Terrestrial Mammal Conservation

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

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Cover image: Cape mountain zebra (*Equus zebra zebra*), De Hoop Nature Reserve, South Africa. Photograph by Rebecca K. Smith, CC-BY.

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8. Threat: Natural system modifications

Background

This chapter includes interventions to address threats that convert or degrade habitat as part of the management of natural or semi-natural systems, often to improve human welfare. This includes suppressing or increasing the intensity of fires and changing the natural flow of water.

8.1. Use prescribed burning

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- **Thirty-seven studies** evaluated the effects on mammals of using prescribed burning. Twenty-five studies were in the USA[1,3,4,6–10,12–16,18,20–24,26,27,29–31,34], three each were in Canada[2,5,25] and South Africa[17,19,36], two each were in Spain[11,37] and Tanzania[28,35] and one each was in France[32] and Australia[33].

COMMUNITY RESPONSE (2 STUDIES)

- **Richness/diversity (2 studies):** A replicated, randomized, controlled study in the USA[14] found similar small-mammal species richness after prescribed burning compared to in unburned forest. A replicated, site-comparison study in Australia[33] found that prescribed burns early in the dry season resulted in higher small-mammal species richness relative to wildfires later in the season.

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POPULATION RESPONSE (16 STUDIES)

- **Abundance (11 studies):** Five of 10 replicated studies (of which eight were controlled and two were site comparisons), in the USA[4,10,14,20,22,24,27], Spain[11,37] and Australia[33], found that prescribed burning did not increase abundances of small mammals[4,14,20,22,24]. Three studies found mixed effects, on cottontail rabbits[10] and small mammals[27,37] and two found that burning increased numbers of European rabbits[11] and small mammals[33]. A systematic review in the USA[31] found that two mammal species showed positive responses (abundance or reproduction) to prescribed burning, while three showed no response.
- **Reproductive success (1 study):** A before-and-after, site comparison study in South Africa[19] found that 92% of Cape mountain zebra foals were produced in the three years post-fire compared to 8% in the three years pre-fire.
- **Condition (1 study):** A replicated, controlled study, in the USA[9], found that prescribed burning did not reduce bot fly infestation rates among rodents and cottontail rabbits.
- **Occupancy/range (3 studies):** Two of three studies (including two site comparisons and one controlled study) in the USA[21,34] and Canada[25], found that prescribed burning resulted in larger areas being occupied by black-tailed prairie dog colonies[21] and smaller individual home ranges of Mexican fox squirrels[34]. The third study found that prescribed burning did not increase occupancy rates of beaver lodges[25].

BEHAVIOUR (22 STUDIES)

- **Use (21 studies):** Ten of 21 studies (including eight controlled studies and eight site comparisons with a further four being before-and-after studies), in the USA[1,3,6,7,8,12,13,15,16,18,23,26,29,30], Canada[2,5], South Africa[17,19,36], Tanzania[28] and France[32], found that prescribed burning increased use of areas (measured either as time spent in areas or consumption of food resources) by bighorn sheep[1,5,16], mule deer[2], pronghorn antelope[6], elk[8,23], plains bison[15], Cape mountain zebras[19]and mouflon[32]. Six

studies found mixed effects, with responses differing among different ages or sexes of white-tailed deer[12], bison[13] and elk[30], differing among different large herbivore species[17] or varying over time for elk[26], while swift foxes denned more but did not hunt more in burned areas[29]. The other five studies showed that prescribed burning did not increase use or herbivory by elk[3], black-tailed deer[7], white-tailed deer[18] or mixed species groups of mammalian herbivores[28,36].

- **Behaviour change (1 study):** A site comparison study in Tanzania[35] found that vigilance of Thomson's gazelles did not differ between those on burned and unburned areas.

Background

Fire is an integral part of the management and natural dynamics of some ecosystems. Some habitats are naturally fire-prone while in others, habitats are shaped by long-term traditional management (Bowman 1998). Some habitats are now managed through prescribed burning, partly to reduce the risk of uncontrolled wildfires. In other areas, burns are being introduced, following long periods of fire suppression, sometimes accompanied by mechanical clearance of woody material. Whilst burning can have a dramatic effect on the landscape, reducing cover and short-term food resources, feeding on new plant growth within burned areas can also increase an animal's nutritional intake, with concentrations of proteins in particular being elevated (Hobbs & Spowart 1984).

The studies featured generally compare prescribed burning with no management (which in one case means allowing wildfires) but, in some cases, comparisons are with mechanical clearance.

See also: *Burn at specific time of year*.

Hobbs N.T. & Spowart R.A. (1984) Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. *The Journal of Wildlife Management*, 48, 551–560.

Bowman D.M.J.S. (1998) Tansley Review No. 101. The impact of Aboriginal landscape burning on the Australian biota. *New Phytologist*, 140, 385–410.

A site comparison in 1975–1978 of shrubland and grassland at a site in Idaho, USA (1) found that bighorn sheep *Ovis canadensis* consumed bluebunch wheatgrass *Agropyron spicatum* growing in burned areas more than they consumed on unburned areas. In the first summer after burning, a higher proportion of bluebunch wheatgrass stems was grazed on burned areas (73%) than on unburned areas (8%). The same pattern was observed, though with reducing magnitude, two years after burning (66 vs 25%), three years after burning (30 vs 10%) and four years after burning (36 vs 22%). Within an 86-km^2 study area, seven areas (0.05–0.45 ha, total area 1.51 ha) had controlled burns carried out in September 1974. One hundred randomly selected bluebunch wheatgrass stems from burned and unburned areas were inspected each year to calculate the proportion that was grazed.

A replicated, controlled study in 1975–1977 on grassland in British Columbia, Canada (2) found that in burned areas, bluebunch wheatgrass *Agropyron spicatum* was consumed more by foraging mule deer *Odocoileus hemionus* than it was in unburned areas. Deer took more bites/observation of bluebunch wheatgrass in burned plots (average 22 bites) than in unburned plots (average two bites). Plots were studied at two sites in sagebrush and two in Douglas fir *Pseudotsuga menziesii* forest. At each site, plots (1.25 × 5 m) were established in a block. In each block, in October 1975, three plots were burned and three were not burned. In April 1976, three deer were fenced onto the block and their selection between plots was assessed through direct observations at intervals through the day. The same three deer were used on all blocks and observed twice/block for one day each time. In April 1977, four deer were observed, on two blocks combined, over four days.

A randomized, replicated, controlled study in 1971–1974 of a grassland in Washington, USA (3) found that burning grass did not increase overwinter use by Rocky Mountain elk *Cervus canadensis nelsoni*. Overwinter use by elk totalled 47–80 elk days/ha on burned areas and 42–79 elk days/ha on unburned areas. Within each of six plots, one 3.1-ha subplot was randomly assigned for burning and one was not burned. Burning was carried out once, in late-autumn 1971. Elk pellets were counted in spring to assess use of plots in the winters of 1971–1972, 1972–1973 and 1973–1974.

A replicated, controlled study in 1981–1983 of a pinyon-juniper woodland in New Mexico, USA (4) found that felled forest areas that were burned did not have more small mammals than did felled unburned areas 13–18 years after treatment. A similar number of small mammals was caught in stands that were bulldozed and burned (408) as in stands that were bulldozed without burning (433). Fewer were caught in undisturbed stands (246). Treatment plots, c.120 ha each, were established in each of two woodland blocks, one in 1965, one in 1970. In each block, one plot was bulldozed (trees pushed over and left), one was bulldozed with trees pushed and piled, then burned and one was undisturbed. Small mammals were trapped in the second and third week of September, each year, in 1981–1983. Each plot was sampled for four days each year.

A replicated, site-comparison study in 1980 of forest in Alberta, Canada (5) found that previously burned areas were used more by Rocky Mountain bighorn sheep *Ovis canadensis canadensis* than were unburned areas. In all five comparisons, at different distances below the treeline, more sheep pellets were found in burned areas (14–424 pellet groups/ha) than in unburned areas (0–108 pellet groups/ha). Three fire-modified sites (burned in 1919–1970) and three unburned sites (average forest age of 81–256 years old) were studied. At each site, three transects ran downslope from the treeline, to the valley bottom. Relative use by sheep of each area was assessed by counting pellet-groups in randomly located plots along these transects in 1980.

