

ConservationEvidence

Providing evidence to improve practice



What Works in Conservation



2018

EDITED BY

WILLIAM J. SUTHERLAND, LYNN V. DICKS,
NANCY OCKENDON, SILVIU O. PETROVAN AND REBECCA K. SMITH

What Works in Conservation 2018

**William J. Sutherland, Lynn V. Dicks, Nancy Ockendon, Silviu O. Petrovan
and Rebecca K. Smith (dir.)**

Publisher: Open Book Publishers
Year of publication: 2018
Published on OpenEdition Books: 21 March 2019
Serie: OBP collection
Electronic ISBN: 9791036524547



<http://books.openedition.org>

Printed version

ISBN: 9781783744282
Number of pages: 606

Electronic reference

SUTHERLAND, William J. (ed.) ; et al. *What Works in Conservation 2018*. New edition [online].
Cambridge: Open Book Publishers, 2018 (generated 25 avril 2021). Available on the Internet: <<http://books.openedition.org/obp/6257>>. ISBN: 9791036524547.

© Open Book Publishers, 2018
Creative Commons - Attribution 4.0 International - CC BY 4.0

WHAT WORKS IN CONSERVATION

What Works in Conservation

2018

Edited by

*William J. Sutherland, Lynn V. Dicks,
Nancy Ockendon, Silviu O. Petrovan and
Rebecca K. Smith*



<http://www.openbookpublishers.com>

© 2018 William J. Sutherland



This work is licensed under a Creative Commons Attribution 4.0 International license (CC BY 4.0). This license allows you to share, copy, distribute and transmit the work; to adapt the work and to make commercial use of the work providing attribution is made to the authors (but not in any way that suggests that they endorse you or your use of the work). Attribution should include the following information:

Sutherland, W.J., Dicks, L.V., Ockendon, N., Petrovan, S.O., and Smith, R.K. *What Works in Conservation 2018*. Cambridge, UK: Open Book Publishers, 2018. <https://doi.org/10.11647/OBP.0131>

In order to access detailed and updated information on the license, please visit <http://www.openbookpublishers.com/product/696#copyright>

Further details about CC BY licenses are available at <http://creativecommons.org/licenses/by/4.0/>

All links were active at the time of publication unless otherwise stated.

Digital material and resources associated with this volume are available at <http://www.openbookpublishers.com/product/696#resources> and <http://www.conservationevidence.com>

ISSN 2059-4232 (Print)

ISSN 2059-4240 (Online)

ISBN Paperback: 978-1-78374-428-2

ISBN Hardback: 978-1-78374-429-9

ISBN Digital (PDF): 978-1-78374-430-5

ISBN Digital ebook (epub): 978-1-78374-431-2

ISBN Digital ebook (mobi): 978-1-78374-432-9

DOI: 10.11647/OBP.0131


Funded by Arcadia, DEFRA, ESRC, MAVA Foundation, NERC, Natural England, Robert Bosch Stiftung, Synchronicity Earth, South West Water and Waitrose Ltd.

Cover image: A close up shot of the underside of a Dwarf Cavendish (*Musa acuminata*) by Ben Clough, CC BY-SA 3.0. Wikimedia http://commons.wikimedia.org/wiki/File:Dwarf_cavendish_leaf_2.jpg. Cover design: Heidi Coburn

All paper used by Open Book Publishers is SFI (Sustainable Forestry Initiative) and PEFC (Programme for the Endorsement of Forest Certification Schemes) certified.

Printed in the United Kingdom, United States and Australia
by Lightning Source for Open Book Publishers (Cambridge, UK).

Contents

Introduction	1
Who is <i>What Works in Conservation</i> for?	1
The Conservation Evidence project	1
Which conservation interventions are included?	2
How we review the literature	3
What does <i>What Works in Conservation</i> include?	4
Expert assessment of the evidence	4
Categorization of interventions	5
How to use <i>What Works in Conservation</i>	5
 1. AMPHIBIAN CONSERVATION	9
1.1 Threat: Residential and commercial development	11
Legal protection of species	11
Protect brownfield or ex-industrial sites	12
Restrict herbicide, fungicide and pesticide use on and around ponds on golf courses	12
1.2 Threat: Agriculture	13
1.2.1 Engage farmers and other volunteers	13
Engage landowners and other volunteers to manage land for amphibians	13
Pay farmers to cover the costs of conservation measures	13
1.2.2 Terrestrial habitat management	14
Manage silviculture practices in plantations	14
Manage cutting regime	14
Manage grazing regime	14
Maintain or restore hedges	15
Plant new hedges	15
Reduced tillage	15
1.2.3 Aquatic habitat management	15
Manage ditches	15
Exclude domestic animals or wild hogs from ponds by fencing	16
1.3 Threat: Energy production and mining	17
Artificially mist habitat to keep it damp	17

1.4 Threat: Transportation and service corridors	18
Close roads during seasonal amphibian migration	18
Modify gully pots and kerbs	19
Install barrier fencing along roads	19
Install culverts or tunnels as road crossings	19
Use signage to warn motorists	20
Use humans to assist migrating amphibians across roads	20
1.5 Threat: Biological resource use	21
1.5.1 Hunting and collecting terrestrial animals	21
Reduce impact of amphibian trade	21
Use legislative regulation to protect wild populations	22
Commercially breed amphibians for the pet trade	22
Use amphibians sustainably	22
1.5.2 Logging and wood harvesting	22
Retain riparian buffer strips during timber harvest	23
Use shelterwood harvesting instead of clearcutting	23
Leave coarse woody debris in forests	23
Use patch retention harvesting instead of clearcutting	24
Leave standing deadwood/snags in forests	24
Use leave-tree harvesting instead of clearcutting	24
Harvest groups of trees instead of clearcutting	25
Thin trees within forests	25
1.6 Threat: Human intrusions and disturbance	26
Use signs and access restrictions to reduce disturbance	26
1.7 Threat: Natural system modifications	27
Regulate water levels	27
Mechanically remove mid-storey or ground vegetation	28
Use herbicides to control mid-storey or ground vegetation	28
Use prescribed fire or modifications to burning regime (forests)	28
Use prescribed fire or modifications to burning regime (grassland)	29
1.8 Threat: Invasive and other problematic species	30
1.8.1 Reduce predation by other species	30
Remove or control fish by drying out ponds	30
Remove or control fish population by catching	31
Remove or control invasive bullfrogs	31
Remove or control invasive viperine snake	31
Remove or control mammals	31
Remove or control fish using Rotenone	32
Exclude fish with barriers	32
Encourage aquatic plant growth as refuge against fish predation	32
Remove or control non-native crayfish	32
1.8.2 Reduce competition with other species	33
Reduce competition from native amphibians	33
Remove or control invasive Cuban tree frogs	33
Remove or control invasive cane toads	33

1.8.3	Reduce adverse habitat alteration by other species	34
	Control invasive plants	34
	Prevent heavy usage/exclude wildfowl from aquatic habitat	34
1.8.4	Reduce parasitism and disease – chytridiomycosis	35
	Use temperature treatment to reduce infection	35
	Use antifungal treatment to reduce infection	35
	Add salt to ponds	36
	Immunize amphibians against infection	36
	Remove the chytrid fungus from ponds	36
	Sterilize equipment when moving between amphibian sites	37
	Treating amphibians in the wild or pre-release	37
	Use gloves to handle amphibians	37
	Use antibacterial treatment to reduce infection	37
	Use antifungal skin bacteria or peptides to reduce infection	38
	Use zooplankton to remove zoospores	38
1.8.5	Reduce parasitism and disease – ranaviruses	38
	Sterilize equipment to prevent ranaviruses	38
1.9	Threat: Pollution	39
1.9.1	Agricultural pollution	39
	Create walls or barriers to exclude pollutants	39
	Plant riparian buffer strips	39
	Reduce pesticide, herbicide or fertilizer use	40
	Prevent pollution from agricultural lands or sewage treatment facilities entering watercourses	40
1.9.2	Industrial pollution	40
	Add limestone to water bodies to reduce acidification	40
	Augment ponds with ground water to reduce acidification	41
1.10	Threat: Climate change and severe weather	42
	Create microclimate and microhabitat refuges	42
	Maintain ephemeral ponds	42
	Deepen ponds to prevent desiccation	43
	Use irrigation systems for amphibian sites	43
	Artificially shade ponds to prevent desiccation	43
	Protect habitat along elevational gradients	43
	Provide shelter habitat	43
1.11	Habitat protection	44
	Retain buffer zones around core habitat	44
	Protect habitats for amphibians	45
	Retain connectivity between habitat patches	45
1.12	Habitat restoration and creation	46
1.12.1	Terrestrial habitat	46
	Replant vegetation	46
	Clear vegetation	47
	Create artificial hibernacula or aestivation sites	47


Create refuges	47
Restore habitat connectivity	48
Change mowing regime	48
Create habitat connectivity	48
1.12.2 Aquatic habitat	48
Create ponds (amphibians in general)	49
Create ponds (frogs)	50
Create ponds (natterjack toads)	50
Create ponds (salamanders including newts)	50
Create wetlands	50
Deepen, de-silt or re-profile ponds	51
Restore wetlands	51
Create ponds (great crested newts)	52
Create ponds (green toads)	52
Create ponds (toads)	52
Remove specific aquatic plants	52
Restore ponds	53
Remove tree canopy to reduce pond shading	53
Add nutrients to new ponds as larvae food source	54
Add specific plants to aquatic habitats	54
Add woody debris to ponds	54
Create refuge areas in aquatic habitats	54
1.13 Species management	55
1.13.1 Translocate amphibians	55
Translocate amphibians (amphibians in general)	55
Translocate amphibians (great crested newts)	56
Translocate amphibians (natterjack toads)	56
Translocate amphibians (salamanders including newts)	56
Translocate amphibians (toads)	57
Translocate amphibians (wood frogs)	57
Translocate amphibians (frogs)	57
1.13.2 Captive breeding, rearing and releases	58
Release captive-bred individuals (amphibians in general)	59
Release captive-bred individuals (frogs)	59
Breed amphibians in captivity (frogs)	59
Breed amphibians in captivity (harlequin toads)	60
Breed amphibians in captivity (Mallorcan midwife toad)	60
Breed amphibians in captivity (salamanders including newts)	60
Breed amphibians in captivity (toads)	60
Head-start amphibians for release	61
Release captive-bred individuals (Mallorcan midwife toad)	61
Release captive-bred individuals (toads)	62
Use artificial fertilization in captive breeding	62
Use hormone treatment to induce sperm and egg release	62

Release captive-bred individuals (salamanders including newts)	63
Freeze sperm or eggs for future use	63
Release captive-bred individuals (green and golden bell frogs)	63
1.14 Education and awareness raising	64
Engage volunteers to collect amphibian data (citizen science)	64
Provide education programmes about amphibians	64
Raise awareness amongst the general public through campaigns and public information	65

2. BAT CONSERVATION 67

2.1 Threat: Residential and commercial development	69
Protect brownfield sites	69
Provide foraging habitat in urban areas	70
Change timing of building works	70
Conserve existing roosts within developments	70
Conserve old buildings or structures as roosting sites for bats within developments	70
Create alternative roosts within buildings	70
Maintain bridges and retain crevices for roosting	70
Retain or relocate access points to bat roosts	70
Retain or replace existing bat commuting routes within development	70
2.2 Threat: Agriculture	71
2.2.1 Land use change	71
Protect or create wetlands as foraging habitat for bats	71
Retain or plant trees on agricultural land to replace foraging habitat for bats	72
Conserve old buildings or structures on agricultural land as roosting sites for bats	72
Retain old or dead trees with hollows and cracks as roosting sites for bats on agricultural land	72
Retain or replace existing bat commuting routes on agricultural land	72
2.2.2 Intensive farming	72
Convert to organic farming	73
Encourage agroforestry	73
Introduce agri-environment schemes	73
2.3 Threat: Energy production – wind turbines	74
Switch off turbines at low wind speeds to reduce bat fatalities	74
Deter bats from turbines using ultrasound	75
Deter bats from turbines using radar	75
Automatically switch off wind turbines when bat activity is high	75
Close off nacelles on wind turbines to prevent roosting bats	75
Leave a minimum distance between turbines and habitat features used by bats	75

	Modify turbine design to reduce bat fatalities	75
	Modify turbine placement to reduce bat fatalities	75
	Remove turbine lighting to avoid attracting bats	75
2.4	Threat: Energy production – mining	76
	Legally protect bat hibernation sites in mines from reclamation	76
	Provide artificial hibernacula to replace roosts lost in reclaimed mines	76
	Relocate bats from reclaimed mines to new hibernation sites	76
2.5	Threat: Transportation and service corridors	77
	Install underpasses as road crossing structures for bats	77
	Divert bats to safe crossing points with plantings or fencing	78
	Install bat gantries or bat bridges as road crossing structures for bats	78
	Install overpasses as road crossing structures for bats	78
	Deter bats with lighting	78
	Install green bridges as road crossing structures for bats	78
	Install hop-overs as road crossing structures for bats	78
	Replace or improve habitat for bats around roads	78
2.6	Threat: Biological resource use	79
	2.6.1 Hunting	79
	Educate local communities about bats and hunting	79
	Introduce and enforce legislation to control hunting of bats	79
	Introduce sustainable harvesting of bats	79
	2.6.2 Guano harvesting	80
	Introduce and enforce legislation to regulate the harvesting of bat guano	80
	Introduce sustainable harvesting of bat guano	80
	2.6.3 Logging and wood harvesting	80
	Incorporate forested corridors or buffers into logged areas	81
	Use selective harvesting/reduced impact logging instead of clearcutting	81
	Use shelterwood cutting instead of clearcutting	81
	Retain residual tree patches in logged areas	82
	Thin trees within forests	82
	Manage woodland or forest edges for bats	82
	Replant native trees	82
	Retain deadwood/snags within forests for roosting bats	82
2.7	Threat: Human disturbance – caving and tourism	83
	Impose restrictions on cave visits	83
	Use cave gates to restrict public access	84
	Educate the public to reduce disturbance to hibernating bats	84
	Legally protect bat hibernation sites	84
	Maintain microclimate at underground hibernation/roost sites	84
	Provide artificial hibernacula for bats to replace disturbed sites	84

2.8	Threat: Natural system modification – natural fire and fire suppression	85
	Use prescribed burning	85
2.9	Threat: Invasive species	86
2.9.1	Invasive species	86
	Remove invasive plant species	86
	Translocate to predator or disease free areas	87
	Control invasive predators	87
2.9.2	White-nose syndrome	87
	Control anthropogenic spread	87
	Cull infected bats	87
	Increase population resistance	87
	Modify cave environments to increase bat survival	87
2.10	Threat: Pollution	88
2.10.1	Domestic and urban waste water	88
	Change effluent treatments of domestic and urban waste water	88
2.10.2	Agricultural and forestry effluents	89
	Introduce legislation to control use of fertilizers, insecticides and pesticides	89
	Change effluent treatments used in agriculture and forestry	89
2.10.3	Light and noise pollution	89
	Leave bat roosts, roost entrances and commuting routes unlit	89
	Minimize excess light pollution	90
	Restrict timing of lighting	90
	Use low pressure sodium lamps or use UV filters	90
	Impose noise limits in proximity to roosts and bat habitats	90
2.10.4	Timber treatments	90
	Use mammal safe timber treatments in roof spaces	90
	Restrict timing of treatment	91
2.11	Providing artificial roost structures for bats	92
	Provide artificial roost structures for bats	92
2.12	Education and awareness raising	93
	Provide training to professionals	93
	Educate homeowners about building and planning laws	93
	Educate to improve public perception and raise awareness	93
	3. BIRD CONSERVATION	95
3.1	Habitat protection	97
	Legally protect habitats for birds	97
	Provide or retain un-harvested buffer strips	97
	Ensure connectivity between habitat patches	98
3.2	Education and awareness raising	99
	Raise awareness amongst the general public through campaigns and public information	99

