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A systematic review of ground-based shooting to control overabundant mammal populations

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Table S1. Summary of studies used in the systematic review of ground-based shooting to control overabundant mammal populations, arranged by taxonomic Order, Family and Genus

Ref	Species	Main shooters	Objective	Target metric	Region	Landscape	Status	Population change indicator	Damage indicator	Main conclusions relevant to this review
1	*Capra hircus*	Government	None	Density	Australasia	Mixed	Exotic	Relative abundance	na	Goats were nearly eradicated from a small area, but the population recovered substantially within a year due to immigration and survivors' reproduction.
2	*Capra hircus*	Recreational hunter	None	Density	Australasia	Native	Exotic	Abundance	na	Hunting with dogs reduced and supressed the goat population over 38 years. This resulted in a visible, but not measured, recovery of susceptible plant spp. Eradication would require annual removal of > 90% of the population.
3	*Capra hircus*	Government	Eradication	Eradication	Australasia	Mixed	Exotic	Presence	Native vegetation	A prolonged shooting program using a small number of staff successfully eradicated feral goats.
4	*Capra hircus*	Government	Eradication	Eradication	Australasia	Native	Exotic	Presence	na	Eradication was unsuccessful, despite high efficiency, because of reinvasion from adjacent areas that were not targeted.
4	*Capra hircus*	Government	Eradication	Eradication	Australasia	Native	Exotic	Presence	na	Eradication, mainly by ground hunting with dogs, was successful but inefficient.
5	*Hemitragus jemlahicus*	Recreational hunter	Density	Density	Australasia	Native	Exotic	Abundance; Class Structure	na	Recreational hunting did not reduce tahr densities below the 'intervention threshold' of 2.5 tahr km^{-2}. Tahr increased over 12 years of study at two sites, despite hunting.
6	*Ovis aries, O. gmelini*	Recreational hunter	Eradication	Eradication	North America	Native	Exotic	Presence	Native vegetation	21 years of public hunting and supplementary aerial shooting failed to eradicate or reduce ungulate (mainly sheep) numbers and impacts. Threatened bird (palila) is declining, but also due to factors other than introduced ungulates.
7	*Capreolus capreolus*	Recreational hunter	None	Damage	Europe	Native	Native	na	Native vegetation	Browse damage decreased, on average, across most game management districts where management recommendations were made to increase the harvest. Damage decrease was greater than expected from reduced deer density

alone.

8	*Capreolus capreolus*	Recreational hunter	None	Density	Europe	Mixed	Native	Density	na	Forest and grassland areas were sources of emigrants, despite active management from three types of shooters. This was attributed to the absence of informed management objectives, rather than a failure of shooting operations to meet objectives.
9	*Cervus elaphus*	Commercial wildlife management contractor	Eradication	Eradication	Australasia	Native	Exotic	Presence	na	Secretary Island: five year eradication program removed 633 deer: 542 during initial knockdown phase (aiming for 80%) and 91 during two year mop up. Mop up was ongoing when the paper was published.
10	*Cervus elaphus*	Government	None	Density	Australasia	Native	Exotic	Abundance	na	Waihaha site only (only site with significant ground hunting): index declined in nil-treatment site, but not at ground hunting site. Helicopter hunting was more effective at sites where it could be used.
11	*Cervus elaphus*	Recreational hunter	None	Density	Australasia	Native	Exotic	Relative abundance	na	Deer populations were stable over the four years of the study. Hunters probably contributed substantially to inhibiting population growth.
12	*Cervus elaphus*	Recreational hunter	None	Density	Australasia	Native	Exotic	Relative abundance	Native vegetation	Recreational hunting had some benefit in maintaining an intact forest canopy, but much lower deer densities would be required to reverse the damage that has been caused by deer.
13	*Cervus elaphus*	Recreational hunter	Density	Density	Europe	Native	Native	Density	na	Structured population model from bag records and genetic capture-mark-recapture both indicated a decrease at the site over 10 years, but not yet to desired levels, while bag records increased at other sites.
14	*Cervus elaphus*	Recreational hunter	None	Density	Australasia	Native	Exotic	Relative abundance	Native vegetation	Aerial shooting was effective at reducing deer and increasing seedling growth in the high intensity site, but recreational and commercial shooting had no impact on deer density or seedling growth in the other 3 sites.