A site comparison study in 1985–1986 of prairie in Alberta, USA (6) found that pronghorn antelope *Antilocapra americana* made greater use of burned areas, relative to their availability, than of unburned areas in five of the 12 months surveyed. The number of pronghorn groups on burned areas was greater than expected in September, October, November, January and April. During these months, 5–22 pronghorn groups were found on burned areas, from totals of 38–97 pronghorn groups overall. If no preference was shown for or against burned ground, 5% of groups would be expected on it. Pronghorns especially favoured burns containing pricklypear cactus *Opuntia polyacantha*. Areas were burned in July–August 1985. Pronghorn were surveyed monthly, from July 1985 to June 1986. Groups <1 km away were mapped along a 138-km route, travelled by vehicle at <50 km/hour.

A site comparison study in 1983–1985 of a shrubland site in California, USA (7) found that prescribed burning did not increase use of such areas by black-tailed deer *Odocoileus hemionus*, relative to unburned areas. There was no significant difference in density of faecal pellet groups between burned and unburned plots over the two years following burning (data not reported). In an area of chaparral shrubland, approximately 20% (7 km^2) was burned in November 1983. Twenty-three circular plots, each 100 m^2, were surveyed for faecal clumps. Eleven plots were in burned areas and 12 were in unburned areas. Faecal pellet clumps were cleared and counted at end of each wet (November–April) and dry (May–October) season from November 1983 to October 1985.

A replicated, randomized, controlled study in 1983–1987 of a rough fescue *Festuca scabrella*-dominated grassland in Montana, USA (8) found that burning increased grazing of rough fescue by elk *Cervus canadensis nelsoni* in the first, but not subsequent, winters following burning. The proportion of rough fescue plants grazed was greater in burned plots (39%) than in unburned plots (15%) over the winter following autumn burning. Over the subsequent three winters, the proportion grazed did not differ between burned plots (including spring burns; 98–100%) and unburned plots (87–97%). Additionally, a higher proportion of rough fescue biomass was utilized over the first two winters following burning (82–86%) than was utilized in unburned plots (24–69%). Six plots were burned on 17 October 1983 and six on 15 April 1984. Three plots were not burned. Plots were 2 ha in extent. Treatments were assigned randomly. Elk utilization of rough fescue was assessed by inspecting the closest plant to 50 points along each of two transects/plot and determining the proportion that was grazed. Additionally, six caged and six non-caged samples on each treatment were clipped, in April 1985 and 1986, to determine elk utilization by biomass.

A replicated, controlled study in 1986–1988 in a wooded area in Oklahoma, USA (9) found that prescribed burning did not reduce bot fly *Cuterebra* infestation rates among rodents and cottontail rabbits *Sylvilagus floridanus*. The percentage of animals infested with *Cuterebra* larvae did not differ significantly between areas that were burned and sprayed with herbicide (14–20% of animals) and areas sprayed but not burned (18–20%). Eight plots (32.4 ha each) were burned annually in

April, from 1985, and eight were not burned. Four burned and four unburned plots were sprayed with the herbicide, tebuthiuron (at 2.2 kg/ha), in March 1983. Remaining plots were treated with the herbicide, triclopyr (at 2.2 kg/ha), in June 1983. Rodents were surveyed using snap traps, in July–September and December–March 1986–1988. Cottontail rabbits were collected by shooting in January and July 1987–1988. Animal carcasses were opened up and examined for *Cuterebra* presence.

A replicated, controlled study in 1986–1988 of a forest and grassland site in Oklahoma, USA (10) found that burning and spraying pastures with herbicide had mixed effects on cottontail rabbit *Sylvilagus floridanus* abundance when compared with spraying with herbicide alone. In seven of 10 comparisons, there was no significant difference between the number of cottontails found in pastures that were burned compared to those not burned. For three of 10 comparisons, there were more cottontails on burned areas (0.1–1.40 cottontails/ha) than on unburned areas (0–0.4). Eight 32-ha pastures were treated with the herbicides tebuthiuron or triclopyr (at 2.2 kg/ha in March 1983 or June 1983). Four of these pastures were burned in April 1985, 1986 and 1987. Rabbit density was estimated by walking transects, three times each in July and February, from July 1986 to February 1988.

A replicated, controlled, paired sites study in 1991–1992 of scrubland in a national park in southern Spain (11) found that burned plots hosted higher densities of European rabbits *Oryctolagus cuniculus* than did unburned plots. More rabbit pellets were counted in burned plots both in wet scrubland (burned: 11.6 pellets/plot/year; unburned: 9.8) and in dry scrubland (burned: 6.8; unburned: 1.6). Four plots each in wet and dry scrubland were burned in summer 1989. Each was paired with an unburned plot 1 km away, in the same habitat. Plots measured 300 × 200 m. Rabbit pellets were counted monthly in 1991 and 1992 at random sample locations in each plot.

A randomized, replicated, controlled study in 1988–1989, in a mixed forest and prairie site in Oklahoma, USA (12) found that burning areas of forest had mixed effects on use by white-tailed deer *Odocoileus virginianus*, depending on season and sex. Female deer preferred burned plots in spring and summer, but unburned plots in winter. Male deer preferred burned plots in summer and autumn. There was no habitat selection for other sex/season combinations. Data presented

as proportions of radio-tracking locations. See paper for details. Four blocks, each containing five 32-ha plots, were studied. In each block, two plots were sprayed with herbicide and burned, two were sprayed with herbicide but not burned and one was not sprayed or burned. Burning was done each April in 1985–1987. Herbicide was applied in 1983. Ten female and seven male deer were radio-tracked in 1988–1989, and the use of burned and unburned areas relative to their size was assessed.

A study in 1993–1995 of a prairie site in Oklahoma, USA (13) found that burned areas were selected for grazing by mixed-age and mixed-sex bison *Bison bison* groups, but were avoided by mature bull groups. Burned areas were selected in a higher proportion than their availability by mixed groups during 23% of observations and avoided during 13%. Unburned areas were selected in 0% of observations and avoided in 63%. Burned areas were selected by bull groups in 4% of observations, and avoided in 46%. Unburned areas were selected in 29% of observations, and avoided in 14%. Three hundred bison were reintroduced into a 1,973-ha study area in October 1993. The area was expanded by 292 ha in 1995. Controlled burns were carried out five times between September 1993 and December 1995. Bison usage of burned and unburned areas was surveyed 4–12 times/month in 1994 and 1995. Herds were generally mature (>5 year-old) bulls and mixed groups of cows, calves and younger bulls.

A replicated, randomized, controlled study in 1992–1994 of pine forest in a mountainous area of Arkansas, USA (14) found similar small mammal numbers and species richness after prescribed burning compared to in unburned forest. Small mammal capture rates in burned stands (animals caught on 2.3–7.1% of trap nights) did not significantly differ to those in unburned stands (3.9–7.4%). Average species richness did not differ between burned (2.7–4.3 species/plot) and unburned plots (1.7–4.7/plot). In nine plots (14–45 ha), mid-storey trees were removed and, the following spring, plots were burnt. In three plots, mid-storey trees were not removed and plots were not burned. Management was carried out to benefit red-cockaded woodpeckers *Picoides borealis*. Small mammals were surveyed using 80 live-trap stations/plot from 27 December to 4 January in 1992–1993 and 1993–1994.

A replicated, site comparison study in 1990–1996 of one prairie site in each of Nebraska and Oklahoma, USA (15) found that plains bison *Bison*

bison bison preferentially selected burned areas in most years. At one site, bison made more use of burned areas, relative to their availability, in five of seven years. There was no consistent pattern in the second site but, in the largest single range (65% of the site), bison selected burned areas in two of three years. In both cases, results were presented as deviation from modelled predictions. At one site, monitored from 1990–1996, approximately 13.5% of the site was burned each year. The second site, monitored from 1993–1996, had approximately 20% burned each year. Locations of mixed bison groups (females, bulls <4 years old and occasionally adult bulls) were determined at least monthly during respective monitoring periods at each site.