Provide bird feeding materials to families with young children	100
Enhance bird taxonomy skills through higher education and training	100
Provide training to conservationists and land managers on bird ecology and conservation	100
3.3 Threat: Residential and commercial development	101
Angle windows to reduce bird collisions	101
Mark windows to reduce bird collisions	101
3.4 Threat: Agriculture	103
3.4.1 All farming systems	103
Plant wild bird seed or cover mixture	104
Provide (or retain) set-aside areas in farmland	105
Create uncultivated margins around intensive arable or pasture fields	105
Increase the proportion of natural/semi-natural habitat in the farmed landscape	106
Manage ditches to benefit wildlife	106
Pay farmers to cover the costs of conservation measures	106
Plant grass buffer strips/margins around arable or pasture fields	107
Plant nectar flower mixture/wildflower strips	107
Leave refuges in fields during harvest	107
Reduce conflict by deterring birds from taking crops (using bird scarers)	108
Relocate nests at harvest time to reduce nestling mortality	108
Use mowing techniques to reduce mortality	108
Control scrub on farmland	108
Offer per clutch payment for farmland birds	109
Manage hedges to benefit wildlife	109
Plant new hedges	109
Reduce conflict by deterring birds from taking crops (using repellents)	109
Take field corners out of management	110
Mark bird nests during harvest or mowing	110
Cross compliance standards for all subsidy payments	110
Food labelling schemes relating to biodiversity-friendly farming	110
Manage stone-faced hedge banks to benefit birds	110
Plant in-field trees	110
Protect in-field trees	110
Reduce field size (or maintain small fields)	110
Support or maintain low-intensity agricultural systems	110
Tree pollarding, tree surgery	110
3.4.2 Arable farming	111
Create 'skylark plots' (undrilled patches in cereal fields)	111
Leave overwinter stubbles	112
Leave uncropped cultivated margins or fallow land (includes lapwing and stone curlew plots)	112

	Sow crops in spring rather than autumn	113
	Undersow spring cereals, with clover for example	113
	Reduce tillage	113
	Implement mosaic management	114
	Increase crop diversity to benefit birds	114
	Plant more than one crop per field (intercropping)	114
	Create beetle banks	114
	Plant cereals in wide-spaced rows	115
	Revert arable land to permanent grassland	115
	Add 1% barley into wheat crop for corn buntings	115
	Create corn bunting plots	115
	Leave unharvested cereal headlands within arable fields	115
	Plant nettle strips	115
3.4.3	Livestock farming	116
	Delay mowing date on grasslands	116
	Leave uncut rye grass in silage fields	117
	Maintain species-rich, semi-natural grassland	117
	Maintain traditional water meadows	117
	Mark fencing to avoid bird mortality	118
	Plant cereals for whole crop silage	118
	Reduce grazing intensity	118
	Reduce management intensity of permanent grasslands	119
	Exclude livestock from semi-natural habitat	119
	Create open patches or strips in permanent grassland	119
	Maintain upland heath/moor	120
	Protect nests from livestock to reduce trampling	120
	Provide short grass for waders	120
	Raise mowing height on grasslands	120
	Use traditional breeds of livestock	121
	Maintain lowland heathland	121
	Maintain rush pastures	121
	Maintain wood pasture and parkland	121
	Plant Brassica fodder crops	121
	Use mixed stocking	121
3.4.4	Perennial, non-timber crops	121
	Maintain traditional orchards	121
	Manage perennial bioenergy crops to benefit wildlife	122
3.4.5	Aquaculture	122
	Deter birds from landing on shellfish culture gear	123
	Disturb birds at roosts	123
	Provide refuges for fish within ponds	123
	Use electric fencing to exclude fish-eating birds	123
	Use 'mussel socks' to prevent birds from attacking shellfish	124
	Use netting to exclude fish-eating birds	124

Increase water turbidity to reduce fish predation by birds	124
Translocate birds away from fish farms	124
Use in-water devices to reduce fish loss from ponds	124
Disturb birds using foot patrols	125
Spray water to deter birds from ponds	125
Scare birds from fish farms	125
3.5 Threat: Energy production and mining	126
Paint wind turbines to increase their visibility	126
3.6 Threat: Transportation and service corridors	127
3.6.1 Verges and airports	127
Scare or otherwise deter birds from airports	127
Mow roadside verges	127
Sow roadside verges	128
3.6.2 Power lines and electricity pylons	128
Mark power lines	128
Bury or isolate power lines	129
Insulate electricity pylons	129
Remove earth wires from power lines	129
Use perch-deterrents to stop raptors perching on pylons	129
Thicken earth wires	129
Add perches to electricity pylons	130
Reduce electrocutions by using plastic, not metal, leg rings to mark birds	130
Use raptor models to deter birds from power lines	130
3.7 Threat: Biological resource use	131
3.7.1 Reducing exploitation and conflict	131
Use legislative regulation to protect wild populations	132
Use wildlife refuges to reduce hunting disturbance	132
Employ local people as 'biomonitors'	132
Increase 'on-the-ground' protection to reduce unsustainable levels of exploitation	132
Introduce voluntary 'maximum shoot distances'	133
Mark eggs to reduce their appeal to collectors	133
Move fish-eating birds to reduce conflict with fishermen	133
Promote sustainable alternative livelihoods	133
Provide 'sacrificial grasslands' to reduce conflict with farmers	134
Relocate nestlings to reduce poaching	134
Use education programmes and local engagement to help reduce persecution or exploitation of species	134
Use alerts during shoots to reduce mortality of non-target species	134
3.7.2 Reducing fisheries bycatch	135
Use streamer lines to reduce seabird bycatch on longlines	136
Mark trawler warp cables to reduce seabird collisions	136
Reduce seabird bycatch by releasing offal overboard when setting longlines	136

Weight baits or lines to reduce longline bycatch of seabirds	137
Set lines underwater to reduce seabird bycatch	137
Set longlines at night to reduce seabird bycatch	137
Dye baits to reduce seabird bycatch	138
Thaw bait before setting lines to reduce seabird bycatch	138
Turn deck lights off during night-time setting of longlines to reduce bycatch	138
Use a sonic scarer when setting longlines to reduce seabird bycatch	138
Use acoustic alerts on gillnets to reduce seabird bycatch	138
Use bait throwers to reduce seabird bycatch	139
Use bird exclusion devices such as 'Brickle curtains' to reduce seabird mortality when hauling longlines	139
Use high visibility mesh on gillnets to reduce seabird bycatch	139
Use shark liver oil to deter birds when setting lines	139
Use a line shooter to reduce seabird bycatch	140
Reduce bycatch through seasonal or area closures	140
Reduce 'ghost fishing' by lost/discarded gear	140
Reduce gillnet deployment time to reduce seabird bycatch	140
Set longlines at the side of the boat to reduce seabird bycatch	140
Tow buoys behind longlining boats to reduce seabird bycatch	140
Use a water cannon when setting longlines to reduce seabird bycatch	140
Use high-visibility longlines to reduce seabird bycatch	140
Use larger hooks to reduce seabird bycatch on longlines	140
3.8 Threat: Human intrusions and disturbance	141
Provide paths to limit disturbance	141
Start educational programmes for personal watercraft owners	142
Use signs and access restrictions to reduce disturbance at nest sites	142
Use voluntary agreements with local people to reduce disturbance	142
Habituate birds to human visitors	142
Use nest covers to reduce the impact of research on predation of ground-nesting seabirds	143
Reduce visitor group sizes	143
Set minimum distances for approaching birds (buffer zones)	143
3.9 Threat: Natural system modifications	144
Create scrapes and pools in wetlands and wet grasslands	146
Provide deadwood/snags in forests (use ring-barking, cutting or silvicides)	146
Use patch retention harvesting instead of clearcutting	146
Clear or open patches in forests	147
Employ grazing in artificial grasslands/pastures	147
Employ grazing in natural grasslands	147
Employ grazing in non-grassland habitats	148

Manage water level in wetlands	148
Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (forests)	148
Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (mowing or cutting natural grasslands)	149
Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (mowing or cutting semi-natural grasslands/pastures)	149
Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (shrublands)	150
Raise water levels in ditches or grassland	150
Thin trees within forests	150
Use prescribed burning (grasslands)	151
Use prescribed burning (pine forests)	151
Use prescribed burning (savannahs)	152
Use prescribed burning (shrublands)	152
Use selective harvesting/logging instead of clearcutting	152
Clearcut and re-seed forests	153
Coppice trees	153
Fertilise grasslands	153
Manage woodland edges for birds	154
Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (reedbeds)	154
Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (savannahs)	154
Plant trees to act as windbreaks	155
Plough habitats	155
Provide deadwood/snags in forests (adding woody debris to forests)	155
Remove coarse woody debris from forests	155
Replace non-native species of tree/shrub	156
Re-seed grasslands	156
Use environmentally sensitive flood management	156
Use fire suppression/control	156
Use greentree reservoir management	157
Use prescribed burning (Australian sclerophyll forest)	157
Use shelterwood cutting instead of clearcutting	157
Use variable retention management during forestry operations	157
Apply herbicide to mid- and understorey vegetation	158
Treat wetlands with herbicides	158
Use prescribed burning (coastal habitats)	158
Use prescribed burning (deciduous forests)	159
Protect nest trees before burning	159

3.10	Habitat restoration and creation	160
	Restore or create forests	160
	Restore or create wetlands and marine habitats (inland wetlands)	161
	Restore or create grassland	161
	Restore or create traditional water meadows	162
	Restore or create wetlands and marine habitats (coastal and intertidal wetlands)	162
	Restore or create shrubland	163
	Restore or create wetlands and marine habitats (kelp forests)	163
	Restore or create wetlands and marine habitats (lagoons)	163
	Restore or create savannahs	163
	Revegetate gravel pits	163
3.11	Threat: Invasive alien and other problematic species	164
3.11.1	Reduce predation by other species	164
	Control mammalian predators on islands	165
	Remove or control predators to enhance bird populations and communities	165
	Control avian predators on islands	165
	Control invasive ants on islands	166
	Reduce predation by translocating predators	166
	Control predators not on islands	166
3.11.2	Reduce incidental mortality during predator eradication or control	167
	Distribute poison bait using dispensers	167
	Use coloured baits to reduce accidental mortality during predator control	167
	Use repellents on baits	167
	Do birds take bait designed for pest control?	168
3.11.3	Reduce nest predation by excluding predators from nests or nesting areas	168
	Physically protect nests from predators using non-electric fencing	169
	Physically protect nests with individual enclosures/barriers or provide shelters for chicks	169
	Protect bird nests using electric fencing	169
	Use artificial nests that discourage predation	170
	Guard nests to prevent predation	170
	Plant nesting cover to reduce nest predation	170
	Protect nests from ants	170
	Use multiple barriers to protect nests	170
	Use naphthalene to deter mammalian predators	171
	Use snakeskin to deter mammalian nest predators	171
	Play spoken-word radio programmes to deter predators	171
	Use 'cat curfews' to reduce predation	171
	Use lion dung to deter domestic cats	171
	Use mirrors to deter nest predators	171

	Use ultrasonic devices to deter cats	171
	Can nest protection increase nest abandonment?	171
	Can nest protection increase predation of adults and chicks?	172
3.11.4	Reduce mortality by reducing hunting ability or changing predator behaviour	172
	Reduce predation by translocating nest boxes	172
	Use collar-mounted devices to reduce predation	173
	Use supplementary feeding to reduce predation	173
	Use aversive conditioning to reduce nest predation	173
3.11.5	Reduce competition with other species for food and nest sites	174
	Reduce inter-specific competition for food by removing or controlling competitor species	174
	Protect nest sites from competitors	175
	Reduce competition between species by providing nest boxes	175
	Reduce inter-specific competition for nest sites by modifying habitats to exclude competitor species	175
	Reduce inter-specific competition for nest sites by removing competitor species (ground nesting seabirds)	176
	Reduce inter-specific competition for nest sites by removing competitor species (songbirds)	176
	Reduce inter-specific competition for nest sites by removing competitor species (woodpeckers)	176
3.11.6	Reduce adverse habitat alteration by other species	177
	Control or remove habitat-altering mammals	177
	Reduce adverse habitat alterations by excluding problematic species (terrestrial species)	177
	Reduce adverse habitat alterations by excluding problematic species (aquatic species)	178
	Remove problematic vegetation	178
	Use buffer zones to reduce the impact of invasive plant control	178
3.11.7	Reduce parasitism and disease	179
	Remove/control adult brood parasites	179
	Remove/treat endoparasites and diseases	180
	Alter artificial nest sites to discourage brood parasitism	180
	Exclude or control 'reservoir species' to reduce parasite burdens	180
	Remove brood parasite eggs from target species' nests	180
	Remove/treat ectoparasites to increase survival or reproductive success (provide beneficial nesting material)	181
	Remove/treat ectoparasites to increase survival or reproductive success (remove ectoparasites from feathers)	181
	Use false brood parasite eggs to discourage brood parasitism	181
	Remove/treat ectoparasites to increase survival or reproductive success (remove ectoparasites from nests)	181
3.11.8	Reduce detrimental impacts of other problematic species	182
	Use copper strips to exclude snails from nests	182

3.12 Threat: Pollution	183
3.12.1 Industrial pollution	183
Use visual and acoustic ‘scarers’ to deter birds from landing on pools polluted by mining or sewage	183
Relocate birds following oil spills	184
Use repellents to deter birds from landing on pools polluted by mining	184
Clean birds after oil spills	184
3.12.2 Agricultural pollution	185
Leave headlands in fields unsprayed (conservation headlands)	185
Provide food for vultures to reduce mortality from diclofenac	186
Reduce pesticide, herbicide and fertiliser use generally	186
Reduce chemical inputs in permanent grassland management	186
Restrict certain pesticides or other agricultural chemicals	186
Make selective use of spring herbicides	187
Provide buffer strips along rivers and streams	187
Provide unfertilised cereal headlands in arable fields	187
Use buffer strips around in-field ponds	187
Use organic rather than mineral fertilisers	187
3.12.3 Air-borne pollutants	187
Use lime to reduce acidification in lakes	187
3.12.4 Excess energy	188
Shield lights to reduce mortality from artificial lights	188
Turning off lights to reduce mortality from artificial lights	188
Use flashing lights to reduce mortality from artificial lights	189
Use lights low in spectral red to reduce mortality from artificial lights	189
Reduce the intensity of lighthouse beams	189
Using volunteers to collect and rehabilitate downed birds	189
3.13 Threat: Climate change, extreme weather and geological events	190
Replace nesting habitats when they are washed away by storms	190
Water nesting mounds to increase incubation success in malleefowl	191
3.14 General responses to small/ declining populations	192
3.14.1 Inducing breeding, rehabilitation and egg removal	192
Rehabilitate injured birds	192
Remove eggs from wild nests to increase reproductive output	193
Use artificial visual and auditory stimuli to induce breeding in wild populations	193
3.14.2 Provide artificial nesting sites	193
Provide artificial nests (falcons)	194
Provide artificial nests (owls)	195
Provide artificial nests (songbirds)	195
Provide artificial nests (wildfowl)	196
Clean artificial nests to increase occupancy or reproductive success	196