9	*Cervus elaphus*	Commercial wildlife management contractor	Eradication	Eradication	Australasia	Native	Exotic	Presence	na	Anchor Island: five year eradication program removed 29 deer and no deer were found in the following two years. Almost all deer were killed by ground hunters because conditions were unsuitable for baiting or aerial shooting.
10	*Cervus nippon*	Government	None	Density	Australasia	Native	Exotic	Abundance	na	Waihaha site only (only site with significant ground hunting): Index declined in nil-treatment site, but not at ground hunting site. Helicopter hunting was more effective at sites where it could be used.
15	*Cervus nippon*	Government	Eradication	Eradication	Australasia	Native	Exotic	Abundance	na	Recreational hunting slowed the rate of population growth, but the population only began to decline after very intensive government control started.
12	*Cervus nippon*	Recreational hunter	None	Density	Australasia	Native	Exotic	Relative abundance	Native vegetation	Recreational hunting had some benefit in maintaining an intact forest canopy, but much lower deer densities would be required to reverse the damage that has been caused by deer.
14	*Cervus nippon*	Recreational hunter	None	Density	Australasia	Native	Exotic	Relative abundance	Native vegetation	Aerial shooting was effective at reducing deer and increasing seedling growth in the high intensity site, but recreational and commercial shooting had no impact on deer density or seedling growth in the other three sites.
16	*Cervus nippon*	Recreational hunter	Growth	Growth	Asia	Native	Native	Modelled Abundance	na	Emergency population control (maximise female harvest) measures initiated after high estimated densities failed to reduce the population to desired levels.
17	*Cervus nippon*	Recreational hunter	None	Density	Asia	Native	Native	Relative abundance	na	Effects of localised hunting and culling were outweighed by movement between sites.
18	*Cervus unicolor*	Commercial wildlife management contractor	None	Damage	Australasia	Native	Exotic	Relative abundance	Faecal density	Intensive bouts of ground shooting reduced faecal deposition and pollution risk near the water, but the effects only persisted while shooting was occurring.

19	*Dama dama*	Government	Eradication	Eradication	Australasia	Mixed	Exotic	Presence	na	Evaluation of 54 programs aiming to eradicate new deer populations, mainly using ground based hunting. 35/54 programs were effective, and the overall program was thought to be effective.
3	*Dama dama*	Government	Eradication	Eradication	Australasia	Mixed	Exotic	Presence	na	A prolonged shooting program using a small number of staff successfully eradicated deer.
20	*Dama dama*	Recreational hunter	None	Density	Australasia	Native	Exotic	Density	na	The reliability of recreational hunters to control deer populations depended on the size of the hunter population within 100 km and on the extent of road access.
8	*Muntiacus reevesi*	Recreational hunter	None	Density	Europe	Mixed	Exotic	Density	na	Forest and grassland areas were sources of emigrants, despite active management from three types of shooters. This was attributed to the absence of informed management objectives, rather than a failure of shooting operations to meet objectives.
21	*Odocoileus hemionus*	Recreational hunter	None	Damage	North America	Native	Exotic	na	Native vegetation	Deer impacts on tree regeneration were lower in sites with good hunter access, although hunting pressure was probably only about 10% of mortality.
22	*Odocoileus virginianus*	Commercial wildlife management contractor	None	Density	North America	Peri urban	Native	Density	Vehicle collisions	Targeted shooting reduced deer populations and deer:vehicle collisions by an average of 67% at three suburban sites.
23	*Odocoileus virginianus*	Government	None	Density	North America	Peri urban	Native	Relative abundance	Vehicle collisions	Public hunting combined with three different types of government shooting reduced deer density index by 46% and reported vehicle collisions by 30%.
24	*Odocoileus virginianus*	Government	Growth	Growth	North America	Mixed	Native	Abundance	na	Shooting effectively reduced deer densities from very high (136 km^2) to acceptable (<10 km^{-2}). Maintenance at that level was thought to be achievable and affordable (however, a later study showed higher densities and concluded it was impossible to reach 10 km^{-2}).
25	*Odocoileus virginianus*	Recreational hunter	None	Density	North America	Peri urban	Native	Relative abundance	Native vegetation	A very intensively managed 15 year hunting program reduced deer density to acceptable levels within a small peri-urban reserve and adjacent agricultural area, while deer density and damage