A before-and-after, site comparison study in 1986–1991 of a mixed grassland, shrubland and woodland site in Utah, USA (16) found that prescribed burning of sagebrush-grass shrublands and pinyon-juniper woodland increased use of these areas by Rocky Mountain bighorn sheep *Ovis canadensis*. Use of burned areas by sheep increased by 148% and use of unmanaged areas decreased by 45%. Following burning, more sheep used the area (82 sheep groups; average of 14 sheep/group) than before burning (117 sheep groups; average of nine sheep/group). On a 353-ha study area, 18% was burned and 49% was unmanaged. Additionally, 32% was clearcut (results not presented here). Sheep-use patterns were assessed pre-treatment, from June 1986 to September 1988, by observing 25–30 radio-collared sheep daily. Post-treatment use was assessed in June–September 1991, by counting sheep 62 times from an 11-km transect.

A before-and-after study in 2000 of a shrubland ranch in South Africa (17) found that prescribed burning of an area increased its use by roan antelope *Hippotragus equinus* and tsessebe *Damaliscus lunatus*, but not by Lichtenstein's hartebeest *Alcelaphus lichtensteini* or sable antelope *Hippotragus niger*. Roan were seen more frequently on burned areas (113 sightings) than on unburned areas (81 sightings) relative to their availability (31% of the study area was burned). Tsessebe showed a similar pattern (burned: 77 sightings; unburned: 54 sightings) as did zebra *Equus burchelli* (burned: 96 sightings; unburned: 24) There was no consistent selection for burned areas by hartebeest (burned: 27; unburned: 24) or sable antelope (burned: 12; unburned: 27). See paper for further details of timings of use of burned areas. Rare herbivores

were farmed on a 2,700-ha game ranch. A 280-ha area was burned in October 2001 and a 565-ha area was burned in November 2001. Animal positions were surveyed from roads in early morning and late afternoon from October to December 2000.

A randomized, paired-sites, before-and-after study in 2001–2002 of a shrubland site in Texas, USA (18) found that burning plots already subject to mechanical vegetation clearance did not increase plot utilization by white-tailed deer *Odocoileus virginianus* relative to carrying out a second mechanical clearance. There was no significant difference in deer track counts between plots before (burning: 36; mechanical clearance: 37 track crossings/km) or after (burning: 43; mechanical clearance: 47 track crossings/km) treatments were applied. Ten plots (3–9 ha), established in a 6,154-ha study area, were paired by size, soil and vegetation. In March–April 1999, all plots were cleared of brush using a mechanical aerator pulled by a tractor. In September 2000, one plot from each pair was burned and the other was mechanically cleared a second time. Treatment assignment within pairs was random. Deer utilization was assessed by counting tracks along prepared track lanes, over three days, before and after treatments were applied.

A before-and-after, site comparison study in 1982–1997 in a shrubland in the Western Cape, South Africa (19) found that Cape mountain zebra *Equus zebra zebra* used burned areas more than unburned areas, and 92% of foals were produced in the three years post-fire compared to 8% in the three years pre-fire. Mountain zebras with access to burned areas used those areas 83% of the time (data not provided). By comparison, whilst the total areas burned were not stated, 23% of fires in the south-east section and 89% of fires in the north burned ≤25% the area. Of the foals produced within three years of a fire, 24 were produced in the three years post-fire compared to two pre-fire. Mountain zebras were monitored in two of three sections of the 9,428-ha nature reserve, the north (2,263 ha) and south-east (3,583 ha), where zebras mostly occurred. One of nine fires recorded since establishment of the reserve in 1974 was a prescribed fire (year not stated); others were natural fires (average interval between fires was seven years). Use of burned and unburned areas was monitored between the fires of 1992 and 1996. The number of foals produced was monitored three years before and after the fires of 1982, 1992, 1996–1997.

A replicated, randomized, controlled, before-and-after study in 2001–2003 in North Carolina, USA (20) found that prescribed burning did not alter the abundance of eight small mammal species. After burning, the numbers of captures of eight small mammal species did not differ significantly between burned (0–28 animals/plot) and unburned plots (0–17 animals/plot). Similarly, before burning, numbers did not differ between plots assigned for burning (0–24 animals/plot) and unburned plots (0–19 animals/plot). See paper for full breakdown of species abundances. Three blocks were established, containing plots of >14 ha. In each block, one plot was burned in March 2003 and one plot was not burned. Small mammals were live-trapped over 10 consecutive days and nights in July and August of 2001–2003.

A replicated, controlled, before-and-after study in 2002–2003 in a national park in North Dakota, USA (21) found that burning and clearing woody vegetation led to greater areas occupied by black-tailed prairie dog *Cynomys ludovicianus* colonies and more prairie dog burrows. The study does not distinguish between the effects of burning and mechanical vegetation clearance. After one year, prairie dog colonies occupied a greater area in plots where vegetation was cleared and burned (18–70% of available habitat) than in plots that were not cleared or burned (0–5%). Cleared and burned plots also had more new burrows (191–458) than did plots that were not cleared or burned (41–116). In each of three prairie dog colonies, a 2-ha plot just beyond the colony boundary underwent prescribed burning in May 2002 and mechanical brush removal in June 2002. Similar 2-ha plots that were not burned or cleared were used for comparison. Colony boundaries were mapped in May–September 2002 and May–August 2003. New burrows were mapped monthly during these periods.

A replicated, randomized, controlled, before-and-after study in 2001–2004 of a coniferous woodland in California, USA (22) found that prescribed fire did not increase the abundance of small mammals. Deer mouse *Peromyscus maniculatus* abundance was not significantly higher on burned than on unburned plots (results presented as modelled effect size). Similarly, lodgepole chipmunk *Neotamias speciosus* abundance and total small mammal biomass were not significantly higher in burned than in unburned plots. Nine plots, 15–20 ha in area, were studied. Three were burned between 28 September and 28 October 2001 and

three were burned on 20 or 27 June 2002. Three plots were not burned. Treatments were allocated randomly to plots. Small mammals were sampled by live-trapping over eight consecutive nights and days each year. Sampling occurred in June–August 2001 (pre-treatment) and in June–September of 2002 and 2003 and June–August 2004.

A controlled study in 1984–1999 in a sagebrush shrubland in Montana, USA (23) found that prescribed burning increased use of the area by elk *Cervus canadensis*. Elk used areas that had been burned more frequently (163–628 elk-use days) than they used areas that had not been burned (32–298 elk-use days). Burned areas had higher grass and forb cover and lower sagebrush cover than unburned areas. In October 1984, a 40-ha area of sagebrush shrubland was burned and, in April 1988, a 30-ha area was burned. Five permanent 404-m² plots (20.1 × 20.1 m) were established in each burned area and another five placed within the unburned portion, one in 1988 and four more in 1993. In June 1988–1993 and 1999, elk use of plots was estimated by counting the number of pellets within 1 m of six transects laid in each plot. Vegetation cover was estimated within five 25 × 51 cm randomly placed quadrats each plot. No livestock were present in the study area.

A replicated, randomized, controlled study in 2003–2004 in a mixed forest site in North Carolina, USA (24) found that prescribed fire did not alter abundances of four shrew species. In both sampling years, numbers of northern short-tailed shrews *Blarina brevicauda* caught did not differ between plots that were burned (2–6 animals/plot) and plots that were not burned (3–10 animals/plot). The same pattern was seen for smoky shrews *Sorex fumeus* (1–2 animals/plot vs 1–2 animals/plot), American pygmy shrews *Sorex hoyi* (2–4 animals/plot vs 0–2 animals/plot), and southeastern shrew *Sorex longirostris* (1–4 animals/plot vs 1–-5 animals/plot). In each of three blocks, established in 2001, one plot was burned in March 2003 and one plot was not burned. Plots were >14 ha. Shrews were surveyed using pitfall traps and drift fencing over 123 nights in 2003 and 125 nights in 2004.