Provide artificial nests (burrow-nesting seabirds)	197
Provide artificial nests (divers/loons)	197
Provide artificial nests (ground- and tree-nesting seabirds)	197
Provide artificial nests (oilbirds)	198
Provide artificial nests (raptors)	198
Provide artificial nests (wildfowl – artificial/floating islands)	198
Artificially incubate eggs or warm nests	198
Guard nests	199
Provide artificial nests (gamebirds)	199
Provide artificial nests (grebes)	199
Provide artificial nests (ibises and flamingos)	199
Provide artificial nests (parrots)	199
Provide artificial nests (pigeons)	200
Provide artificial nests (rails)	200
Provide artificial nests (rollers)	200
Provide artificial nests (swifts)	200
Provide artificial nests (trogons)	201
Provide artificial nests (waders)	201
Provide artificial nests (woodpeckers)	201
Provide nesting habitat for birds that is safe from extreme weather	201
Provide nesting material for wild birds	202
Remove vegetation to create nesting areas	202
Repair/support nests to support breeding	202
Use differently-coloured artificial nests	202
3.14.3 Foster chicks in the wild	203
Foster eggs or chicks with wild conspecifics (raptors)	203
Foster eggs or chicks with wild non-conspecifics (cross-fostering) (songbirds)	204
Foster eggs or chicks with wild conspecifics (bustards)	204
Foster eggs or chicks with wild conspecifics (cranes)	204
Foster eggs or chicks with wild conspecifics (gannets and boobies)	204
Foster eggs or chicks with wild conspecifics (owls)	205
Foster eggs or chicks with wild conspecifics (parrots)	205
Foster eggs or chicks with wild conspecifics (vultures)	205
Foster eggs or chicks with wild conspecifics (waders)	205
Foster eggs or chicks with wild conspecifics (woodpeckers)	206
Foster eggs or chicks with wild non-conspecifics (cross-fostering) (cranes)	206
Foster eggs or chicks with wild non-conspecifics (cross-fostering) (ibises)	206
Foster eggs or chicks with wild non-conspecifics (cross-fostering) (petrels and shearwaters)	206
Foster eggs or chicks with wild non-conspecifics (cross-fostering) (waders)	206

3.14.4 Provide supplementary food	207
Provide supplementary food to increase adult survival (songbirds)	209
Place feeders close to windows to reduce collisions	209
Provide calcium supplements to increase survival or reproductive success	210
Provide supplementary food to increase adult survival (cranes)	210
Provide supplementary food to increase reproductive success (gulls, terns and skuas)	210
Provide supplementary food to increase reproductive success (owls)	210
Provide supplementary food to increase reproductive success (raptors)	211
Provide supplementary food to increase reproductive success (songbirds)	211
Provide perches to improve foraging success	212
Provide supplementary food through the establishment of food populations	212
Provide supplementary food to allow the rescue of a second chick	213
Provide supplementary food to increase adult survival (gamebirds)	213
Provide supplementary food to increase adult survival (gulls, terns and skuas)	213
Provide supplementary food to increase adult survival (hummingbirds)	213
Provide supplementary food to increase adult survival (nectar-feeding songbirds)	214
Provide supplementary food to increase adult survival (pigeons)	214
Provide supplementary food to increase adult survival (raptors)	214
Provide supplementary food to increase adult survival (vultures)	215
Provide supplementary food to increase adult survival (waders)	215
Provide supplementary food to increase adult survival (wildfowl)	215
Provide supplementary food to increase adult survival (woodpeckers)	215
Provide supplementary food to increase reproductive success (auks)	216
Provide supplementary food to increase reproductive success (gamebirds)	216
Provide supplementary food to increase reproductive success (gannets and boobies)	216
Provide supplementary food to increase reproductive success (ibises)	217
Provide supplementary food to increase reproductive success (kingfishers)	217
Provide supplementary food to increase reproductive success (parrots)	217
Provide supplementary food to increase reproductive success (petrels)	217

Provide supplementary food to increase reproductive success (pigeons)	218
Provide supplementary food to increase reproductive success (rails and coots)	218
Provide supplementary food to increase reproductive success (vultures)	218
Provide supplementary food to increase reproductive success (waders)	219
Provide supplementary food to increase reproductive success (wildfowl)	219
Provide supplementary water to increase survival or reproductive success	219
3.14.5 Translocations	219
Translocate birds to re-establish populations or increase genetic variation (birds in general)	221
Translocate birds to re-establish populations or increase genetic variation (raptors)	221
Translocate birds to re-establish populations or increase genetic variation (parrots)	221
Translocate birds to re-establish populations or increase genetic variation (pelicans)	221
Translocate birds to re-establish populations or increase genetic variation (petrels and shearwaters)	222
Translocate birds to re-establish populations or increase genetic variation (rails)	222
Translocate birds to re-establish populations or increase genetic variation (songbirds)	222
Translocate birds to re-establish populations or increase genetic variation (wildfowl)	222
Translocate birds to re-establish populations or increase genetic variation (woodpeckers)	223
Use decoys to attract birds to new sites	223
Use techniques to increase the survival of species after capture	223
Use vocalisations to attract birds to new sites	224
Translocate birds to re-establish populations or increase genetic variation (gamebirds)	224
Alter habitats to encourage birds to leave	224
Ensure translocated birds are familiar with each other before release	224
Translocate birds to re-establish populations or increase genetic variation (auks)	225
Translocate birds to re-establish populations or increase genetic variation (herons, storks and ibises)	225
Translocate birds to re-establish populations or increase genetic variation (megapodes)	225
Translocate birds to re-establish populations or increase genetic variation (owls)	225
Translocate nests to avoid disturbance	226
Ensure genetic variation to increase translocation success	226

3.15	Captive breeding, rearing and releases (<i>ex situ</i> conservation)	227
3.15.1	Captive breeding	227
	Artificially incubate and hand-rear birds in captivity (raptors)	229
	Artificially incubate and hand-rear birds in captivity (seabirds)	229
	Artificially incubate and hand-rear birds in captivity (songbirds)	229
	Artificially incubate and hand-rear birds in captivity (waders)	230
	Use captive breeding to increase or maintain populations (raptors)	230
	Artificially incubate and hand-rear birds in captivity (bustards)	230
	Artificially incubate and hand-rear birds in captivity (cranes)	231
	Artificially incubate and hand-rear birds in captivity (gamebirds)	231
	Artificially incubate and hand-rear birds in captivity (parrots)	231
	Artificially incubate and hand-rear birds in captivity (penguins)	231
	Artificially incubate and hand-rear birds in captivity (rails)	232
	Artificially incubate and hand-rear birds in captivity (storks and ibises)	232
	Artificially incubate and hand-rear birds in captivity (vultures)	232
	Artificially incubate and hand-rear birds in captivity (wildfowl)	232
	Freeze semen for artificial insemination	233
	Use artificial insemination in captive breeding	233
	Use captive breeding to increase or maintain populations (bustards)	233
	Use captive breeding to increase or maintain populations (cranes)	234
	Use captive breeding to increase or maintain populations (pigeons)	234
	Use captive breeding to increase or maintain populations (rails)	234
	Use captive breeding to increase or maintain populations (seabirds)	234
	Use captive breeding to increase or maintain populations (songbirds)	234
	Use captive breeding to increase or maintain populations (storks and ibises)	235
	Use captive breeding to increase or maintain populations (tinamous)	235
	Use puppets to increase the success of hand-rearing	235
	Wash contaminated semen and use it for artificial insemination	236
	Can captive breeding have deleterious effects?	236
3.15.2	Release captive-bred individuals	236
	Provide supplementary food after release	237
	Release captive-bred individuals into the wild to restore or augment wild populations (cranes)	238
	Release captive-bred individuals into the wild to restore or augment wild populations (raptors)	238
	Release captive-bred individuals into the wild to restore or augment wild populations (songbirds)	238
	Release captive-bred individuals into the wild to restore or augment wild populations (vultures)	239
	Clip birds' wings on release	239
	Release birds as adults or sub-adults not juveniles	239
	Release birds in groups	240

Release captive-bred individuals into the wild to restore or augment wild populations (bustards)	240
Release captive-bred individuals into the wild to restore or augment wild populations (gamebirds)	240
Release captive-bred individuals into the wild to restore or augment wild populations (owls)	240
Release captive-bred individuals into the wild to restore or augment wild populations (parrots)	241
Release captive-bred individuals into the wild to restore or augment wild populations (pigeons)	241
Release captive-bred individuals into the wild to restore or augment wild populations (rails)	241
Release captive-bred individuals into the wild to restore or augment wild populations (storks and ibises)	242
Release captive-bred individuals into the wild to restore or augment wild populations (waders)	242
Release captive-bred individuals into the wild to restore or augment wild populations (wildfowl)	242
Release chicks and adults in 'coveys'	242
Use 'anti-predator training' to improve survival after release	243
Use appropriate populations to source released populations	243
Use 'flying training' before release	243
Use holding pens at release sites	243
Use microlites to help birds migrate	244

4. FARMLAND CONSERVATION 245


4.1 All farming systems 247

Create uncultivated margins around intensive arable or pasture fields	248
Plant grass buffer strips/margins around arable or pasture fields	249
Plant nectar flower mixture/wildflower strips	249
Plant wild bird seed or cover mixture	249
Provide or retain set-aside areas in farmland	250
Manage ditches to benefit wildlife	250
Manage hedgerows to benefit wildlife (includes no spray, gap-filling and laying)	251
Pay farmers to cover the cost of conservation measures (as in agri-environment schemes)	251
Provide supplementary food for birds or mammals	251
Connect areas of natural or semi-natural habitat	252
Increase the proportion of semi-natural habitat in the farmed landscape	252
Make direct payments per clutch for farmland birds	252
Manage the agricultural landscape to enhance floral resources	252
Mark bird nests during harvest or mowing	253

Plant new hedges	253
Provide nest boxes for bees (solitary bees or bumblebees)	253
Provide nest boxes for birds	253
Provide other resources for birds (water, sand for bathing)	254
Provide refuges during harvest or mowing	254
Apply 'cross compliance' environmental standards linked to all subsidy payments	254
Implement food labelling schemes relating to biodiversity-friendly farming (organic, LEAF marque)	254
Introduce nest boxes stocked with solitary bees	254
Maintain in-field elements such as field islands and rockpiles	254
Manage stone-faced hedge banks to benefit wildlife	254
Manage woodland edges to benefit wildlife	254
Plant in-field trees (not farm woodland)	254
Protect in-field trees (includes management such as pollarding and surgery)	255
Provide badger gates	255
Provide foraging perches (e.g. for shrikes)	255
Provide otter holts	255
Provide red squirrel feeders	255
Reduce field size (or maintain small fields)	255
Restore or maintain dry stone walls	255
Support or maintain low intensity agricultural systems	255
4.2 Arable farming	256
Create skylark plots	257
Leave cultivated, uncropped margins or plots (includes 'lapwing plots')	257
Create beetle banks	257
Leave overwinter stubbles	258
Reduce tillage	258
Undersow spring cereals, with clover for example	258
Convert or revert arable land to permanent grassland	259
Create rotational grass or clover leys	259
Increase crop diversity	259
Plant cereals in wide-spaced rows	259
Plant crops in spring rather than autumn	260
Plant nettle strips	260
Sow rare or declining arable weeds	260
Add 1% barley into wheat crop for corn buntings	260
Create corn bunting plots	260
Leave unharvested cereal headlands in arable fields	260
Use new crop types to benefit wildlife (such as perennial cereal crops)	260
Implement 'mosaic management', a Dutch agri-environment option	261

Plant more than one crop per field (intercropping)	261
Take field corners out of management	261
4.3 Perennial (non-timber) crops	262
Maintain traditional orchards	262
Manage short-rotation coppice to benefit wildlife (includes 8 m rides)	262
Restore or create traditional orchards	262
4.4 Livestock farming	263
Restore or create species-rich, semi-natural grassland	264
Use mowing techniques to reduce mortality	264
Delay mowing or first grazing date on grasslands	265
Leave uncut strips of rye grass on silage fields	265
Maintain species-rich, semi-natural grassland	265
Maintain traditional water meadows (includes management for breeding and/or wintering waders/waterfowl)	266
Maintain upland heath/moorland	266
Reduce management intensity on permanent grasslands (several interventions at once)	266
Restore or create traditional water meadows	267
Add yellow rattle seed <i>Rhinanthus minor</i> to hay meadows	267
Employ areas of semi-natural habitat for rough grazing (includes salt marsh, lowland heath, bog, fen)	267
Exclude livestock from semi-natural habitat (including woodland)	268
Maintain wood pasture and parkland	268
Plant cereals for whole crop silage	268
Raise mowing height on grasslands	268
Restore or create upland heath/moorland	269
Restore or create wood pasture	269
Use traditional breeds of livestock	269
Reduce grazing intensity on grassland (including seasonal removal of livestock)	269
Maintain rush pastures	270
Mark fencing to avoid bird mortality	270
Plant brassica fodder crops (grazed in situ)	270
Create open patches or strips in permanent grassland	270
Provide short grass for birds	270
Use mixed stocking	270
4.5 Threat: Residential and commercial development	271
Provide owl nest boxes (tawny owl, barn owl)	271
Maintain traditional farm buildings	271
Provide bat boxes, bat grilles, improvements to roosts	271
4.6 Threat: Agri-chemicals	272
Leave headlands in fields unsprayed (conservation headlands)	272
Reduce fertilizer, pesticide or herbicide use generally	273

	Use organic rather than mineral fertilizers	273
	Reduce chemical inputs in grassland management	273
	Provide buffer strips alongside water courses (rivers and streams)	274
	Restrict certain pesticides	274
	Buffer in-field ponds	274
	Make selective use of spring herbicides	274
4.7	Threat: Transport and service corridors	275
	Manage land under power lines to benefit wildlife	275
4.8	Threat: Hunting and trapping (for pest control, food or sport)	276
	Enforce legislation to protect birds against persecution	276
	Provide 'sacrificial' grasslands to reduce the impact of wild geese on crops	277
	Avoid use of lead shot	277
	Use alerts to reduce grey partridge by-catch during shoots	277
	Use scaring devices (e.g. gas guns) and other deterrents to reduce persecution of native species	277
4.9	Threat: Natural system modification	278
	Raise water levels in ditches or grassland	278
	Create scrapes and pools	279
	Manage heather by swiping to simulate burning	279
	Manage heather, gorse or grass by burning	279
	Remove flood defence banks to allow inundation	279
	Re-wet moorland	280
4.10	Threat: Invasive and other problematic species	281
	Control predatory mammals and birds (foxes, crows, stoats and weasels)	281
	Control scrub	282
	Control weeds without damaging other plants in conservation areas	282
	Protect individual nests of ground-nesting birds	282
	Control grey squirrels	282
	Erect predator-proof fencing around important breeding sites for waders	283
	Manage wild deer numbers	283
	Remove coarse fish	283
	Control bracken	283
	Control invasive non-native plants on farmland (such as Himalayan balsam, Japanese knotweed)	283
	Control mink	283
	Provide medicated grit for grouse	283
4.11	Threat: Education and awareness	284
	Provide specialist advice, assistance preparing conservation plans	284
	Provide training for land managers, farmers and farm advisers	284

