with dogs (14 minutes) than when scared by people with dogs and slingshots, drums and burning sticks (10 minutes), by people with dogs, drums and large fires (4 minutes) or when sprayed with capsicum oleoresin (2 minutes). The study was conducted in communal lands surrounding a research area. Attempts were made to deter elephants raiding crops, 15 times by one person with dogs, 11 times by 4–7 people with dogs, drums and large fires, 11 times by 2–3 people with dogs and slingshots, drums and burning sticks and 18 times using a spray with 10% capsicum oleoresin. Behavioural responses were monitored using a monocular. Distance between elephants and farmers was 20–40 m. Tests were conducted between 18:30 and 06:30 h. The number of fields was not reported.

(1) Osborn F.V. (2002) Capsicum oleoresin as an elephant repellent: field trials in the communal lands of Zimbabwe. *The Journal of Wildlife Management*, 66, 674–677, https://doi.org/10.2307/3803133

3.77. Drive wild animals away using domestic animals of the same species to reduce human-wildlife conflict

https://www.conservationevidence.com/actions/2513

- **One study** evaluated the effects of using domestic animals to drive away wild mammals to reduce human-wildlife conflict. This study was in India[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (0 STUDIES)

OTHER (1 STUDY)

- **Human-wildlife conflict (1 study):** One study in India[1] found that using domestic elephants to drive wild Asian elephants away from villages did not reduce the probability of elephants damaging crops.

Background

Domestic mammals may be used in attempts to repel wild mammals of the same species that are causing nuisance, such as be crop-raiding. This intervention is likely to be especially relevant where the wild animal presents a potential threat to people such that simply chasing animals away may not always be a viable or effective option. If the intervention is effective, this could reduce incentives for carrying out lethal control of the focal species.

A study in 2006–2009, in two areas of Assam, India (1) found that using domestic elephants to drive wild Asian elephants *Elephas maximus* away from villages did not reduce the probability of elephants damaging crops. The chance of crop damage occurring was not lower when domestic elephants were used to deter crop-raiding wild elephants, in comparison with a range of other interventions or no intervention (results presented as statistical model coefficients). Within two study areas, 33 community members trained as monitors recorded 1,761 crop-raiding incidents, from 1 March 2006 to 28 February 2009. A range of deterrence methods was used, singly or in combination, including using domesticated elephants to repel wild elephants, chili smoke (from burning dried chilies, tobacco, and straw), spotlights, two-strand electric fences, chili fencing (engine grease and ground chili paste, on a jute or coconut rope), fire and noise.

(1) Davies T.E., Wilson S., Hazarika N., Chakrabarty J., Das D., Hodgson D.J. & Zimmermann A. (2011) Effectiveness