A before-and-after, site comparison study in 1989–2001 within a mixed forest national park in Alberta, Canada (25) found that prescribed burning did not increase occupancy of lodges by beavers *Castor canadensis*. For lodges subject to prescribed burning once, the occupancy rate in the year after burning (25%) was lower than in the year before

burning (41%). Some lodges were burned more than once and the odds of occupancy decreased by 58% for each additional burn. In a 194-km^2 national park, occupancy of 734 beaver lodges, located between 1989 and 2001, was monitored by aerial or ground surveys, every 1–3 years. There were 121 prescribed fires (1–1,059 ha in extent) from 1979–2001. All but six (in October) were lit between April and June. Around 49% of the park was not burned in the study period.

A site comparison study in 1989–1999 in a sagebrush shrubland in Montana, USA (26) found that prescribed burning was associated with a short-term, but not long-term, increase in elk *Cervus canadensis* usage. In the first year after burning, elk use of burned plots increased (from 116 to 210 elk-use days) and declined on unburned plots (from 189 to 120 elk-use days). After 10 years, elk use declined and was similar on both burned plots (72 elk-use days) and unburned plots (56 elk-use days). A 50-ha prescribed burn was made in April 1989, while 200 ha of the site was not burned. Five plots (404 m^2 each) were established each in burned and unburned areas. Unburned plots, damaged by wildfire in 1991, were replaced in 1993 by three plots on remaining unburned land. Elk used the site from November–May. Elk pellet groups were counted in June 1989–1991, 1993, and 1999 along transects across each plot.

A replicated, randomized, controlled, before-and-after study in 2001–2003 of a forest in California, USA (27) found that prescribed burning increased abundance of deer mouse *Peromyscus maniculatus*, but not California ground squirrels *Spermophilus beecheyi*, long-eared chipmunks *Tamias quadrimaculatus* or brush mice *Peromyscus boylii*. Deer mouse abundance increased with fire (after: 2.0; before: 0.5/100 trap nights) and declined at the same time in unburned plots (after: 1.3; before: 1.9/100 trap nights). Changes in capture rates from before to after treatments did not differ between burned and unburned plots for California ground squirrel, long-eared chipmunk or brush mouse (see paper for data). Forests stands were 14–29 ha each. Four stands were burned in October–November 2002 and four stands were not burned. Small mammals were live-trapped over nine consecutive days and nights in July–August 2001 (pre-burn) and 2003 (post-burn).

A replicated, controlled study in 2003–2004 of savanna grassland in a national park in Tanzania (28) found that prescribed burning did not result in a higher level of herbivory by mammals. The amount consumed

by herbivores varied by season but the overall average amount in burned plots (223 g/m^2) was not significantly different to that in unburned plots (176 g/m^2). Six study areas (each ≥10 ha, 1–40 km apart) were selected. Each consisted of one patch burned in May–July 2003 and one unburned patch. Herbivore consumption was measured monthly, from September 2003 to July 2004, as biomass differences between caged and uncaged areas in study plots.

A before-and-after study in 2003–2005 of grassland in Colorado, USA (29) found that after a prescribed fire, swift foxes *Vulpes velox* denned more in the burned area but hunting use of the area did not significantly increase. Two foxes with core home ranges in the burn area denned inside the burn area more after the burn (100% of denning locations) than before (60–75% of locations). For four foxes with home ranges overlapping the burn area, the proportion of times they were located hunting in the burn area was not significantly higher after burning (45% of locations inside burn area) than before (32%). In January 2003–December 2004, ten foxes were radio-collared. Location was recorded ≥three times/week in 2003–2005. In March 2005, an area of 260 ha was burned by prescribed fire. Sufficient locations were obtained from four foxes to determine pre-and post-burn home range use.

A replicated, controlled study in 2005–2006 in a coniferous forest site in Oregon, USA (30) found that thinning, followed by prescribed burning was associated with mixed effects on use by North American elk *Cervus canadensis*, depending on season, stand age and sex. Thinning and burning were carried out on the same plots, so their influences could not be separated. Female elk used plots burned two and three years previously, proportionally to their availability, preferentially selected 4-year-old burns, and avoided 5-year-old burns. Male elk spent less time in all burned plots relative to their availability (data presented as selection ratios). In 2001–2003, twenty-six forest stands (average 26 ha) were thinned between May and October, followed by prescribed fire during September or October of either the same or the following year. Twenty-seven similar stands (average 55 ha) were not thinned or burned. Radio-collars were fitted on 18 female and five male elk in spring 2005, and 30 female and nine male elk in spring 2006. Locations were recorded automatically, within 1 hour of sunset or sunrise.

A systematic review in 2008 of management aimed at restoring natural processes in conifer forests in southwestern USA (31) found that, in forests where a prescribed burn of low to moderate severity followed thinning, two mammal species showed positive responses (abundance or reproduction) compared to in unmanaged forests, while three showed no response. Responses of tassel-eared squirrel *Sciurus aberti* and deer mouse *Peromyscus maniculatus* to burning after thinning were positive. No significant responses were detected for golden-mantled ground squirrel *Spermophilus lateralis*, gray-collared chipmunk *Tamias cinereicollis* or Mexican woodrat *Neotoma mexicana*. The specific effects of thinning versus burning were not separated, though a different part of the same study found no response by tassel-eared squirrel or deer mouse to thinning (without burning) by removal of small-to intermediate-diameter trees. The review used evidence from 22 studies and considered responses of species recorded in ≥5 studies. Responses of species to five ways of managing ponderosa pine *Pinus ponderosa* forests to recreate natural conditions and forest dynamics, and reduce wildfire risk, were assessed against responses to unmanaged controls. A controlled study in 2004–2008 of heather moorland at a site in southern France (32) found that burning heather (*Calluna vulgaris* and *Erica tetralix*) resulted in greater use of the moorland by mouflon *Ovis gmelini musimon* × *Ovis* sp. The average density of feeding mouflon (modelled to account for temperature-driven variations) was higher on burned plots (36/ha) than on unburned plots (5/ha). Before burning, each 360 × 80-m plot, had not been modified for >40 years. Two plots were burned in spring 2004 and two were left unburned. Mouflon use of plots was determined by counting feeding animals in each plot, at 20-minute intervals, for two hours up to sunset. In total, 668 such counts were made in 2004–2008.

A replicated, site comparison study in 2004–2010 of grassland in Western Australia, Australia (33) found that prescribed burns early in the dry season resulted in higher abundance and species richness of small mammals relative to extensive mid-to late-dry season wildfires. More mammals were found in plots with prescribed burning (5.7/plot) than in areas subject to wildfire (3.5/plot). The same was true for species richness (prescribed burning: 1.4/plot; wildfire: 1.1/plot). Fire history was determined from satellite imagery from 1999–2010.

Prescribed burning was initiated in 2004. Areas burned less frequently than average were regarded as being managed by prescribed burning earlier in the dry season. Areas burned more frequently than average were regarded as being wildfire areas, burned later in the dry season. Forty small mammal traps/0.25-ha plot were operated for 120 trap-nights/year. The number of plots surveyed is not stated.

A site comparison study in 2002–2003 in a shrubland site in Arizona, USA (34) found that prescribed burning resulted in smaller individual home ranges and shorter daily movements for Mexican fox squirrels *Sciurus nayaritensis chiricahuae* than did fire suppression. The average home range in prescribed burning areas (2.9 ha) was smaller than in fire-suppression areas (6.6 ha). Average daily movements were lower in prescribed burning areas (212 m) than in fire-suppression areas (336 m). In a 5,000-ha protected area, prescribed burning was initiated in 1976. In 1980–2001, there were 33 fires, over 260-ha total extent. Forty-three squirrels were live-trapped. Adults were radio-collared and data were analysed from 11 male and nine females, with ≥30 location fixes per season, from May 2002 to September 2003. Daily movements were measured by locating animals three times from 05:00 h to 11:00 h.