 5. FOREST CONSERVATION	285
5.1 Threat: Residential and commercial development	287
5.1.1 Housing and urban areas	287
Compensate for woodland removal with compensatory planting	287
Incorporate existing trees or woods into the landscape of new developments	287
Provide legal protection of forests from development	287
5.1.2 Tourism and recreation areas	288
Adopt ecotourism	288
Create managed paths/signs to contain disturbance	288
Re-route paths, control access or close paths	288
Use warning signs to prevent fire	288
5.2 Threat: Agriculture	289
5.2.1 Livestock farming	289
Use wire fences within grazing areas to exclude livestock from specific forest sections	289
Prevent livestock grazing in forests	290
Reduce the intensity of livestock grazing in forests	290
Shorten livestock grazing period or control grazing season in forests	290
Provide financial incentives not to graze	291
5.3 Threat: Transport and service corridors	292
Maintain/create habitat corridors	292
5.4 Threat: Biological resource use	293
5.4.1 Thinning and wood harvesting	293
Log/remove trees within forests: effects on understory plants	294
Thin trees within forests: effects on understory plants	294
Thin trees within forests: effects on young trees	294
Use shelterwood harvest instead of clearcutting	295
Thin trees within forests: effects on mature trees	295
Log/remove trees within forests: effects on young trees	295
Use partial retention harvesting instead of clearcutting	295
Use summer instead of winter harvesting	296
Remove woody debris after timber harvest	296
Log/remove trees within forests: effect on mature trees	296
Log/remove trees within forests: effect on effects on non-vascular plants	297
Thin trees within forests: effects on non-vascular plants	297
Adopt continuous cover forestry	297
Use brush mats during harvesting to avoid soil compaction	297
5.4.2 Harvest forest products	297
Adopt certification	298
Sustainable management of non-timber products	298
5.4.3 Firewood	298
Provide fuel efficient stoves	298
Provide paraffin stoves	298

5.5	Habitat protection	299
5.5.1	Changing fire frequency	299
	Use prescribed fire: effect on understory plants	299
	Use prescribed fire: effect on young trees	300
	Use prescribed fire: effect on mature trees	300
	Mechanically remove understory vegetation to reduce wildfires	300
	Use herbicides to remove understory vegetation to reduce wildfires	300
5.5.2	Water management	301
	Construct water detention areas to slow water flow and restore riparian forests	301
	Introduce beavers to impede water flow in forest watercourses	301
	Recharge groundwater to restore wetland forest	301
5.5.3	Changing disturbance regime	301
	Use clearcutting to increase understory diversity	302
	Use group-selection harvesting	302
	Use shelterwood harvesting	303
	Thin trees by girdling (cutting rings around tree trunks)	303
	Use herbicides to thin trees	303
	Use thinning followed by prescribed fire	303
	Adopt conservation grazing of woodland	304
	Coppice trees	304
	Halo ancient trees	304
	Imitate natural disturbances by pushing over trees	304
	Pollard trees (top cutting or top pruning)	304
	Reintroduce large herbivores	304
	Retain fallen trees	304
5.6	Threat: Invasive and other problematic species	305
5.6.1	Invasive plants	305
	Manually/mechanically remove invasive plants	305
	Use herbicides to remove invasive plant species	306
	Use grazing to remove invasive plant species	306
	Use prescribed fire to remove invasive plant species	306
5.6.2	Native plants	306
	Manually/mechanically remove native plants	306
5.6.3	Herbivores	306
	Use wire fences to exclude large native herbivores	307
	Use electric fencing to exclude large native herbivores	307
	Control large herbivore populations	307
	Control medium-sized herbivores	307
	Use fencing to enclose large herbivores (e.g. deer)	307
5.6.4	Rodents	308
	Control rodents	308
5.6.5	Birds	308
	Control birds	308

5.7 Threat: Pollution	309
Maintain/create buffer zones	309
Remove nitrogen and phosphorus using harvested products	309
5.8 Threat: Climate change and severe weather	310
Prevent damage from strong winds	310
5.9 Habitat protection	311
Adopt community-based management to protect forests	311
Legal protection of forests	311
Adopt Protected Species legislation (impact on forest management)	312
5.10 Habitat restoration and creation	313
5.10.1 Restoration after wildfire	313
Thin trees after wildfire	313
Remove burned trees	314
Sow tree seeds after wildfire	314
Plant trees after wildfire	314
5.10.2 Restoration after agriculture	314
Restore wood pasture (e.g. introduce grazing)	315
5.10.3 Manipulate habitat to increase planted tree survival during restoration	315
Apply herbicides after restoration planting	315
Cover the ground using techniques other than plastic mats after restoration planting	316
Cover the ground with plastic mats after restoration planting	316
Use selective thinning after restoration planting	316
5.10.4 Restore forest community	316
Build bird-perches to enhance natural seed dispersal	317
Plant a mixture of tree species to enhance diversity	317
Sow tree seeds	317
Water plants to preserve dry tropical forest species	317
Restore woodland herbaceous plants using transplants and nursery plugs	317
Use rotational grazing to restore oak savannas	317
5.10.5 Prevent/encourage leaf litter accumulation	318
Remove or disturb leaf litter to enhance germination	318
Encourage leaf litter development in new planting	318
5.10.6 Increase soil fertility	318
Use vegetation removal together with mechanical disturbance to the soil	319
Add organic matter	319
Use fertilizer	319
Use soil scarification or ploughing to enhance germination	320
Add lime to the soil to increase fertility	320
Use soil disturbance to enhance germination (excluding scarification or ploughing)	320

Enhance soil compaction	321
5.11 Actions to improve survival and growth rate of planted trees	322
Prepare the ground before tree planting	323
Use mechanical thinning before or after planting	323
Fence to prevent grazing after tree planting	323
Use herbicide after tree planting	324
Use prescribed fire after tree planting	324
Apply insecticide to protect seedlings from invertebrates	324
Add lime to the soil after tree planting	325
Add organic matter after tree planting	325
Cover the ground with straw after tree planting	325
Improve soil quality after tree planting (excluding applying fertilizer)	325
Manage woody debris before tree planting	325
Use shading for planted trees	326
Use tree guards or shelters to protect planted trees	326
Use weed mats to protect planted trees	326
Water seedlings	326
Mechanically remove understory vegetation after tree planting	326
Use different planting or seeding methods	327
Use fertilizer after tree planting	327
Apply fungicide to protect seedlings from fungal diseases	327
Infect tree seedlings with mycorrhizae	327
Introduce leaf litter to forest stands	327
Plant a mixture of tree species to enhance the survival and growth of planted trees	327
Reduce erosion to increase seedling survival	327
Transplant trees	327
Use pioneer plants or crops as nurse-plants	327
5.12 Education and awareness raising	328
Provide education programmes about forests	328
Raise awareness amongst the general public through campaigns and public information	328



6. PEATLAND CONSERVATION	329
6.1 Threat: Residential and commercial development	331
Remove residential or commercial development from peatlands	331
Retain/create habitat corridors in developed areas	331
6.2 Threat: Agriculture and aquaculture	332
6.2.1 Multiple farming systems	332
Retain/create habitat corridors in farmed areas	332
Implement 'mosaic management' of agriculture	333
6.2.2 Wood and pulp plantations	333
Cut/remove/thin forest plantations	333
Cut/remove/thin forest plantations and rewet peat	334

6.2.3 Livestock farming and ranching	335
Exclude or remove livestock from degraded peatlands	335
Reduce intensity of livestock grazing	337
Use barriers to keep livestock off ungrazed peatlands	337
Change type of livestock	337
Change season/timing of livestock grazing	337
6.3 Threat: Energy production and mining	338
Replace blocks of vegetation after mining or peat extraction	338
Retain/create habitat corridors in areas of energy production or mining	339
6.4 Threat: Transportation and service corridors	340
Maintain/restore water flow across service corridors	340
Backfill trenches dug for pipelines	340
Retain/create habitat corridors across service corridors	340
6.5 Threat: Biological resource use	341
Reduce intensity of harvest	341
Reduce frequency of harvest	342
Use low impact harvesting techniques	342
Use low impact vehicles for harvesting	342
Implement 'mosaic management' when harvesting wild biological resources	342
Provide new technologies to reduce pressure on wild biological resources	342
6.6 Threat: Human intrusions and disturbance	343
Physically exclude vehicles from peatlands	343
Restrict vehicle use on peatlands	344
Restrict pedestrian access to peatlands	344
Physically exclude pedestrians from peatlands	344
Install boardwalks/paths to prevent trampling	344
Wear snowshoes to prevent trampling	344
Adopt ecotourism principles/create an ecotourism site	344
6.7 Threat: Natural system modifications	345
6.7.1 Modified water management	345
Rewet peatland (raise water table)	345
Irrigate peatland	348
Reduce water level of flooded peatlands	348
Restore natural water level fluctuations	348
6.7.2 Modified vegetation management	348
Cut/mow herbaceous plants to maintain or restore disturbance	349
Cut large trees/shrubs to maintain or restore disturbance	350
Use grazing to maintain or restore disturbance	351
Remove plant litter to maintain or restore disturbance	352
Use prescribed fire to maintain or restore disturbance	353

6.7.3	Modified wild fire regime	354
	Thin vegetation to prevent wild fires	354
	Rewet peat to prevent wild fires	354
	Build fire breaks	354
	Adopt zero burning policies near peatlands	354
6.8	Threat: Invasive and other problematic species	355
6.8.1	All problematic species	355
	Implement biosecurity measures to prevent introductions of problematic species	355
6.8.2	Problematic plants	355
	Use prescribed fire to control problematic plants	356
	Physically remove problematic plants	357
	Use cutting/mowing to control problematic herbaceous plants	358
	Change season/timing of cutting/mowing	358
	Use cutting to control problematic large trees/shrubs	359
	Use herbicide to control problematic plants	360
	Introduce an organism to control problematic plants	360
	Physically damage problematic plants	360
	Use grazing to control problematic plants	360
	Use covers/barriers to control problematic plants	360
6.8.3	Problematic animals	361
	Exclude wild herbivores using physical barriers	361
	Control populations of wild herbivores	361
6.9	Threat: Pollution	362
6.9.1	Multiple sources of pollution	362
	Divert/replace polluted water source(s)	362
	Clean waste water before it enters the environment	363
	Slow down input water to allow more time for pollutants to be removed	363
	Retain or create buffer zones between pollution sources and peatlands	364
	Use artificial barriers to prevent pollution entering peatlands	364
	Reduce fertilizer or herbicide use near peatlands	364
	Manage fertilizer or herbicide application near peatlands	364
6.9.2	Agricultural and aquacultural effluents	364
	Convert to organic agriculture or aquaculture near peatlands	364
	Limit the density of livestock on farmland near peatlands	364
	Use biodegradable oil in farming machinery	364
6.9.3	Industrial and military effluents	365
	Remove oil from contaminated peatlands	365
6.9.4	Airborne pollutants	365
	Remove pollutants from waste gases before they enter the environment	365
	Add lime to reduce acidity and/or increase fertility	366
	Drain/replace acidic water	366

6.10 Threat: Climate change and severe weather	367
Add water to peatlands to compensate for drought	367
Plant shelter belts to protect peatlands from wind	367
Build barriers to protect peatlands from the sea	367
Restore/create peatlands in areas that will be climatically suitable in the future	367
6.11 Habitat creation and restoration	368
6.11.1 General habitat creation and restoration	368
Restore/create peatland vegetation (multiple interventions)	368
Restore/create peatland vegetation using the moss layer transfer technique	369
6.11.2 Modify physical habitat only	370
Fill/block ditches to create conditions suitable for peatland plants	371
Remove upper layer of peat/soil	371
Excavate pools	372
Reprofile/relandscape peatland	373
Disturb peatland surface to encourage growth of desirable plants	373
Add inorganic fertilizer	374
Cover peatland with organic mulch	374
Cover peatland with something other than mulch	375
Stabilize peatland surface to help plants colonize	375
Build artificial bird perches to encourage seed dispersal	375
Roughen peat surface to create microclimates	376
Bury upper layer of peat/soil	376
Introduce nurse plants	376
6.11.3 Introduce peatland vegetation	376
Add mosses to peatland surface	376
Add mixed vegetation to peatland surface	377
Directly plant peatland mosses	378
Directly plant peatland herbs	378
Directly plant peatland trees/shrubs	379
Introduce seeds of peatland herbs	379
Introduce seeds of peatland trees/shrubs	380
6.12 Actions to complement planting	382
Cover peatland with organic mulch (after planting)	383
Cover peatland with something other than mulch (after planting)	383
Reprofile/relandscape peatland (before planting)	384
Add inorganic fertilizer (before/after planting)	385
Introduce nurse plants (to aid focal peatland plants)	386
Irrigate peatland (before/after planting)	386
Create mounds or hollows (before planting)	386
Add fresh peat to peatland (before planting)	387
Remove vegetation that could compete with planted peatland vegetation	387
Add root-associated fungi to plants (before planting)	387

Add lime (before/after planting)	388
Add organic fertilizer (before/after planting)	388
Rewet peatland (before/after planting)	388
Remove upper layer of peat/soil (before planting)	388
Bury upper layer of peat/soil (before planting)	388
Encapsulate planted moss fragments in beads/gel	388
Use fences or barriers to protect planted vegetation	388
Protect or prepare vegetation before planting (other interventions)	388
6.13 Habitat protection	389
Legally protect peatlands	389
Pay landowners to protect peatlands	390
Increase 'on the ground' protection (e.g. rangers)	390
Create legislation for 'no net loss' of wetlands	390
Adopt voluntary agreements to protect peatlands	390
Allow sustainable use of peatlands	390
6.14 Education and awareness	391
Raise awareness amongst the public (general)	391
Provide education or training programmes about peatlands or peatland management	392
Lobby, campaign or demonstrate to protect peatlands	392
Raise awareness amongst the public (wild fire)	392
Raise awareness amongst the public (problematic species)	392
Raise awareness through engaging volunteers in peatland management or monitoring	392



7. PRIMATE CONSERVATION

7.1 Threat: Residential and commercial development	395
Remove and relocate 'problem' animals	395
Relocate primates to non-residential areas	396
Discourage the planting of fruit trees and vegetable gardens on the urban edge biodiversity-friendly farming	396
7.2 Threat: Agriculture	397
Humans chase primates using random loud noise	398
Prohibit (livestock) farmers from entering protected areas	399
Use nets to keep primates out of fruit trees	399
Create natural habitat islands within agricultural land	399
Use fences as biological corridors for primates	399
Provide sacrificial rows of crops on outer side of fields	399
Compensate farmers for produce loss caused by primates	399
Pay farmers to cover the costs of non-harmful strategies to deter primates	399
Retain nesting trees/shelter for primates within agricultural fields	399
Plant nesting trees/shelter for primates within agricultural fields	399
Regularly remove traps and snares around agricultural fields	399
Certify farms and market their products as 'primate friendly'	400