										continued to increase in adjacent suburbs.
26	*Odocoileus virginianus*	Recreational hunter	Density	Density	North America	Native	Native	Density	na	Recreational hunting reduced deer densities to desired levels within a few years at all blocks within the broader area.
27	*Odocoileus virginianus*	Recreational hunter	Growth	Growth	North America	Native	Native	Relative abundance	Native vegetation	Antlerless deer harvest objectives were achieved, but the program wasn't considered effective because it didn't translate into reduced deer density or reduced damage to vegetation.
28	*Odocoileus virginianus*	Volunteer	Density	Density	North America	Peri urban	Native	Density	Vehicle collisions	Public and private land volunteer shooting greatly reduced deer densities at four sites, but did not reach management objective of 10 deer km^{-2}.
29	*Sus scrofa*	Commercial wildlife management contractor	Eradication	Eradication	North America	Native	Exotic	Abundance	na	Professional hunting was effective at reducing abundance to near zero at most sites, but its effects were compromised by immigration.
30	*Sus scrofa*	Volunteer	None	Growth	Australasia	Native	Exotic	Mortality	na	Hunting removed 22/79 pigs. Authors concluded it was useful after other control methods had been exhausted.
31	*Sus scrofa*	Recreational hunter	None	Density	North America	Native	Exotic	Relative abundance	na	Hunting, combined with trapping, reduced pig activity within a couple of years before stabilising at a lower level. Hunting needed to be more spatially and temporally widespread to have a greater impact.
32	*Sus scrofa*	Recreational hunter	None	Damage	Europe	Mixed	Native	na	Crop damage	Crop damage was negatively, but weakly, related to increasing hunting activity. Fencing and supplementary feeding had negligible benefit.
33	*Sus scrofa*	Commercial harvest	Growth	Growth	Australasia	Mixed	Exotic	Abundance	na	Commercial harvesting was incapable of supressing pig populations. Harvest rates were generally <30% of the estimated population size; much less than the minimum consistent harvest rate that would be expected to inhibit population growth.
34	*Sus scrofa*	Recreational hunter	Damage	Damage	South America	Native	Exotic	Relative abundance	Rooting	Sustained hunting effort reduced relative abundance of pigs and maintained at low levels for 10 years. There was a rapid effect on pig rooting and damage to

										palms, but it took four years to achieve the objective level.
35	*Sus scrofa*	Recreational hunter	None	Growth	North America	Native	Exotic	Growth, Survival	na	Hunting reduced survival but not population growth.
36	*Sus scrofa*	Recreational hunter	None	Growth	Europe	Mixed	Native	Survival	na	Harvest rate of recreational hunters was < total net reproduction.
37	*Sus scrofa*	Government	None	Density	Australasia	Native	Exotic	Density	Diggings	Intensive control reduced estimated pig density by over one third and this resulted in a decrease in rooting damage >50%. Modelling of different culling intervals indicated that only the most intense (3 monthly intervals) would maintain low damage levels.
38	*Sus scrofa*	Government	None	Growth	Australasia	Native	Exotic	Survival	na	Hunting with dogs could be useful for controlling pigs in forested areas, but was likely to be more costly and less effective than poison baiting.
39	*Sus scrofa*	Commercial wildlife management contractor	Eradication	Eradication	North America	Native	Exotic	Presence	na	Ground hunting was critical for killing the last pigs. Fixed price funding model for commercial contractor contributed to efficient eradication.
40	*Sus scrofa*	Recreational hunter	None	Growth	Europe	Native	Native	Growth	na	Population growth was greatest after six short term (1-3 year) hunting bans were relaxed, suggesting that hunting helped to slow population growth. However, negative population growth was uncommon and inconsistent across sites and years.
41	*Sus scrofa*	Government	None	Growth	Europe	Native	Native	Growth	na	Positive population growth in two lightly and heavily hunted populations, but there were differences in many demographic parameters. Harvest rates need to increase substantially to suppress growth.
42	*Sus scrofa*	Recreational hunter	None	Growth	Europe	Native	Native	Survival	na	Annual, seasonal recreational drive hunting did not prevent 5-fold population growth over 20 years despite high hunting and total mortality (>50%).
43	*Vulpes vulpes*	Volunteer	None	Density	Europe	Native	Native	Relative abundance	na	Habitat was the best predictor of change in faecal density, not hunting pressure.
44	*Vulpes vulpes*	Volunteer	Damage	Damage	Europe	Peri urban	Native	Relative abundance	Parasite prevalence	Spotlight shooting did not reduce fox abundance or *Echinococcus multilocularis*