A site comparison study in 2007 of savanna grassland in a park in Tanzania found that vigilance (a measure of perceived predation risk) of Thomson's gazelles *Gazella thomsonii* did not differ between those on burned and unburned areas. There was no difference between burned and unburned areas in group vigilance, individual vigilance or reaction time in the presence of a model cheetah (data not presented). Gazelles were observed in July–August 2007 on 10 burned areas (burned after mid-April with 2 cm average new grass growth) and nine unburned grassland areas. Vigilance was defined as an animal raising its head above shoulder height. Group vigilance was the average proportion of individuals vigilant in a group at 5-minute intervals over 1 hour. Individual vigilance was recorded for randomly selected females, over 2 minutes. Reaction to a model cheetah was timed following model placement from a vehicle 60 m away from the group. A before-and-after study in 2009–2010 on a shrubland reserve in South Africa found that burning reduced the number of locations in which herbivores were present. In each of two main habitats, the proportion of locations at which impala *Aepyceros melampus*, kudu *Tragelaphus strepsiceros*, and

zebra *Equus burchelli* were found was lower after burning than before. In one of two habitats, wildebeest *Connochaetes taurinus* and giraffes were present at a higher proportion of sites after burning than before burning (see paper for full details). Two habitat types were studied, based on underlying quartzite and sandy soils. Mammal presence was quantified by determining presence or absence of faecal pellets for each species in plots along transects through each habitat. Pellets were counted in April–May 2009, burns were carried out in June–November 2009 and plots were resampled in June 2010.

A replicated, site comparison study in 2006–2007 of scrubland at a site in Spain (37) found more of some small mammal species at edges of old burned plots but not in plot centres or in younger plots, relative to unburned plots. In two of four comparisons, there were more Algerian mice *Mus spretus* in burned plots (64–109 captures/1,000 trap nights) than in unburned plots (32 captures/1,000 trap nights). For two of four comparisons, there was no significant difference (burned: 8–22 captures/1,000 trap nights; unburned 32 captures/1,000 trap nights). In three of four comparisons, there was no difference in the abundance of wood mice *Apodemus sylvaticus* between burned (2–7 captures/1,000 trap nights) and unburned areas (2 captures/1,000 trap night). In one of four comparisons there were more wood mice in burned areas (burned: 14 captures/1,000 trap nights; unburned 2 captures/1,000 trap night). There were no significant differences in the abundance of greater white-toothed shrew *Crocidura russula* or garden dormouse *Eliomys quercinus* between burned and unburned plots. Three plots were burned in winter 2003 (three years before sampling), three plots were burned in winter 2006 (one year before sampling) and three were not burned. Plots covered 1 ha and were ≥1 km apart. Small mammals were surveyed by live-trapping in unburned plots and in centres and edges of burned plots, once each in summer, autumn, winter and spring from summer 2006 to spring 2007). Traps were operated for seven consecutive nights (and closed in the day).

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8.2. Burn at specific time of year

https://www.conservationevidence.com/actions/2416

- **Two studies** evaluated the effects on mammals of burning at a specific time of year. One study was in Australia[1], and one was in the USA[2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A replicated, randomized, controlled, before-and-after study in the USA[2] found that carrying out prescribed burns in autumn did not increase small mammal abundances or biomass relative to burning in summer.
- **Survival (1 study):** A randomized, replicated, controlled study in Australia[1] found that in forest burned early in the dry season, northern brown bandicoot survival rate declined less than in forests burned late in the dry season.

BEHAVIOUR (0 STUDIES)

Background

Fire is an integral part of the management and natural dynamics of some ecosystems. Some habitats are naturally fire-prone, while in others, habitats are shaped by long-term traditional management (Bowman 1998). Some habitats are now managed through prescribed burning, partly to reduce the risk of uncontrolled wildfires. The timing of such burns may impact the mammal fauna with changes to different burning dates potentially being beneficial (or, at least, less damaging) to some species.

See also: *Use prescribed burning*.

Bowman D.M.J.S. (1998) Tansley Review No. 101. The impact of Aboriginal landscape burning on the Australian biota. *New Phytologist*, 140, 385–410.

A randomized, replicated, controlled study in 1989–1995 of a forest site in Northern Territory, Australia (1) found that in forest burned early in the dry season, northern brown bandicoot *Isoodon macrourus* survival rate declined less than in forests burned late in the dry season. In early burn sites, the bimonthly survival rate fell during the study from 0.76 to 0.59 compared to a larger reduction in sites burned later in the year, from 0.78 to 0.19. Four compartments each extended across 15–20 km^2. Two were burned early in the dry season

(May–June) and two were burned late in the dry season (September–October, mimicking wildfire). Treatments were assigned randomly to compartments and were applied annually in 1990–1994. Bandicoots were surveyed by live-trapping in each compartment, over two nights, bimonthly, from July 1989 to May 1995.

A replicated, randomized, controlled, before-and-after study in 2001–2004 of a coniferous woodland in California, USA (2) found that carrying out prescribed burns in autumn did not increase small mammal abundances or biomass relative to burning in summer. Timing of burning did not significantly affect abundances of deer mice *Peromyscus maniculatus* or lodgepole chipmunks *Neotamias speciosus* or overall small-mammal biomass (results presented as model outputs). Nine plots, 15–20 ha in area, were studied. Three were burned between 28 September and 28 October 2001 and three were burned on 20 or 27 June 2002. Three plots were not burned. Treatments were allocated randomly to plots. Small mammals were sampled by live-trapping over eight consecutive nights and days each year. Sampling occurred in June–August 2001 (pre-treatment) and in June–September of 2002 and 2003 and June–August 2004.

(1) Pardon L.G., Brook B.W., Griffiths A.D. & Braithwaite R.W. (2003) Determinants of survival for the northern brown bandicoot under a landscape-scale fire experiment. *Journal of Animal Ecology*, 72, 106–115, https://doi.org/10.1046/j.1365-2656.2003.00686.x

(2) Monroe M.E. & Converse S.J. (2006) The effects of early season and late season prescribed fires on small mammals in a Sierra Nevada mixed conifer forest. *Forest Ecology and Management*, 236, 229–240, https://doi.org/10.1016/j.foreco.2006.09.008

8.3. Provide shelter structures after fire

https://www.conservationevidence.com/actions/2418

- We found no studies that evaluated the effects on mammals of providing shelter structures after fire.

'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

Fire is an integral part of the dynamics of some ecosystems. It can clear out woody material, creating ideal conditions for new growth or herbaceous plants and small trees that are utilized by mammalian grazers and browsers. However, fire can also be disruptive to species, by removing cover. It may make them more vulnerable to effects of extreme weather and to predation and can cause them to seek out remaining vegetated areas that provide some degree of shelter (e.g. Pereoglou *et al*. 2011). For rare or otherwise valued species, shelters, such as low boards with space underneath, might be distributed across the burn area to help mitigate these effects.

Pereoglou F., Macgregor C., Banks S.C., Ford F., Wood J. & Lindenmayer D.B. (2011) Refuge site selection by the eastern chestnut mouse in recently burnt heath. *Wildlife Research*, 2011, 38, 290–298, https://doi.org/10.1071/wr11007

8.4. Thin trees to reduce wildfire risk

https://www.conservationevidence.com/actions/2477

- **Three studies** evaluated the effects on mammals of thinning trees to reduce wildfire risk. All three studies were in the USA[1,2,3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (2 STUDIES)

- **Abundance (2 studies):** A replicated, controlled, before-and-after study in the USA[1] found that reducing tree density increased abundances of two of four small mammal species. A systematic review in the USA[3] found that, in thinned forests, two mammal species were recorded in higher densities compared to in unmanaged forests, while three species showed no effect.

BEHAVIOUR (1 STUDY)

- **(1 study):** A replicated, controlled study in the USA[2] found that thinning followed by prescribed burning did not increase use of forest areas by North American elk in most season, stand age and sex comparisons.

Background

Through fire suppression, some forest areas have become denser than was the case under natural fire regimes. To reduce fuel loads and associated wildfire risk, trees may be thinned. By creating a more open woodland structure, this may encourage growth of herbaceous plants, shrubs and trees at lower levels, thus potentially providing increased resources for mammalian herbivores.

See also *Biological resource use — Thin trees within forest*, in which thinning is usually done for extraction of merchantable timber though reducing fuel loads may sometimes be a secondary motivation.