Farm more intensively and effectively in selected areas and spare more natural land	400
Install mechanical barriers to deter primates (e.g. fences, ditches)	400
Use of natural hedges to deter primates	400
Use of unpalatable buffer crops	400
Change of crop (i.e. to a crop less palatable to primates)	400
Plant crops favoured by primates away from primate areas	400
Destroy habitat within buffer zones to make them unusable for primates	400
Use GPS and/or VHF tracking devices on individuals of problem troops to provide farmers with early warning of crop raiding	400
Chase crop-raiding primates using dogs	400
Train langur monkeys to deter rhesus macaques	400
Use loud-speakers to broadcast sounds of potential threats (e.g. barking dogs, explosions, gunshots)	400
Use loud-speakers to broadcast primate alarm calls	400
Strategically lay out the scent of a primate predator (e.g. leopard, lion)	400
Humans chase primates using bright light	400
7.3 Threat: Energy production and mining	401
Minimize ground vibrations caused by open cast mining activities	401
Establish no-mining zones in/near watersheds so as to preserve water levels and water quality	401
Use 'set-aside' areas of natural habitat for primate protection within mining area	401
Certify mines and market their products as 'primate friendly' (e.g. ape-friendly cellular phones)	401
Create/preserve primate habitat on islands before dam construction	401
7.4 Threat: Transportation and service corridors	402
Install rope or pole (canopy) bridges	403
Install green bridges (overpasses)	403
Implement speed limits in particular areas (e.g. with high primate densities) to reduce vehicle collisions with primates	403
Reduce road widths	403
Impose fines for breaking the speed limit or colliding with primates	403
Avoid building roads in key habitat or migration routes	403
Implement a minimum number of roads (and minimize secondary roads) needed to reach mining extraction sites	403
Re-use old roads rather than building new roads	403
Re-route vehicles around protected areas	403
Install speed bumps to reduce vehicle collisions with primates	403
Provide adequate signage of presence of primates on or near roads	403

7.5 Threat: Biological resource use	404
7.5.1 Hunting	404
Conduct regular anti-poaching patrols	405
Regularly de-activate/remove ground snares	405
Provide better equipment (e.g. guns) to anti-poaching ranger patrols	405
Implement local no-hunting community policies/traditional hunting ban	406
Implement community control of patrolling, banning hunting and removing snares	406
Strengthen/support/re-install traditions/taboo that forbid the killing of primates	406
Implement monitoring surveillance strategies (e.g. SMART) or use monitoring data to improve effectiveness of wildlife law enforcement patrols	407
Provide training to anti-poaching ranger patrols	407
Implement no-hunting seasons for primates	407
Implement sustainable harvesting of primates (e.g. with permits, resource access agreements)	407
Encourage use of traditional hunting methods rather than using guns	407
Implement road blocks to inspect cars for illegal primate bushmeat	407
Provide medicine to local communities to control killing of primates for medicinal purposes	407
Introduce ammunition tax	407
Inspect bushmeat markets for illegal primate species	407
Inform hunters of the dangers (e.g., disease transmission) of wild primate meat	407
7.5.2 Substitution	408
Use selective logging instead of clear-cutting	409
Avoid/minimize logging of important food tree species for primates	409
Use patch retention harvesting instead of clear-cutting	409
Implement small and dispersed logging compartments	409
Use shelter wood cutting instead of clear-cutting	409
Leave hollow trees in areas of selective logging for sleeping sites	409
Clear open patches in the forest	409
Thin trees within forests	409
Coppice trees	409
Manually control or remove secondary mid-storey and ground-level vegetation	409
Avoid slashing climbers/lianas, trees housing them, hemi-epiphytic figs, and ground vegetation	410
Incorporate forested corridors or buffers into logged areas	410

Close non-essential roads as soon as logging operations are complete	410
Use 'set-asides' for primate protection within logging area	410
Work inward from barriers or boundaries (e.g. river) to avoid pushing primates toward an impassable barrier or inhospitable habitat	410
Reduce the size of forestry teams to include employees only (not family members)	410
Certify forest concessions and market their products as 'primate friendly'	410
Provide domestic meat to workers of the logging company to reduce hunting	410
7.6 Threat: Human intrusions and disturbance	411
Implement a 'no-feeding of wild primates' policy	411
Put up signs to warn people about not feeding primates	412
Resettle illegal human communities (i.e. in a protected area) to another location	412
Build fences to keep humans out	412
Restrict number of people that are allowed access to the site	412
Install 'primate-proof' garbage bins	412
Do not allow people to consume food within natural areas where primates can view them	412
7.7 Threat: Natural system modifications	413
Use prescribed burning within the context of home range size and use	413
Protect important food/nest trees before burning	413
7.8 Threat: Invasive and other problematic species and genes	414
7.8.1 Problematic animal/plant species and genes	414
Reduce primate predation by non-primate species through exclusion (e.g. fences) or translocation	415
Reduce primate predation by other primate species through exclusion (e.g. fences) or translocation	415
Control habitat-altering mammals (e.g. elephants) through exclusion (e.g. fences) or translocation	415
Control inter-specific competition for food through exclusion (e.g. fences) or translocation	415
Remove alien invasive vegetation where the latter has a clear negative effect on the primate species in question	415
Prevent gene contamination by alien primate species introduced by humans, through exclusion (e.g. fences) or translocation	415
7.8.2 Disease transmission	415
Preventative vaccination of habituated or wild primates	416
Wear face-masks to avoid transmission of viral and bacterial diseases to primates	417
Keep safety distance to habituated animals	417
Limit time that researchers/tourists are allowed to spend with habituated animals	417

Implement quarantine for primates before reintroduction/ translocation	418
Ensure that researchers/tourists are up-to-date with vaccinations and healthy	418
Regularly disinfect clothes, boots etc	418
Treat sick/injured animals	419
Remove/treat external/internal parasites to increase reproductive success/survival	419
Conduct veterinary screens of animals before reintroducing/ translocating them	419
Implement continuous health monitoring with permanent vet on site	420
Detect and report dead primates and clinically determine their cause of death to avoid disease transmission	420
Implement quarantine for people arriving at, and leaving the site	421
Wear gloves when handling primate food, tool items, etc	421
Control 'reservoir' species to reduce parasite burdens/pathogen sources	421
Avoid contact between wild primates and human-raised primates	421
Implement a health programme for local communities	421
7.9 Threat: Pollution	422
7.9.1 Garbage/solid waste	422
Reduce garbage/solid waste to avoid primate injuries	422
Remove human food waste that may potentially serve as food sources for primates to avoid disease transmission and conflict with humans	422
7.9.2 Excess energy	423
Reduce noise pollution by restricting development activities to certain times of the day/night	423
7.10 Education and Awareness	424
Educate local communities about primates and sustainable use	424
Involve local community in primate research and conservation management	425
Regularly play TV and radio announcements to raise primate conservation awareness	425
Implement multimedia campaigns using theatre, film, print media, and discussions	425
Install billboards to raise primate conservation awareness	426
Integrate local religion/taboo into conservation education	426
7.11 Habitat protection	427
7.11.1 Habitat protection	427
Create/protect habitat corridors	427
Legally protect primate habitat	428
Establish areas for conservation which are not protected by national or international legislation (e.g. private sector standards and codes)	428

	Create/protect forest patches in highly fragmented landscapes	428
	Create buffer zones around protected primate habitat	429
	Demarcate and enforce boundaries of protected areas	429
7.11.2	Habitat creation or restoration	429
	Plant indigenous trees to re-establish natural tree communities in clear-cut areas	429
	Restore habitat corridors	430
	Plant indigenous fast-growing trees (will not necessarily resemble original community) in clear-cut areas	430
	Use weeding to promote regeneration of indigenous tree communities	430
7.12	Species management	431
7.12.1	Species management	431
	Guard habituated primate groups to ensure their safety/well-being	431
	Habituate primates to human presence to reduce stress from tourists/researchers etc	432
	Implement legal protection for primate species under threat	432
	Implement birth control to stabilize primate community/population size	432
7.12.2	Species recovery	433
	Regularly and continuously provide supplementary food to primates	433
	Regularly provide supplementary food to primates during resource scarce periods only	433
	Provide supplementary food for a certain period of time only	434
	Provide additional sleeping platforms/nesting sites for primates	434
	Provide artificial water sources	434
	Provide salt licks for primates	435
	Provide supplementary food to primates through the establishment of prey populations	435
7.12.3	Species reintroduction	435
	Reintroduce primates into habitat where the species is absent	436
	Translocate (capture and release) wild primates from development sites to natural habitat elsewhere	436
	Translocate (capture and release) wild primates from abundant population areas to non-inhabited environments	436
	Allow primates to adapt to local habitat conditions for some time before introduction to the wild	437
	Reintroduce primates in groups	437
	Reintroduce primates as single/multiple individuals	438
	Reintroduce primates into habitat where the species is present	438
	Reintroduce primates into habitat with predators	438
	Reintroduce primates into habitat without predators	439
7.12.4	<i>Ex-situ</i> conservation	439
	Captive breeding and reintroduction of primates into the wild: born and reared in cages	439

	Captive breeding and reintroduction of primates into the wild: limited free-ranging experience	440
	Captive breeding and reintroduction of primates into the wild: born and raised in a free-ranging environment	440
	Rehabilitate injured/orphaned primates	440
	Fostering appropriate behaviour to facilitate rehabilitation	441
7.13	Livelihood; economic and other incentives	442
7.13.1	Provide benefits to local communities for sustainably managing their forest and its wildlife	442
	Provide monetary benefits to local communities for sustainably managing their forest and its wildlife (e.g. REDD, employment)	443
	Provide non-monetary benefits to local communities for sustainably managing their forest and its wildlife (e.g. better education, infrastructure development)	443
7.13.2	Long-term presence of research/tourism project	444
	Run research project and ensure permanent human presence at site	444
	Run tourism project and ensure permanent human presence at site	445
	Permanent presence of staff/managers	445
	8. SHRUBLAND AND HEATHLAND CONSERVATION	447
8.1	Threat: Residential and commercial development	449
	Remove residential or commercial development	449
	Maintain/create habitat corridors in developed areas	449
8.2	Threat: Agriculture and aquaculture	450
	Reduce number of livestock	450
	Use fences to exclude livestock from shrublands	451
	Change type of livestock	452
	Shorten the period during which livestock can graze	453
8.3	Threat: Energy production and mining	454
	Maintain/create habitat corridors in areas of energy production or mining	454
8.4	Threat: Biological resource use	455
	Legally protect plant species affected by gathering	455
	Place signs to deter gathering of shrubland species	455
	Reduce the frequency of prescribed burning	455
8.5	Threat: Transportation and service corridors	456
	Maintain habitat corridors over or under roads and other transportation corridors	456
	Create buffer zones besides roads and other transportation corridors	456
8.6	Threat: Human intrusions and disturbance	457
	Re-route paths to reduce habitat disturbance	457
	Use signs and access restrictions to reduce disturbance	457
	Plant spiny shrubs to act as barriers to people	457

8.7 Threat: Natural system modifications	458
8.7.1 Modified fire regime	458
Use prescribed burning to mimic natural fire cycle	458
Use prescribed burning to reduce the potential for large wild fires	458
Cut strips of vegetation to reduce the spread of fire	458
8.7.2 Modified vegetation management	459
Reinstate the use of traditional burning practices	459
Use cutting/mowing to mimic grazing	459
Increase number of livestock	460
8.8 Threat: Invasive and other problematic species	462
8.8.1 Problematic tree species	462
Apply herbicide to trees	463
Cut trees	463
Cut trees and remove leaf litter	463
Cut trees and remove seedlings	463
Use prescribed burning to control trees	464
Use grazing to control trees	464
Cut trees and apply herbicide	464
Cut trees and use prescribed burning	465
Increase number of livestock and use prescribed burning to control trees	465
Cut/mow shrubland to control trees	465
Cut trees and increase livestock numbers	465
8.8.2 Problematic grass species	466
Cut/mow to control grass	466
Cut/mow to control grass and sow seed of shrubland plants	467
Rake to control grass	467
Cut/mow and rotovate to control grass	467
Apply herbicide and sow seeds of shrubland plants to control grass	468
Apply herbicide and remove plants to control grass	468
Use grazing to control grass	468
Use prescribed burning to control grass	469
Cut and use prescribed burning to control grass	469
Use herbicide and prescribed burning to control grass	469
Strip turf to control grass	469
Rotovate to control grass	470
Add mulch to control grass	470
Add mulch to control grass and sow seed	470
Cut/mow, rotovate and sow seeds to control grass	470
Use herbicide to control grass	471
8.8.3 Bracken	472
Use herbicide to control bracken	472
Cut to control bracken	473


Cut and apply herbicide to control bracken	473
Cut bracken and rotovate	474
Use 'bracken bruiser' to control bracken	474
Use herbicide and remove leaf litter to control bracken	474
Cut and burn bracken	475
Use herbicide and sow seed of shrubland plants to control bracken	475
Increase grazing intensity to control bracken	475
Use herbicide and increase livestock numbers to control bracken	475
8.8.4 Problematic animals	475
Use fences to exclude large herbivores	475
Reduce numbers of large herbivores	475
Use biological control to reduce the number of problematic invertebrates	476
8.9 Threat: Pollution	477
Mow shrubland to reduce impact of pollutants	477
Burn shrublands to reduce impacts of pollutants	478
Plant vegetation to act as a buffer to exclude vegetation	478
Reduce pesticide use on nearby agricultural/forestry land	478
Reduce herbicide use on nearby agricultural/forestry land	478
Reduce fertilizer use on nearby agricultural/forestry land	478
Add lime to shrubland to reduce the impacts of sulphur dioxide pollution	478
8.10 Threat: Climate change and severe weather	479
Restore habitat in area predicted to have suitable habitat for shrubland species in the future	479
Improve connectivity between areas of shrubland to allow species movements and habitat shifts in response to climate change	479
8.11 Threat: Habitat protection	480
Legally protect shrubland	480
Legally protect habitat around shrubland	480
8.12 Habitat restoration and creation	481
8.12.1 General restoration	481
Allow shrubland to regenerate without active management	481
Restore/create connectivity between shrublands.	482
8.12.2 Modify physical habitat	482
Add topsoil	483
Disturb vegetation	483
Strip topsoil	484
Remove leaf litter	484
Add sulphur to soil	484
Use erosion blankets/mats to aid plant establishment	484
Add mulch and fertilizer to soil	485
Add manure to soil	485
Irrigate degraded shrublands	485