										prevalence. Prevalence increased in the area subjected to shooting.
45	*Vulpes vulpes*	Volunteer	Density	Density	Europe	Mixed	Native	Density	na	Effects of increased control effort were largely negated by compensatory immigration.
46	*Vulpes vulpes*	Commercial wildlife management contractor	None	Density	Australasia	Mixed	Exotic	Relative abundance	na	Shooting produced short term reductions and a slow decline over five years. Participants were mostly happy with results.
47	*Vulpes vulpes*	Volunteer	None	Density	Australasia	Mixed	Exotic	Density	na	Shooting mortality was probably offset by rapid immigration.
48	*Vulpes vulpes*	Volunteer	None	Density	Europe	Mixed	Native	Relative abundance	Predation	Spotlight shooting reduced fox relative abundance at two sites in a crossover trial by 45 and 95%.
49	*Felis catus*	Government	Eradication	Eradication	Australasia	Native	Exotic	Presence	na	Eradication of cats from a small, tropical island was successful. Shooting was the most effective and efficient removal method.
50	*Felis catus*	Government	Eradication	Eradication	Australasia	Native	Exotic	Abundance	na	Intensive shooting began after a major knockdown caused by trapping. Use of detection dogs was critical for locating the last cats and for verifying eradication.
51	*Felis catus*	Commercial wildlife management contractor	Eradication	Eradication	North America	Native	Exotic	Presence	Predation	Poison baiting was the main method used, but shooting and trapping helped remove surviving cats. Cat eradication resulted in decreased sooty tern mortality.
52	*Lynx lynx*	Recreational hunter	None	Density	Europe	Mixed	Native	Abundance	Predation	Recreational hunting can lead to a small reduction in lamb predation when it is sufficient to reduce lynx population size. However, the benefit was very small.
53	*Macropus fuliginosus*	Commercial harvest	None	Density	Australasia	Peri urban	Native	Density	na	Estimated 88% density reduction in an insular kangaroo population.
54	*Macropus rufogriseus*	Government	Growth	Growth	Australasia	Native	Exotic	Abundance	na	Small scale, intensive hunting with dogs was able to reduce local population densities below the 70% level needed for ground shooting to be the most cost effective option.
55	*Macropus rufogriseus*	Commercial wildlife management	None	Density	Australasia	Mixed	Native	Relative abundance	na	Shooting reduced macropod activity on agricultural land, with a diminishing effect with distance from the shooting

		contractor								operation. A companion paper noted that survivors increased their use of agricultural land.
55	*Thylogale billardierii*	Commercial wildlife management contractor	None	Density	Australasia	Mixed	Native	Relative abundance	na	Shooting reduced macropod activity on agricultural land, with a diminishing effect with distance from the shooting operation. A companion paper noted that survivors increased their use of agricultural land.
56	*Oryctolagus cuniculus*	Government	Eradication	Eradication	Australasia	Native	Exotic	Presence	Native vegetation	Hunting, in combination with trapping, was used after poison baiting and biological control to remove the last rabbits form the island.

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