A replicated, controlled, before-and-after study in 1998–2003 of ponderosa pine *Pinus ponderosa* forest in Arizona, USA (1) found that reducing tree density increased abundances of two of four small mammal species. Deer mouse *Peromyscus maniculatus* and gray-collared chipmunk *Tamias cinereicollis* captures were both positively associated with decreasing tree density in treatment plots, but golden-mantled ground squirrel *Spermophilus lateralis* and Mexican woodrat *Neotoma exicana* captures showed no such relationship. Results were presented as statistical model outputs. Three blocks, each with four 14-ha plots, were studied. Treatments comprised removal of all trees except those dating from pre-European settlement and, within 18 m of those trees, retention of 1.5, 2 or 3 trees with dbh ≥41 cm (or twice this many trees with smaller dbh, if larger trees not available). Thinning was conducted in 1999. Most woody debris was then piled up and burned, followed by prescribed burning of the whole plot in April–July 2000. The fourth plot in each block was unmanaged. Small mammals were live-trapped in August–October in 1998–1999 and 2001–2003.

A replicated, controlled study in 2005–2006 in a coniferous forest in Oregon, USA (2) found that thinning followed by prescribed burning did not increase use of areas by North American elk *Cervus canadensis*, in most season, stand age and sex comparisons. Thinning and burning were carried out on the same plots, so their influences could not be separated. In spring, female elk used plots burned two and three years previously, proportionally to their availability, preferentially selected 4-year-old burns, and avoided 5-year-old burns. They showed no preference for thinned and burned plots in summer. Male elk did not show preference for any thinned and burned plots, relative to their availability, in spring or summer. Stands not thinned and burned were avoided by females and selected by males in spring. In summer they were selected by females and males showed no preference. Data all presented as selection ratios. In 2001–2004, twenty-six forest stands (average 26 ha) were thinned between May and October, followed by prescribed burning during September or October of either the same or the following year. Twenty-seven similar stands (average size 55 ha) were not thinned or burned. Eighteen female and five male elk were radio-collared in spring 2005 with 30 female and nine male elk radio-collared in spring 2006. Locations were recorded automatically, within 1 hour of sunset or sunrise.

A systematic review in 2008 of management aimed at restoring natural processes in conifer forests in southwestern USA (3) found that, in forests thinned by removing small-to medium-diameter trees, two mammal species were recorded in higher densities compared to in unmanaged forests, while three species showed no effect. Higher densities associated with thinning were seen in gray-collared chipmunk *Tamias cinereicollis* and Mexican woodrat *Neotoma mexicana*. No significant responses to thinning were detected for tassel-eared squirrel *Sciurus aberti*, deer mouse *Peromyscus maniculatus* or golden-mantled ground squirrel *Spermophilus lateralis*. The review used evidence from 22 studies and considered responses of species recorded in ≥5 studies. Densities of species in ponderosa pine *Pinus ponderosa* forests managed in five ways, to recreate natural conditions and forest dynamics and reduce wildfire risk, were compared with densities in unmanaged forest.

(1) Converse S.J., Block W.M. & White G.C. (2006) Small mammal population and habitat responses to forest thinning and prescribed fire. *Forest Ecology and Management*, 228, 263–273, https://doi.org/10.1016/j.foreco.2006.03.006

(2) Long R.S., Rachlow J.L. & Kie J.G. (2009) Sex-specific responses of North American elk to habitat manipulation. *Journal of Mammalogy*, 90, 423–432, https://doi.org/10.1644/08-mamm-a-181.1

(3) Kalies E.K., Chambers C.L. & Covington W.W. (2010) Wildlife responses to thinning and burning treatments in southwestern conifer forests: A meta-analysis. *Forest Ecology and Management*, 259, 333–342, https://doi.org/10.1016/j.foreco.2009.10.024

8.5. Remove burnt trees and branches after wildfire

https://www.conservationevidence.com/actions/2478

- **One study** evaluated the effects on mammals of removing burnt trees and branches after wildfire. This study was in Spain[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A replicated, randomized, controlled study in Spain[1] found that removing burned trees and branches after wildfire did not increase European wild rabbit numbers compared to removing burned trees but leaving branches in place.

BEHAVIOUR (0 STUDIES)

Background

After wildfires, a frequent management option is to remove burnt trees but to leave branches on the ground for economic reasons and to prevent soil erosion. However, some mammals are thought to benefit from areas with a low density of woody material at ground level (e.g. Beja *et al*. 2007) so removing branches might benefit these species.

Beja P., Pais M. & Palma L. (2007) Rabbit *Oryctolagus cuniculus* habitats in Mediterranean scrubland: the role of scrub structure and composition. *Wildlife Biology*, 13, 28–37, https://doi.org/10.2981/0909-6396(2007)13[28:rochim]2.0.co;2

A replicated, randomized, controlled study in 2006–2008 of a pine-dominated forest in Catalonia, Spain (1) found that removing burned trees and branches after wildfire did not alter European wild rabbit *Oryctolagus cuniculus* numbers compared to removing burned trees but leaving branches in place. There was no significant difference between rabbit pellet numbers in plots with trees and branches removed (1,400–5,100 pellets/plot) and those with trees removed but branches left in place (3,100–7,700 pellets/plot). High-intensity wildfire in summer 2003 burned 4,600 ha of forest. Plots (100 × 100 m) were established, 200–6,615 m apart. All plots had burnt trees trunks removed in 2004. In 20 plots, branches were left on the ground. In 10 plots, branches were initially left on the ground, but most were then removed in spring 2006, though some were piled up and left in the plots. Rabbit relative abundance was assessed in June of 2006, 2007 and 2008 by counting latrines in 500 × 2 m transects.

(1) Rollan A. & Real J. (2011) Effect of wildfires and post-fire forest treatments on rabbit abundance. *European Journal of Wildlife Research*, 57, 201–209, https://doi.org/10.1007/s10344-010-0412-y

8.6. Remove mid-storey vegetation in forest

https://www.conservationevidence.com/actions/2480

- **One study** evaluated the effects on mammals of removing mid-storey vegetation in forest. This study was in the USA[1].

COMMUNITY RESPONSE (1 STUDY)

- **Richness/diversity (1 study):** A randomized, replicated, controlled study in the USA[1] found that after removing mid-storey vegetation, mammal species richness increased.

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A randomized, replicated, controlled study in the USA[1] found that after removing mid-storey vegetation, mammal abundance increased.

BEHAVIOUR (0 STUDIES)

Background

Through fire suppression, some forest areas have developed denser mid-storey vegetation (trees at intermediate height between the ground layer and the forest canopy) than was formerly the case. To reduce wildfire risk and for habitat restoration purposes, mid-storey vegetation may be removed either mechanically or through prescribed burning. This intervention considered specifically manual or mechanical removal of mid-storey vegetation and how this may affect forest mammals.

See also: *Use prescribed burning*.

A randomized, replicated, controlled study in 1992–1994 of pine-grassland in a mountainous area of Arkansas, USA (1) found that after removing mid-storey vegetation, mammal abundance and species richness increased. Small-mammal-trapping success was higher in mid-storey-removal plots (caught in 3.8–7.4% of traps) than in unmanaged plots (0.9–2.2% of traps). Average species richness was higher in mid-storey removal plots (1.7–4.7 species) than in unmanaged plots (1.3–2.7 species). Forest mid-storey was mechanically removed in 14–45-ha plots. Management timing is unclear, but the practice was initiated in the study area in 1990, primarily to benefit red-cockaded woodpeckers *Picoides borealis*. Small mammals were live-trapped at 80 stations/plot from 27 December to 4 January. Surveys were conducted in three plots in 1992–1993 and three different plots in 1993–1994. At the same time, sampling was conducted in three plots with retained mid-storey vegetation.

(1) Masters R.E., Lochmillern R.L., McMurry S.T. & Bukenhofer G.A. (1998) Small mammal response to pine-grassland restoration for red-cockaded woodpeckers. *Wildlife Society Bulletin*, 26, 148–158.