Remove trees/crops to restore shrubland structure	485
Remove trees, leaf litter and topsoil	485
Add peat to soil	485
Burn leaf litter	485
8.12.3 Introduce vegetation or seeds	486
Sow seeds	486
Plant individual plants	487
Sow seeds and plant individual plants	487
Spread clippings	487
Build bird perches to encourage colonization by plants	488
Plant turf	488
8.13 Actions to benefit introduced vegetation	489
Add fertilizer to soil (alongside planting/seeding)	489
Add peat to soil (alongside planting/seeding)	490
Add mulch and fertilizer to soil (alongside planting/seeding)	490
Add gypsum to soil (alongside planting/seeding)	490
Add sulphur to soil (alongside planting/seeding)	490
Strip/disturb topsoil (alongside planting/seeding)	491
Add topsoil (alongside planting/seeding)	491
Plant seed balls	491
Plant/sow seeds of nurse plants alongside focal plants	492
Plant/seed under established vegetation	492
Plant shrubs in clusters	492
Add root associated bacteria/fungi to introduced plants	492
8.14 Education and awareness	493
Raise awareness amongst the general public	493
Provide education programmes about shrublands	493

zoo 9. MANAGEMENT OF CAPTIVE ANIMALS	495
9.1 <i>Ex-situ</i> conservation – breeding amphibians	497
9.1.1 Refining techniques using less threatened species	497
Identify and breed a similar species to refine husbandry techniques prior to working with target species	497
9.1.2 Changing environmental conditions/microclimate	498
Vary enclosure temperature to simulate seasonal changes in the wild	498
Vary quality or quantity (UV% or gradients) of enclosure lighting to simulate seasonal changes in the wild	499
Provide artificial aquifers for species which breed in upwelling springs	499
Vary artificial rainfall to simulate seasonal changes in the wild	499
Vary enclosure humidity to simulate seasonal changes in the wild using humidifiers, foggers/misters or artificial rain	500
Vary duration of enclosure lighting to simulate seasonal changes in the wild	500

	Simulate rainfall using sound recordings of rain and/or thunderstorms	500
	Allow temperate amphibians to hibernate	500
	Allow amphibians from highly seasonal environments to have a period of dormancy	500
	Vary water flow/speed of artificial streams in enclosures for torrent breeding species	500
9.1.3	Changing enclosure design for spawning or egg laying sites	500
	Provide multiple egg laying sites within an enclosure	501
	Provide natural substrate for species which do not breed in water (e.g. burrowing/tunnel breeders)	501
	Provide particular plants as breeding areas or egg laying sites	501
9.1.4	Manipulate social conditions	502
	Manipulate sex ratio within the enclosure	502
	Play recordings of breeding calls to simulate breeding season in the wild	503
	Allow female mate choice	503
	Provide visual barriers for territorial species	503
	Manipulate adult density within the enclosure	503
9.1.5	Changing the diet of adults	504
	Supplement diets with carotenoids (including for colouration)	504
	Increase caloric intake of females in preparation for breeding	504
	Vary food provision to reflect seasonal availability in the wild	505
	Formulate adult diet to reflect nutritional composition of wild foods	505
	Supplement diets with vitamins/calcium fed to prey (e.g. prey gut loading)	505
	Supplement diets with vitamins/calcium applied to food (e.g. dusting prey).	505
9.1.6	Manipulate rearing conditions for young	505
	Manipulate temperature of enclosure to improve development or survival to adulthood	506
	Formulate larval diets to improve development or survival to adulthood	506
	Manipulate larval density within the enclosure	506
	Leave infertile eggs at spawn site as food for egg-eating larvae	507
	Manipulate humidity to improve development or survival to adulthood	507
	Manipulate quality and quantity of enclosure lighting to improve development or survival to adulthood	507
	Allow adults to attend their eggs	507
9.1.7	Artificial reproduction	507
	Use artificial cloning from frozen or fresh tissue	507
	Use hormone treatment to induce sperm and egg release	507
	Use artificial fertilization in captive breeding	507

9.2 Promoting health and welfare in captive carnivores (felids, canids and ursids) through feeding practices	508
9.2.1 Diet and food type	508
Provide bones, hides or partial carcasses	509
Feed whole carcasses (with or without organs/gastrointestinal tract)	509
Feed commercially prepared diets	510
Feed plant-derived protein	510
Supplement meat-based diets with prebiotic plant material to facilitate digestion	510
Supplement meat-based diet with amino acid	510
Supplement meat-based diet with vitamins or minerals	511
Supplement meat-based diet with fatty acids	511
Increase variety of food items	511
9.2.2 Food presentation and enrichment	511
Hide food around enclosure	511
Present food frozen in ice	512
Present food inside objects (e.g. Boomer balls)	512
Provide devices to simulate live prey, including sounds, lures, pulleys and bungees	512
Change location of food around enclosure	513
Scatter food around enclosure	513
Provide live vertebrate prey	513
Provide live invertebrate prey	513
Present food in/on water	514
Use food as a reward in animal training	514
9.2.3 Feeding schedule	514
Provide food on a random temporal schedule	514
Allocate fast days	515
Alter food abundance or type seasonally	515
Provide food during natural active periods	515
Use automated feeders	515
Alter feeding schedule according to visitor activity	515
Provide food during visitor experiences	515
9.2.4 Social feeding	515
Feed individuals separately	515
Feed individuals within a social group	515
Hand-feed	515
9.3 Promoting natural feeding behaviours in primates in captivity	516
9.3.1 Food Presentation	516
Scatter food throughout enclosure	517
Hide food in containers (including boxes and bags)	517
Present food frozen in ice	517
Present food items whole instead of processed	517



Present feeds at different crowd levels	518
Maximise both vertical and horizontal presentation locations	518
Present food in puzzle feeders	518
Present food in water (including dishes and ponds)	518
Present food dipped in food colouring	519
Provide live vegetation in planters for foraging	519
Present food which required the use (or modification) of tools	519
Paint gum solutions on rough bark	519
Add gum solutions to drilled hollow feeders	519
9.3.2 Diet manipulation	520
Formulate diet to reflect nutritional composition of wild foods (including removal of domestic fruits)	520
Provide cut branches (browse)	520
Provide live invertebrates	521
Provide fresh produce	521
Provide gum (including artificial gum)	521
Provide nectar (including artificial nectar)	521
Provide herbs or other plants for self-medication	521
Modify ingredients/nutrient composition seasonally (not daily) to reflect natural variability	521
9.3.3 Feeding Schedule	522
Change feeding times	522
Change the number of feeds per day	522
Provide food at natural (wild) feeding times	522
Provide access to food at all times (day and night)	522
Use of automated feeders	522
9.3.4 Social group manipulation	523
Feed individuals in social groups	523
Feed individuals separately	523
Feed individuals in subgroups	523
 10. SOME ASPECTS OF CONTROL OF FRESHWATER INVASIVE SPECIES	525
10.1 Threat: Invasive plants	527
10.1.1 Parrot's feather <i>Myriophyllum aquaticum</i>	527
Chemical control using the herbicide 2,4-D	528
Chemical control using the herbicide carfentrazone-ethyl	528
Chemical control using the herbicide triclopyr	528
Chemical control using the herbicide diquat	529
Chemical control using the herbicide endohall	529
Chemical control using other herbicides	529
Reduction of trade through legislation and codes of conduct	530
Biological control using herbivores	530
Water level drawdown	530

	Biological control using plant pathogens	531
	Mechanical harvesting or cutting	531
	Mechanical excavation	531
	Removal using water jets	531
	Suction dredging and diver-assisted suction removal	531
	Manual harvesting (hand-weeding)	531
	Use of lightproof barriers	531
	Dye application	531
	Biological control using fungal-based herbicides	531
	Use of salt	531
	Decontamination / preventing further spread	531
	Public education	531
	Multiple integrated measures	531
10.1.2	Floating pennywort <i>Hydrocotyle ranunculoides</i>	532
	Chemical control using herbicides	532
	Flame treatment	532
	Physical removal	533
	Combination treatment using herbicides and physical removal	533
	Biological control using co-evolved, host-specific herbivores	533
	Use of hydrogen peroxide	533
	Biological control using fungal-based herbicides	534
	Biological control using native herbivores	534
	Environmental control (e.g. shading, reduced flow, reduction of rooting depth, or dredging)	534
	Excavation of banks	534
	Public education	534
	Use of liquid nitrogen	534
10.1.3	Water primrose <i>Ludwigia spp</i>	534
	Biological control using co-evolved, host specific herbivores	535
	Chemical control using herbicides	535
	Combination treatment using herbicides and physical removal	535
	Physical removal	536
	Biological control using fungal-based herbicides	536
	Biological control using native herbivores	536
	Environmental control (e.g. shading, reduced flow, reduction of rooting depth, or dredging)	536
	Excavation of banks	536
	Public education	536
	Use of a tarpaulin	536
	Use of flame treatment	536
	Use of hydrogen peroxide	536
	Use of liquid nitrogen	536
	Use of mats placed on the bottom of the waterbody	536

10.1.4	Skunk cabbage <i>Lysichiton americanus</i>	536
	Chemical control using herbicides	537
	Physical removal	537
	Biological control using co-evolved, host-specific herbivores	538
	Biological control using fungal-based herbicides	538
	Biological control using native herbivores	538
	Combination treatment using herbicides and physical removal	538
	Environmental control (e.g. shading, or promotion of native plants)	538
	Public education	538
	Use of a tarpaulin	538
	Use of flame treatment	538
	Use of hydrogen peroxide	538
	Use of liquid nitrogen	538
10.1.5	New Zealand pigmyweed <i>Crassula helmsii</i>	538
	Chemical control using herbicides	539
	Decontamination to prevent further spread	539
	Use lightproof barriers to control plants	540
	Use salt water to kill plants	540
	Use a combination of control methods	540
	Use dyes to reduce light levels	540
	Use grazing to control plants	540
	Use hot foam to control plants	541
	Use hydrogen peroxide to control plants	541
	Alter environmental conditions to control plants (e.g. shading by succession, increasing turbidity, re-profiling or dredging)	541
	Biological control using fungal-based herbicides	541
	Biological control using herbivores	541
	Bury plants	541
	Dry out waterbodies	541
	Physical control using manual/mechanical control or dredging	541
	Plant other species to suppress growth	541
	Public education	541
	Surround with wire mesh	541
	Use flame throwers	541
	Use hot water	541
	Use of liquid nitrogen	541
10.2	Threat: Invasive molluscs	542
10.2.1	Asian clams	542
	Add chemicals to the water	542
	Change salinity of water	543
	Mechanical removal	543
	Change temperature of water	543

Clean equipment	543
Use of gas-impermeable barriers	544
Reduce oxygen in water	544
Change pH of water	544
Drain the invaded waterbody	544
Exposure to disease-causing organisms	544
Exposure to parasites	544
Hand removal	544
Public awareness and education.	544
10.3 Threat: Invasive crustaceans	545
10.3.1 Ponto-Caspian gammarids	545
Change salinity of the water	545
Change water temperature	546
Dewatering (drying out) habitat	546
Exposure to parasites	546
Add chemicals to water	546
Change water pH	546
Control movement of gammarids	547
Biological control using predatory fish	547
Cleaning equipment	547
Exchange ballast water	547
Exposure to disease-causing organisms	547
10.3.2 <i>Procambarus</i> spp. crayfish	547
Add chemicals to the water	548
Sterilization of males	548
Trapping and removal	548
Trapping combined with encouragement of predators	548
Create barriers	549
Encouraging predators	549
Draining the waterway	549
Food source removal	549
Relocate vulnerable crayfish	549
Remove the crayfish by electrofishing	549
10.4 Threat: Invasive fish	550
10.4.1 Brown and black bullheads	550
Application of a biocide	551
Netting	551
Biological control of beneficial species	551
Biological control using native predators	551
Changing salinity	551
Changing pH	551
Draining invaded waterbodies	551
Electrofishing	551

Habitat manipulation	551
Increasing carbon dioxide concentrations	551
Public education	551
Trapping using sound or pheromonal lures	551
Using a combination of netting and electrofishing	551
UV radiation	551
10.4.2 Ponto-Caspian gobies	552
Changing salinity	552
Use of barriers to prevent migration	553
Application of a biocide	553
Biological control of beneficial species	553
Biological control using native predators	553
Changing pH	553
Draining invaded waterbodies	553
Electrofishing	553
Habitat manipulation	553
Increasing carbon dioxide concentrations	553
Netting	553
Public education	553
Trapping using visual, sound and pheromonal lures	553
Using a combination of netting and electrofishing	553
UV radiation	553
10.5 Threat: Invasive reptiles	554
10.5.1 Red-eared terrapin <i>Trachemys scripta</i>	554
Direct removal of adults	554
Application of a biocide	555
Biological control using native predators	555
Draining invaded waterbodies	555
Public education	555
Search and removal using sniffer dogs	555
10.6 Threat: Invasive amphibians	556
10.6.1 American bullfrog <i>Lithobates catesbeiana</i>	556
Biological control using native predators	556
Direct removal of adults	557
Direct removal of juveniles	557
Application of a biocide	557
Biological control of co-occurring beneficial species	558
Collection of egg clutches	558
Draining ponds	558
Fencing	558
Habitat modification	558
Pond destruction	558
Public education	558

	11. SOME ASPECTS OF ENHANCING NATURAL PEST CONTROL	559
	11.1 Reducing agricultural pollution	561
	Alter the timing of insecticide use	561
	Delay herbicide use	562
	Incorporate parasitism rates when setting thresholds for insecticide use	563
	Use pesticides only when pests or crop damage reach threshold levels	563
	Convert to organic farming	564
	11.2 All farming systems	566
	Grow non-crop plants that produce chemicals that attract natural enemies	566
	Use chemicals to attract natural enemies	567
	Leave part of the crop or pasture unharvested or uncut	568
	Plant new hedges	569
	Use alley cropping	569
	Use mass-emergence devices to increase natural enemy populations	570
	11.3 Arable farming	571
	Combine trap and repellent crops in a push-pull system	571
	Use crop rotation in potato farming systems	572
	Create beetle banks	573
	Incorporate plant remains into the soil that produce weed-controlling chemicals	574
	11.4 Perennial farming	576
	Exclude ants that protect pests	576
	Allow natural regeneration of ground cover beneath perennial crops	577
	Isolate colonies of beneficial ants	578
	11.5 Livestock farming and pasture	579
	Grow plants that compete with damaging weeds	579
	Delay mowing or first grazing date on pasture or grassland	580
	Use grazing instead of cutting for pasture or grassland management	581
	Use mixed pasture	581
	12. ENHANCING SOIL FERTILITY	583
	12.1 Reducing agricultural pollution	585
	Change the timing of manure application	585
	Reduce fertilizer, pesticide or herbicide use generally	586
	12.2 All farming systems	587
	Control traffic and traffic timing	587
	Change tillage practices	588
	Convert to organic farming	590
	Plant new hedges	590
	Change the timing of ploughing	591

12.3 Arable farming	592
Amend the soil using a mix of organic and inorganic amendments	593
Grow cover crops when the field is empty	593
Use crop rotation	594
Amend the soil with formulated chemical compounds	595
Grow cover crops beneath the main crop (living mulches) or between crop rows	596
Add mulch to crops	596
Amend the soil with fresh plant material or crop remains	597
Amend the soil with manures and agricultural composts	598
Amend the soil with municipal wastes or their composts	599
Incorporate leys into crop rotation	599
Retain crop residues	600
Amend the soil with bacteria or fungi	600
Amend the soil with composts not otherwise specified	601
Amend the soil with crops grown as green manures	601
Amend the soil with non-chemical minerals and mineral wastes	601
Amend the soil with organic processing wastes or their composts	601
Encourage foraging waterfowl	602
Use alley cropping	602
12.4 Livestock and pasture farming	603
Reduce grazing intensity	603
Restore or create low input grasslands	604

Introduction

This book has been created to help you make decisions about practical conservation management by providing an assessment, from the available scientific evidence, of what works and what does not work in conservation. It also tells you if no evidence has been found about whether or not a conservation intervention is effective. This is the 2018 edition of *What Works in Conservation*, which was first published in 2015 and will be updated annually.

Who is *What Works in Conservation* for?

This book is for people who have to make decisions about how best to support or conserve biodiversity. These include land managers, conservationists in the public or private sector, farmers, campaigners, advisors or consultants, policymakers, researchers or people taking action to protect local wildlife. *What Works in Conservation* and the associated synopses summarize scientific evidence relevant to conservation objectives and the actions that could be taken to achieve them. *What Works in Conservation* also provides an assessment of the effectiveness of interventions based on available evidence.

We do not aim to make decisions for people, but to support decision-making by providing what evidence there is (or is not) about the effects that your planned actions could have. It is important that you read the full details of the evidence, freely available online at www.conservationevidence.com, before making any decisions about implementing an intervention.

The Conservation Evidence project

The Conservation Evidence project has four parts, all of which are available from our website conservationevidence.com:

1. An ever-expanding searchable **database of over 5,400 summaries** of previously published scientific papers, reports, reviews or systematic reviews that document the effects of interventions.

2. **Synopses** of the evidence captured in part 1) relating to particular species groups, habitats or conservation issues. Synopses bring together the evidence for all possible interventions. Synopses are also available to purchase in printed book form, or can be downloaded for free as electronic material.
3. *What Works in Conservation* provides an assessment of the effectiveness of interventions based on available evidence. It contains both the key messages from the evidence for each conservation intervention from the relevant synopses, and an assessment of the effectiveness of each intervention by expert panels.
4. An online, **open access journal** *Conservation Evidence* that publishes new pieces of research on the effects of conservation management interventions. All our papers are written by, or in conjunction with, those who carried out the conservation work and include some monitoring of its effects.

Alongside this project, the Centre for Evidence-Based Conservation (<http://www.cebc.bangor.ac.uk>) and the Collaboration for Environmental Evidence (<http://www.environmentalevidence.org>) carry out and compile systematic reviews of evidence on the effectiveness of particular conservation interventions. We recommend carrying out a systematic review, which is more comprehensive than our summaries of evidence, when decisions have to be made with particularly important consequences. Systematic reviews are included in the Conservation Evidence database.

Which conservation interventions are included?

Lists of interventions for each synopsis are developed and agreed in partnership with an advisory board made up of international conservationists and academics with expertise in the subject. We aim to include all actions that have been carried out or advised for the conservation of the specific group of species or habitat or for the specific conservation issue.

The lists of interventions are organized into categories based on the International Union for the Conservation of Nature (IUCN) classifications of direct threats and conservation actions (<http://www.iucnredlist.org/technical-documents/classification-schemes>). Interventions are primarily

grouped according to the relevant direct threats. However, some interventions can be used in response to many different threats and so these have been grouped according to conservation action.

How we review the literature

We gather evidence by searching relevant scientific journals from volume one through to the most recent volume. Thirty general conservation journals are regularly searched by Conservation Evidence. Specialist journals are also searched for each synopsis (231 have been searched so far). We also search reports, unpublished literature and evidence provided by our advisory boards. Two of the synopses used systematic mapping exercises undertaken by, or in partnership with, other institutions. Systematic mapping uses a rigorous search protocol (involving an array of specified search terms) to retrieve studies from several scientific databases. Evidence published in languages other than English is included when it is identified. Evidence from all around the world is included in synopses. One exception is farmland conservation, which only covers northern Europe (all European countries west of Russia, but not those south of France, Switzerland, Austria, Hungary and Romania). Any apparent bias towards evidence from some regions in a particular synopsis reflects the current biases in published research papers available to Conservation Evidence.

The criteria for inclusion of studies in the Conservation Evidence database are as follows:

- A conservation intervention must have been carried out.
- The effects of the intervention must have been monitored quantitatively.

These criteria exclude studies examining the effects of specific interventions without actually doing them. For example, predictive modelling studies and studies looking at species distributions in areas with long-standing management histories (correlative studies) are excluded. Such studies can suggest that an intervention could be effective, but do not provide direct evidence of a causal relationship between the intervention and the observed biodiversity pattern.

We summarise the results of each study that are relevant to each intervention. Unless specifically stated, results reflect statistical tests performed on the data within the papers.

What does *What Works in Conservation* include?

What Works in Conservation includes **only the key messages from each synopsis**, which provide a rapid overview of the evidence. These messages are condensed from the summary text for each intervention within each synopsis. **For the full text and references see www.conservationevidence.com**

Panels of experts have assessed the collated evidence for each intervention to determine effectiveness, certainty of the evidence and, in most cases, whether there are negative side-effects (harms). Using these assessments, interventions are categorized based on a combination of effectiveness (the size of benefit or harm) and certainty (the strength of the evidence). The following categories are used: Beneficial, Likely to be beneficial, Trade-off between benefit and harms, Unknown effectiveness, Unlikely to be beneficial, Likely to be ineffective or harmful (for more details see below).

Expert assessment of the evidence

The average of several experts' opinions has been shown to be a more reliable and accurate assessment than the opinion of a single expert. We therefore ask a panel of experts to use their judgement to assess whether evidence within the synopsis indicates that an intervention is effective or not. They are also asked to assess how certain they are of the effectiveness given the quality of evidence available for that intervention (certainty of the evidence). Negative side-effects described in the collated evidence are also assessed (harms). They base their assessment solely on the evidence in the synopsis. We use a modified Delphi method to quantify the effectiveness and certainty of evidence of each intervention, based on the summarized evidence. The Delphi method is a structured process that involves asking a panel of experts to state their individual opinion on a subject by scoring anonymously. They can then revise their own scores after seeing a summary of scores and comments from the rest of the panel. Final scores are then collated. Scores and comments are kept anonymous throughout the process so that participants are not overly influenced by any single member of the panel.

For each intervention, experts are asked to read the summarized evidence in the synopsis and then score to indicate their assessment of the following:

Effectiveness: 0 = no effect, 100% = always effective.

Certainty of the evidence: 0 = no evidence, 100% = high quality evidence; complete certainty. This is certainty of effectiveness of intervention, not of harms.

Harms: 0 = none, 100% = major negative side-effects to the group of species/habitat of concern.

Categorization of interventions

After one or two rounds of initial scoring, interventions are categorized by their effectiveness, as assessed by the expert panel. The median score from all the experts' assessments is calculated for the effectiveness, certainty and harms for each intervention. Categorization is based on these median values i.e. on a combination of the size of the benefit and harm and the strength of the evidence. The table and figure overleaf show how interventions are categorized using the median scores. There is an important distinction between lack of benefit and lack of evidence of benefit.

Once interventions are categorized, experts are given the chance to object if they believe an intervention has been categorized incorrectly. Interventions that receive a specified number (depending on the size of the panel) of strong objections from experts are re-scored by the expert panel and re-categorized accordingly. Experts did not see the categories for the farmland synopsis or for the 'Reduce predation by other species' section of the bird synopsis and so those categories are based on the second round of scoring.

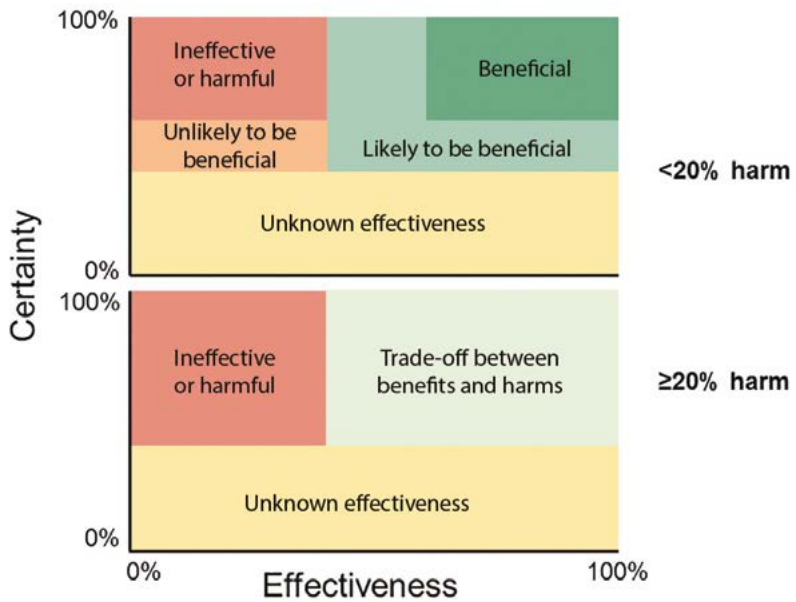
How to use *What Works in Conservation*

Please remember that the categories provided in this book are meant as a guide and a starting point in assessing the effectiveness of conservation interventions. The assessments are based on the available evidence for the target group of species for each intervention and may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence, in order to assess their relevance to your species or system. Full details of the evidence are available at www.conservationevidence.com.

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in our assessment. A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

Table of categories of effectiveness

Category	Description	General criteria	Thresholds
Beneficial	Effectiveness has been demonstrated by clear evidence. Expectation of harms is small compared with the benefits	High median benefit score High median certainty score Low median harm score	Effectiveness: >60% Certainty: >60% Harm: <20%
Likely to be beneficial	Effectiveness is less well established than for those listed under 'beneficial' OR There is clear evidence of medium effectiveness	High benefit score Lower certainty score Low harm score OR Medium benefit score High certainty score Low harm score	Effectiveness: >60% Certainty: 40–60% Harm: <20% OR Effectiveness: 40–60% Certainty: ≥40% Harm: <20%
Trade-off between benefit and harms	Interventions for which practitioners must weigh up the beneficial and harmful effects according to individual circumstances and priorities	Medium benefit and medium harm scores OR High benefit and high harm scores High certainty score	Effectiveness: ≥40% Certainty: ≥40% Harm: ≥20%
Unknown effectiveness (limited evidence)	Currently insufficient data, or data of inadequate quality	Low certainty score	Effectiveness: Any Certainty: <40% Harm: Any
Unlikely to be beneficial	Lack of effectiveness is less well established than for those listed under 'likely to be ineffective or harmful'	Low benefit score Medium certainty score and/or some variation between experts	Effectiveness: <40% Certainty: 40–60% Harm: <20%
Likely to be ineffective or harmful	Ineffectiveness or harmfulness has been demonstrated by clear evidence	Low benefit score High certainty score (regardless of harms) OR Low benefit score High harm score (regardless of certainty of effectiveness)	Effectiveness: <40% Certainty: >60% Harm: Any OR Effectiveness: <40% Certainty: ≥ 40% Harm: ≥20%



Categories of effectiveness based on a combination of effectiveness (the size of the benefit and harm) and certainty (the strength of the evidence). The top graph refers to interventions with harms <20% and the bottom graph to interventions with harms ≥20%.

1. AMPHIBIAN CONSERVATION

Rebecca K. Smith, Helen Meredith & William J. Sutherland

Expert assessors

Ariadne Angulo, Co-Chair of the Amphibian Specialist Group, Peru

Robert Brodman, Saint Joseph's College, Indiana, USA

Andrew Cunningham, Institute of Zoology, Zoological Society of London, UK

Jeff Dawson, Durrell Wildlife Conservation Trust, UK

Rob Gandola, University of Southampton, UK

Jaime García Moreno, International Union for Conservation of Nature, The Netherlands

Trent Garner, Institute of Zoology, Zoological Society of London, UK

Richard Griffiths, Durrell Institute of Conservation and Ecology, UK

Sergei Kuzmin, Russian Academy of Sciences

Michael Lanoo, Indiana University, USA

Michael Lau, WWF-Hong Kong

James Lewis, Amphibian Survival Alliance/Global Wildlife Conservation, USA

An Martel, Ghent University, Belgium

LeGrand Nono Gonwouo, Cameroon Herpetology-Conservation Biology Foundation

Deanna Olson, US Forest Service

Timo Paasikunnas, Curator of Conservation at Helsinki Zoo, Finland

Frank Pasmans, Ghent University, Belgium

Silviu Petrovan, Froglife, UK

Carlos Martínez Rivera, Philadelphia Zoo, USA

Gonçalo Rosa, Institute of Zoology, Zoological Society of London, UK

David Sewell, Durrell Institute of Conservation and Ecology, UK

Rebecca K. Smith, University of Cambridge, UK

Ben Tapley, Herpetology Department, Zoological Society of London, UK

Jeanne Tarrant, Endangered Wildlife Trust, South Africa

Karthikeyan Vasudevan, Wildlife Institute of India

Victor Wasonga, National Museums of Kenya

Ché Weldon, North-West University, South Africa

Sally Wren, Amphibian Specialist Group Programme Officer, New Zealand

Scope of assessment: for native wild amphibian species across the world.

Assessed: 2014.

Effectiveness measure is the median % score for effectiveness.

Certainty measure is the median % certainty of evidence for effectiveness, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects to the group of species of concern.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

1.1 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Legal protection of species
No evidence found (no assessment)	<ul style="list-style-type: none">• Protect brownfield or ex-industrial sites• Restrict herbicide, fungicide and pesticide use on and around ponds on golf courses

Unknown effectiveness (limited evidence)

● Legal protection of species

Three reviews, including one systematic review, in the Netherlands and UK found that legal protection of amphibians was not effective at protecting populations during development. Two reviews found that the number of great crested newt mitigation licences issued in England and Wales increased over 10 years. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 35%; harms 7%).*

<http://www.conservazionevidence.com/actions/779>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Protect brownfield or ex-industrial sites
- Restrict herbicide, fungicide and pesticide use on and around ponds on golf courses

1.2 Threat: Agriculture

1.2.1 Engage farmers and other volunteers

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for engaging farmers and other volunteers?	
Likely to be beneficial	<ul style="list-style-type: none">● Engage landowners and other volunteers to manage land for amphibians● Pay farmers to cover the costs of conservation measures

Likely to be beneficial

● Engage landowners and other volunteers to manage land for amphibians

Three studies, including one replicated and one controlled study, in Estonia, Mexico and Taiwan found that engaging landowners and other volunteers in habitat management increased amphibian populations and axolotl weight. Six studies in Estonia, the USA and UK found that up to 41,000 volunteers were engaged in habitat restoration programmes for amphibians and restored up to 1,023 ponds or 11,500 km² of habitat. *Assessment: likely to be beneficial (effectiveness 70%; certainty 55%; harms 5%).*

<http://www.conservationevidence.com/actions/777>

● Pay farmers to cover the costs of conservation measures

Four of five studies, including two replicated studies, in Denmark, Sweden and Taiwan found that payments to farmers increased amphibian

populations, numbers of species or breeding habitat. One found that amphibian habitat was not maintained. *Assessment: likely to be beneficial (effectiveness 70%; certainty 53%; harms 10%).*

<http://www.conservationevidence.com/actions/818>

1.2.2 Terrestrial habitat management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for terrestrial habitat management in agricultural systems?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Manage cutting regime• Manage grazing regime
No evidence found (no assessment)	<ul style="list-style-type: none">• Maintain or restore hedges• Plant new hedges• Reduced tillage

Manage silviculture practices in plantations

Studies investigating the effects of silviculture practices are discussed in 'Threat: Biological resource use — Logging and wood harvesting'.