8.7. Remove understorey vegetation in forest

https://www.conservationevidence.com/actions/2482

- **Three studies** evaluated the effects on mammals of removing understorey vegetation in forest. All three studies were in the USA[1,2,3].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (3 STUDIES)

- **Abundance (3 studies):** Three replicated, randomized, controlled studies (two also before-and-after), in the USA[1,2,3], found that compared to prescribed burning, mechanically removing understorey vegetation growth in forests did not increase abundances of white-footed mice[1], shrews[2] or four rodent species[3].

BEHAVIOUR (0 STUDIES)

Background

Through fire suppression, some forest areas have developed denser understorey vegetation than was the case under natural fire regimes. To reduce fuel loads and associated wildfire risk, understorey vegetation may be removed. Prescribed burning is one option for doing this, but the rapid habitat change that this causes, together with potential loss of food resources and shelter, could negatively impact forest-floor mammals. This intervention, therefore, considers specifically manual or mechanical removal of understorey vegetation as an alternative to prescribed burning, and how this affects forest mammals.

See also: *Use prescribed burning*.

A replicated, randomized, controlled, before-and-after study in 2001–2003 in North Carolina, USA (1) found that mechanically removing understorey vegetation in forest, to reduce fuel load and associated wildfire risk, did not increase white-footed mouse *Peromyscus*

leucopus abundance compared to using prescribed fire. Mouse abundance increased across all treatments during the study, but the rate of increase in understorey removal plots (from 14 to 30 mice/plot) was not significantly different to that in prescribed burning plots (from 9 to 36 mice/plot). Plots (each >14 ha) were established in three blocks. In each block, understorey growth was mechanically felled in one plot in winter 2001–2002 and prescribed burning was carried out in a different plot in March 2003. Mice were live-trapped over 10 consecutive days and nights in July and August of 2001 (before management) and 2003 (after management).

A replicated, randomized, controlled study in 2003–2004 in North Carolina, USA (2) found that mechanically removing understorey vegetation in forest, to reduce fuel load and associated wildfire risk, did not increase shrew abundance compared to using prescribed fire. The number of shrews caught did not differ significantly between understorey removal plots and prescribed burning plots in the first year (understorey removal: 22 shrews/plot; burning: 15) or the second year (understorey removal: 7 shrews/plot; burning: 6) after treatments were applied. Plots (each >14 ha) were established in three blocks. Within each block, understorey growth was mechanically felled in one plot in winter 2001–2002 and prescribed burning was carried out in a different plot in March 2003. Shrews were surveyed using pitfall traps and drift fencing over 123 nights in 2003 and 125 nights in 2004.

A replicated, randomized, controlled, before-and-after study in 2001–2003 of a forest in California, USA (3) found that mechanically removing understorey vegetation in forest, to reduce fuel load and associated wildfire risk, did not increase abundances of California ground squirrels *Spermophilus beecheyi*, long-eared chipmunks *Tamias quadrimaculatus*, brush mice *Peromyscus boylii* or deer mice *Peromyscus maniculatus*, compared to using prescribed burning. Changes in capture rates between before and after treatments did not differ significantly between understorey removal plots and fire plots for California ground squirrel (understorey removal: 2.6 to 11.0; fire: 4.2 to 7.6/100 trap nights), long-eared chipmunk (understorey removal: 0.7 to 2.4; fire: 0.7 to 1.7/100 trap nights) or brush mouse (understorey removal: 0.6 to 1.4; fire: 0.1 to 1.4/100 trap nights). Deer mouse abundance declined with understorey removal (from 2.0 to 1.2/100 trap nights) compared to an increase with

fire (from 0.5 to 2.0/100 trap nights). Forests stands were 14–29 ha each. In four stands, 90% of understorey trees were removed in 2001–2002. Four different stands were burned in October–November 2002. Small mammals were live-trapped over nine consecutive days and nights in July–August of 2001 (pre-treatment) and 2003 (post-treatment).

(1) Greenberg C.H., Otis D.L., Waldrop T.A. (2006) Response of white-footed mice (*Peromyscus leucopus*) to fire and fire surrogate fuel reduction treatments in a southern Appalachian hardwood forest. *Forest Ecology and Management*, 234, 355–362, https://doi.org/10.1016/j.foreco.2006.07.022

(2) Greenberg C.H., Miller S. & Waldrop T.A. (2007) Short-term response of shrews to prescribed fire and mechanical fuel reduction in a Southern Appalachian upland hardwood forest. *Forest Ecology and Management*, 243, 231–236, https://doi.org/10.1016/j.foreco.2007.03.003

(3) Amacher A.J., Barrett R.H., Moghaddas J.J. & Stephens S.L. (2008) Preliminary effects of fire and mechanical fuel treatments on the abundance of small mammals in the mixed-conifer forest of the Sierra Nevada. *Forest Ecology and Management*, 255, 3193–3202, https://doi.org/10.1016/j.foreco.2007.10.059

8.8. Remove trees and shrubs to recreate open areas of land

https://www.conservationevidence.com/actions/2483

- **Two studies** evaluated the effects on mammals of removing trees and shrubs to recreate open areas of land. Both studies were in the USA[1,2].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Abundance (1 study):** A controlled study in the USA[1] found that where Ashe juniper trees were removed, there were higher abundances of three rodent species.

BEHAVIOUR (1 STUDY)

- **Use (1 study):** A before-and-after, site comparison study in the USA[2] found that removing trees increased use of areas by Rocky Mountain bighorn sheep.

Background

Through fire suppression, some forest areas have spread onto previously open ground or have developed denser understorey vegetation than was the case under natural fire regimes. To reduce fuel loads and restore more open habitats for mammalian herbivores, trees and shrubs may be removed. Specifically, this intervention includes studies where the intention is to recreate open areas on land onto which forest and scrub has spread.

For interventions that remove just limited vegetation layers within forests, or reduce tree density but leave forest cover, see *Remove mid-storey vegetation in forest*, *Remove understorey vegetation in forest* and *Thin trees to reduce wildfire risk.* For interventions looking to benefit mammals through management of longer-established forest, especially where these are carried out through timber harvesting operations, see *Biological Resource Use*.

A controlled study in 1995–1997 at a former savanna in Texas, USA (1) found that where Ashe juniper *Juniperus ashei* trees were removed, there were higher abundances of three rodent species. Results were not tested for statistical significance. There were more white-ankled mice *Peromyscus pectoralis* in areas where Ashe juniper were cut (96 mice caught) than in areas where no trees were cut (10 caught). The same pattern was true for white-footed mouse *Peromyscus leucopus* (cut: 22 mice caught; uncut: 1 mouse) and for hispid cotton rat *Sigmodon hispidus* (cut: 4 rats caught; uncut: 0 rats). In 1995–1996, Ashe juniper in three areas was cut with a chainsaw. In two further areas, no trees were cut. In all areas, native oak trees *Quercus* spp. were left uncut. In October 1995–May 1996, once a month, 20 traps baited with oats were laid along a 100-m-long transect in one cut area and similarly in two areas that had not been cut. In October 1996 to March 1997, three to four times each month, three cut areas and two uncut areas were monitored in the same way. Traps were set in the morning and checked at dawn. Animals caught were ear-tagged to enable identification of recaptures.

A before-and-after, site comparison study in 1986–1991 of a mixed grassland, shrubland and woodland site in Utah, USA (2) found that

removing ponderosa pine *Pinus ponderosa* and mountain mahogany *Cercocarpus* spp. trees increased use of these areas by Rocky Mountain bighorn sheep *Ovis canadensis*. In areas where trees were removed, sheep activity increased by 165%, but in areas where no trees were cut, sheep activity declined by 45%. Across a 353-ha study area, 32% was clearcut, 49% was unmanaged and 18% was burned (results of burning treatment not present here). Sheep use patterns were assessed, before cutting or burning, from June 1986 to September 1988, by observing 25–30 radio-collared sheep daily. After burning and cutting, use was assessed in June–September 1991, by counting sheep, 62 times, from an 11-km transect.

(1) Schnepf K.A., Heselmeyer J.A. & Ribble D.O. (1998) Effects of cutting Ashe juniper woodlands on small mammal populations in the Texas Hill Country. *Natural Areas Journal*, 18, 333–337.

(2) Smith T.S., Hardin P.J. & Flinders J.T. (1999) Response of bighorn sheep to clearcut logging and prescribed burning. *Wildlife Society Bulletin*, 27, 840–845.

8.9. Provide artificial waterholes in dry season

https://www.conservationevidence.com/actions/2484

- **Three studies** evaluated the effects on mammals of providing artificial waterholes in the dry season. One study was in South Africa[1], one was in Tanzania[2] and one was in Jordan[3].

COMMUNITY RESPONSE (1 STUDY)

- **Richness/diversity (1 study):** A site comparison study in Tanzania[2] found that artificial waterholes were used by a similar number of large mammal species as was a natural waterhole.

POPULATION RESPONSE (0 STUDIES)

BEHAVIOUR (2 STUDIES)

- **Use (2 studies):** A study in South Africa[1] found that areas around artificial waterholes were used more by eight out of 13 mammalian herbivore species than was the wider landscape. A study in Jordan[3] found that artificial waterholes were used by striped hyenas.

Background

In response to reduced availability of natural water sources for mammals, artificial water holes may be constructed. These can help to enhance survival during drought periods. However, there are also concerns about negative effects on mammals from artificial waterholes, such as there being increased numbers of some common water-dependent species at expense of rarer herbivores (Smuts 1978), or that artificial waterholes maintain high populations that are then vulnerable to starvation (Walker *at al*. 1987).

Smuts G.L. (1978) Interrelations between predators, prey and their environment. *Bioscience*, 28, 316–320.

Walker B.H., Emslie R.H., Owen-Smith R.N., Scholes R.J. (1987) To cull or not to cull: lessons from a southern African drought. *Journal of Applied Ecology*, 24, 381–401.

A study in 1987–1993 in a mostly dry savanna protected area in the eastern Lowveld region, South Africa (1) found that, during the dry season, areas around artificial waterholes were used by higher numbers of animals of eight out of 13 mammalian herbivore species than was the wider landscape. Higher abundances near waterholes than across the wider landscape were recorded for eland *Taurotragus oryx*, Burchell's zebra *Equus burchelli*, buffalo *Syncerus caffer*, blue wildebeest *Connochaetes taurinus*, sable *Hippotragus niger*, white rhinoceros *Ceratotherium simum*, tsessebe *Damaliscus lunatus*, and roan *Hippotragus equinus* (data expressed as model results). However, the abundance of waterbuck *Kobus elipsiprimnus*, kudu *Tragelaphus strepsiceros*, giraffe *Giraffa camelopardalis*, impala *Aepyceros melampus* and elephant *Loxondonta africana* was lower near waterholes than across the wider landscape (data expressed as model results). In the 1930–1980s, more than 300 boreholes were drilled, 50 earth dams were constructed and seasonal and perennial rivers were dammed across Kruger National Park (>20,000 km^2). Mammals were counted during daytime by four observers, from a fixed-wing aircraft, during the dry season (May–August), in 1987–1993. Counts were made within 800-m wide transects, from 65–70 m high, flying at 95–100 knots.

A site comparison study in 2006 in a national park comprising woodland and savanna in Tanzania (2) found that artificial waterholes

were used by a similar number of large mammal species as was a natural waterhole. Results were not tested for statistical significance. The number of species recorded at artificial waterholes (4–5 species) was similar to the number at the natural waterhole (three). Average numbers of impala *Aepyceros melampus* were considerably higher at one artificial waterhole (64 impalas) than at the natural waterhole (9). Giraffe *Giraffa camelopardalis* numbers were also higher at one artificial waterhole (26 giraffes) than at the natural waterhole (8). Two artificial waterholes and one natural waterhole were monitored. Large mammal numbers were estimated, in November 2006, by counting footprints and droppings in three 100-m^2 quadrats at each waterhole and by direct observation, for one day, from a vehicle.

A study in 2010–2012 in desert in a national park in Jordan (3) found that artificial waterholes were used by striped hyenas *Hyaena hyaena*. In the first year of monitoring, an estimated nine hyenas visited the two artificial waterholes with 10 hyenas visiting in the second year. Within a 320-km^2 national park, one artificial waterhole was created in 2003 and one in 2010. They were approximately 1 m in diameter and located 460 m apart. Hyenas were monitored using one camera trap at each water hole through August and September of 2010 and 2012. The park also contained approximately 60 permanent and semi-permanent natural waterholes and springs.

(1) Smit I.P.J., Grant C.C. & Devereux B.J. (2007) Do artificial waterholes influence the way herbivores use the landscape? Herbivore distribution patterns around rivers and artificial surface water sources in a large African savanna park. *Biological Conservation*, 136, 85–99, https://doi.org/10.1016/j.biocon.2006.11.009

(2) Epaphras A.M., Gereta E., Lejora I.A., Ole Meing'ataki G.E., Ng'umbi G., Kiwango Y., Mwangomo E., Semanini F., Vitalis L., Balozi J. & Mtahiko M.G.G. (2008) Wildlife water utilization and importance of artificial waterholes during dry season at Ruaha National Park, Tanzania. *Wetlands Ecology and Management*, 16, 183–188, https://doi.org/10.1007/s11273-007-9065-3

(3) Attum O., Rosenbarger D., Al awaji M., Kramer A & Eida E. (2017) Population size and artificial waterhole use by striped hyenas in the Dana Biosphere Reserve, Jordan. *Mammalia*, 81, 415–419, https://doi.org/10.1515/mammalia-2015-0155

8.10. Use fencing to protect water sources for use by wild mammals

https://www.conservationevidence.com/actions/2493

- We found no studies that evaluated the effects of using fencing to protect water sources for use by wild 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

Water, from natural or artificial sources, can be an important resource, shaping the distribution of wild mammals in arid areas. Fencing may be installed to protect these water sources from domestic or wild animals whilst still permitting entry of smaller mammals (e.g. Gaudioso Lacasa *et al*. 2010).

Gaudioso Lacasa V., Sánchez García-Abad C., Prieto Martín R., Bartolomé Rodríguez D.J., Pérez Garrido J.A. & Alonso de La Varga M.E. (2010) Small game water troughs in a Spanish agrarian pseudo steppe: visits and water site choice by wild fauna. *European Journal of Wildlife Research*, 56, 591–599, https://doi.org/10.1007/s10344-009-0352-6

8.11. Provide supplementary food after fire

https://www.conservationevidence.com/actions/2494

- **One study** evaluated the effects on mammals of providing supplementary food after fire. This study was in the USA[1].

COMMUNITY RESPONSE (0 STUDIES)

POPULATION RESPONSE (1 STUDY)

- **Survival (1 study):** A replicated, randomized, controlled study in the USA[1] found that supplementary feeding did not

increase survival of hispid cotton rats following prescribed fire.

BEHAVIOUR (0 STUDIES)

Background

This intervention specifically covers cases where supplementary food is provided in an attempt to offset threats associated with fire. Natural or prescribed fires, whilst being integral parts of some ecosystems, can temporarily reduce or remove available food. Supplementary food may be provided for rare or otherwise valued mammal species.

A replicated, randomized, controlled study in 2005–2009 of woodland in Georgia, USA (1) found that supplementary feeding did not increase survival rates of hispid cotton rats *Sigmodon hispidus* following prescribed fire. Survival rates over a 13-week post-fire period during which supplementary food was offered (0.02–0.04) were similar to those with no supplementary food offered (0.02–0.04). Eight plots (40 ha each) were studied. Four plots (exclosures) were surrounded by electric fencing to deter predator entry. All plots were burned in February of 2005, 2007, and 2009. From June 2007 to August 2009, two exclosures and two non-fenced plots received supplementary feed of rabbit chow. No food was provided at the other four plots. Pairs of grids were live-trapped four times/year from January 2005 to June 2007 and eight times/year from July 2007 to June 2009.

(1) Morris G., Hostetler J.A., Conner L.M. & Oli M.K. (2011) Effects of prescribed fire, supplemental feeding, and mammalian predator exclusion on hispid cotton rat populations. *Oecologia*, 167, 1005–1016, https://doi.org/10.1007/s00442-011-2053-6