Unknown effectiveness (limited evidence)

● Manage cutting regime

One before-and-after study in Australia found that restoration that included reduced mowing increased numbers of frog species. *Assessment for 'Change mowing regime' from 'Habitat restoration and creation' section: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/788>

● Manage grazing regime

Two studies, including one replicated, controlled study, in the UK and USA found that grazed plots had lower numbers of toads than ungrazed plots and that grazing, along with burning, decreased numbers of amphibian

species. Five studies, including four replicated studies, in Denmark, Estonia and the UK found that habitat management that included reintroduction of grazing maintained or increased toad populations. *Assessment: unknown effectiveness — limited evidence (effectiveness 45%; certainty 39%; harms 10%).*

<http://www.conservationevidence.com/actions/780>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain or restore hedges
- Plant new hedges
- Reduced tillage

1.2.3 Aquatic habitat management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for aquatic habitat management in agricultural systems?	
Likely to be beneficial	<ul style="list-style-type: none"> • Manage ditches
Likely to be ineffective or harmful	<ul style="list-style-type: none"> • Exclude domestic animals or wild hogs from ponds by fencing

Likely to be beneficial

● Manage ditches

One controlled, before-and-after study in the UK found that managing ditches increased toad numbers. One replicated, site comparison study in the Netherlands found that numbers of amphibians and species were higher in ditches managed under agri-environment schemes compared to those managed conventionally. *Assessment: likely to be beneficial (effectiveness 71%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/749>

Likely to be ineffective or harmful

● Exclude domestic animals or wild hogs from ponds by fencing

Four replicated studies, including one randomized, controlled, before-and-after study, in the USA found that excluding livestock from streams or ponds did not increase overall numbers of amphibians, species, eggs or larval survival, but did increase larval and metamorph abundance. One before-and-after study in the UK found that pond restoration that included livestock exclusion increased pond use by breeding toads. *Assessment: likely to be ineffective or harmful (effectiveness 31%; certainty 50%; harms 25%).*

<http://www.conservationevidence.com/actions/746>

1.3 Threat: Energy production and mining

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for energy production and mining?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Artificially mist habitat to keep it damp

Unknown effectiveness (limited evidence)

● Artificially mist habitat to keep it damp

One before-and-after study in Tanzania found that installing a sprinkler system to mitigate against a reduction of river flow did not maintain a population of Kihansi spray toads. *Assessment: unknown effectiveness — limited evidence (effectiveness 24%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/755>

1.4 Threat: Transportation and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for transportation and service corridors?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Close roads during seasonal amphibian migration ● Modify gully pots and kerbs
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Install barrier fencing along roads ● Install culverts or tunnels as road crossings
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Use signage to warn motorists
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Use humans to assist migrating amphibians across roads

Likely to be beneficial

● Close roads during seasonal amphibian migration

Two studies, including one replicated study, in Germany found that road closure sites protected large numbers of amphibians from mortality during breeding migrations. *Assessment: likely to be beneficial (effectiveness 85%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/842>



● Modify gully pots and kerbs

One before-and-after study in the UK found that moving gully pots 10 cm away from the kerb decreased the number of great crested newts that fell in by 80%. *Assessment: likely to be beneficial (effectiveness 80%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/782>

Trade-off between benefit and harms

● Install barrier fencing along roads

Seven of eight studies, including one replicated and two controlled studies, in Germany, Canada and the USA found that barrier fencing with culverts decreased amphibian road deaths, in three cases depending on fence design. One study found that few amphibians were diverted by barriers. *Assessment: trade-offs between benefits and harms (effectiveness 65%; certainty 68%; harms 23%).*

<http://www.conservationevidence.com/actions/756>

● Install culverts or tunnels as road crossings

Thirty-two studies investigated the effectiveness of installing culverts or tunnels as road crossings for amphibians. Six of seven studies, including three replicated studies, in Canada, Europe and the USA found that installing culverts or tunnels decreased amphibian road deaths. One found no effect on road deaths. Fifteen of 24 studies, including one review, in Australia, Canada, Europe and the USA found that tunnels were used by amphibians. Four found mixed effects depending on species, site or culvert type. Five found that culverts were not used or were used by less than 10% of amphibians. Six studies, including one replicated, controlled study, in Canada, Europe and the USA investigated the use of culverts with flowing water. Two found that they were used by amphibians. Three found that they were rarely or not used. Certain culvert designs were found not to be suitable for amphibians. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 75%; harms 25%).*

<http://www.conservationevidence.com/actions/884>

Unknown effectiveness (limited evidence)

● Use signage to warn motorists

One study in the UK found that despite warning signs and human assistance across roads, some toads were still killed on roads. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/841>

Unlikely to be beneficial

● Use humans to assist migrating amphibians across roads

Three studies, including one replicated study, in Italy and the UK found that despite assisting toads across roads during breeding migrations, toads were still killed on roads and 64–70% of populations declined. Five studies in Germany, Italy and the UK found that large numbers of amphibians were moved across roads by up to 400 patrols. *Assessment: unlikely to be beneficial (effectiveness 35%; certainty 40%; harms 3%).*

<http://www.conservationevidence.com/actions/784>

1.5 Threat: Biological resource use

1.5.1 Hunting and collecting terrestrial animals

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for hunting and collecting terrestrial animals?	
Likely to be beneficial	<ul style="list-style-type: none">• Reduce impact of amphibian trade
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Use legislative regulation to protect wild populations
No evidence found (no assessment)	<ul style="list-style-type: none">• Commercially breed amphibians for the pet trade• Use amphibians sustainably

Likely to be beneficial

● Reduce impact of amphibian trade

One review found that reducing trade through legislation allowed frog populations to recover from over-exploitation. *Assessment: likely to be beneficial (effectiveness 76%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/824>

Unknown effectiveness (limited evidence)

● **Use legislative regulation to protect wild populations**

One review found that legislation to reduce trade resulted in the recovery of frog populations. One study in South Africa found that the number of permits issued for scientific and educational use of amphibians increased from 1987 to 1990. *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 30%; harms 5%).*

<http://www.conservationevidence.com/actions/785>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Commercially breed amphibians for the pet trade
- Use amphibians sustainably

1.5.2 Logging and wood harvesting

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for logging and wood harvest?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Retain riparian buffer strips during timber harvest ● Use shelterwood harvesting instead of clearcutting
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Leave coarse woody debris in forests
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Use patch retention harvesting instead of clearcutting
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Leave standing deadwood/snags in forests ● Use leave-tree harvesting instead of clearcutting
Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Harvest groups of trees instead of clearcutting ● Thin trees within forests

Likely to be beneficial

● Retain riparian buffer strips during timber harvest

Six replicated and/or controlled studies in Canada and the USA compared amphibian numbers following clearcutting with or without riparian buffer strips. Five found mixed effects and one found that abundance was higher with riparian buffers. Two of four replicated studies, including one randomized, controlled, before-and-after study, in Canada and the USA found that numbers of species and abundance were greater in wider buffer strips. Two found no effect of buffer width. *Assessment: likely to be beneficial (effectiveness 50%; certainty 61%; harms 10%).*

<http://www.conservationevidence.com/actions/747>

● Use shelterwood harvesting instead of clearcutting

Three studies, including two randomized, replicated, controlled, before-and-after studies, in the USA found that compared to clearcutting, shelterwood harvesting resulted in higher or similar salamander abundance. One meta-analysis of studies in North America found that partial harvest, which included shelterwood harvesting, resulted in smaller reductions in salamander populations than clearcutting. *Assessment: likely to be beneficial (effectiveness 40%; certainty 57%; harms 10%).*

<http://www.conservationevidence.com/actions/851>

Trade-off between benefit and harms

● Leave coarse woody debris in forests

Two replicated, controlled studies in the USA found that abundance was similar in clearcuts with woody debris retained or removed for eight of nine amphibian species, but that the overall response of amphibians was more negative where woody debris was retained. Two replicated, controlled studies in the USA and Indonesia found that the removal of coarse woody debris from standing forest did not affect amphibian diversity or overall amphibian abundance, but did reduce species richness. One replicated, controlled study in the USA found that migrating amphibians used clearcuts where woody debris was retained more than where it was removed. One

replicated, site comparison study in the USA found that within clearcut forest, survival of juvenile amphibians was significantly higher within piles of woody debris than in open areas. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 60%; harms 26%).*

<http://www.conservationevidence.com/actions/843>

Unknown effectiveness (limited evidence)

● Use patch retention harvesting instead of clearcutting

We found no evidence for the effect of retaining patches of trees rather than clearcutting on amphibian populations. One replicated study in Canada found that although released red-legged frogs did not move towards retained tree patches, large patches were selected more and moved out of less than small patches. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/847>

Unlikely to be beneficial

● Leave standing deadwood/snags in forests

One randomized, replicated, controlled, before-and-after study in the USA found that compared to total clearcutting, leaving dead and wildlife trees did not result in higher abundances of salamanders. One randomized, replicated, controlled study in the USA found that numbers of amphibians and species were similar with removal or creation of dead trees within forest. *Assessment: unlikely to be beneficial (effectiveness 5%; certainty 58%; harms 2%).*

<http://www.conservationevidence.com/actions/845>

● Use leave-tree harvesting instead of clearcutting

Two studies, including one randomized, replicated, controlled, before-and-after study, in the USA found that compared to clearcutting, leaving a low density of trees during harvest did not result in higher salamander abundance. *Assessment: unlikely to be beneficial (effectiveness 10%; certainty 48%; harms 11%).*

<http://www.conservationevidence.com/actions/846>

Likely to be ineffective or harmful

● Harvest groups of trees instead of clearcutting

Three studies, including two randomized, replicated, controlled, before-and-after studies, in the USA found that harvesting trees in small groups resulted in similar amphibian abundance to clearcutting. One meta-analysis and one randomized, replicated, controlled, before-and-after study in North America and the USA found that harvesting, which included harvesting groups of trees, resulted in smaller reductions in salamander populations than clearcutting. *Assessment: likely to be ineffective or harmful (effectiveness 33%; certainty 60%; harms 23%).*

<http://www.conservationevidence.com/actions/844>

● Thin trees within forests

Six studies, including five replicated and/or controlled studies, in the USA compared amphibians in thinned to unharvested forest. Three found that thinning had mixed effects and one found no effect on abundance. One found that amphibian abundance increased following thinning but the body condition of ensatina salamanders decreased. One found a negative overall response of amphibians. Four studies, including two replicated, controlled studies, in the USA compared amphibians in thinned to clearcut forest. Two found that thinning had mixed effects on abundance and two found higher amphibian abundance or a less negative overall response of amphibians following thinning. One meta-analysis of studies in North America found that partial harvest, which included thinning, decreased salamander populations, but resulted in smaller reductions than clearcutting. *Assessment: likely to be ineffective or harmful (effectiveness 35%; certainty 60%; harms 40%).*

<http://www.conservationevidence.com/actions/852>

1.6 Threat: Human intrusions and disturbance

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for human intrusions and disturbance?

No evidence found (no assessment)	<ul style="list-style-type: none">• Use signs and access restrictions to reduce disturbance
--	---

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Use signs and access restrictions to reduce disturbance

1.7 Threat: Natural system modifications

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for natural system modifications?	
Beneficial	<ul style="list-style-type: none"> ● Regulate water levels
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Mechanically remove mid-storey or ground vegetation
Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Use herbicides to control mid-storey or ground vegetation ● Use prescribed fire or modifications to burning regime: forests ● Use prescribed fire or modifications to burning regime: grassland

Beneficial

● Regulate water levels

Three studies, including one replicated, site comparison study, in the UK and USA found that maintaining pond water levels, in two cases with other habitat management, increased or maintained amphibian populations or increased breeding success. One replicated, controlled study in Brazil found that keeping rice fields flooded after harvest did not change amphibian abundance or numbers of species, but changed species composition. One replicated, controlled study in the USA found that draining ponds

increased abundance and numbers of amphibian species. *Assessment: beneficial (effectiveness 70%; certainty 65%; harms 10%).*

<http://www.conservationevidence.com/actions/833>

Unknown effectiveness (limited evidence)

● Mechanically remove mid-storey or ground vegetation

One randomized, replicated, controlled study in the USA found that mechanical understory reduction increased numbers of amphibian species, but not amphibian abundance. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/781>

Likely to be ineffective or harmful

● Use herbicides to control mid-storey or ground vegetation

Three studies, including two randomized, replicated, controlled studies, in the USA found that understory removal using herbicide had no effect or negative effects on amphibian abundance. One replicated, site comparison study in Canada found that following logging, abundance was similar or lower in stands with herbicide treatment and planting compared to those left to regenerate naturally. *Assessment: likely to be ineffective or harmful (effectiveness 10%; certainty 50%; harms 50%).*

<http://www.conservationevidence.com/actions/778>

● Use prescribed fire or modifications to burning regime (forests)

Eight of 15 studies, including three randomized, replicated, controlled studies, in Australia, North America and the USA found no effect of prescribed forest fires on amphibian abundance or numbers of species. Four found that fires had mixed effects on abundance. Four found that abundance, numbers of species or hatching success increased and one that abundance decreased. *Assessment: likely to be ineffective or harmful (effectiveness 30%; certainty 58%; harms 40%).*

<http://www.conservationevidence.com/actions/877>



- **Use prescribed fire or modifications to burning regime (grassland)**

Two of three studies, including one replicated, before-and-after study, in the USA and Argentina found that prescribed fires in grassland decreased amphibian abundance or numbers of species. One found that spring, but not autumn or winter burns in grassland, decreased abundance. *Assessment: likely to be ineffective or harmful (effectiveness 10%; certainty 40%; harms 70%).*

<http://www.conservationevidence.com/actions/862>

1.8 Threat: Invasive and other problematic species

1.8.1 Reduce predation by other species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing predation by other species?	
Beneficial	<ul style="list-style-type: none"> ● Remove or control fish by drying out ponds
Likely to be beneficial	<ul style="list-style-type: none"> ● Remove or control fish population by catching ● Remove or control invasive bullfrogs ● Remove or control invasive viperine snake ● Remove or control mammals
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Remove or control fish using Rotenone
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Exclude fish with barriers
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Encourage aquatic plant growth as refuge against fish predation ● Remove or control non-native crayfish

Beneficial

● Remove or control fish by drying out ponds

One before-and-after study in the USA found that draining ponds to eliminate fish increased numbers of amphibian species. Four studies, including one review, in Estonia, the UK and USA found that pond drying

to eliminate fish, along with other management activities, increased amphibian abundance, numbers of species and breeding success. *Assessment: beneficial (effectiveness 80%; certainty 66%; harms 3%).*

<http://www.conservationevidence.com/actions/826>

Likely to be beneficial

● Remove or control fish population by catching

Four of six studies, including two replicated, controlled studies, in Sweden, the USA and UK found that removing fish by catching them increased amphibian abundance, survival and recruitment. Two found no significant effect on newt populations or toad breeding success. *Assessment: likely to be beneficial (effectiveness 50%; certainty 52%; harms 0%).*

<http://www.conservationevidence.com/actions/827>

● Remove or control invasive bullfrogs

Two studies, including one replicated, before-and-after study, in the USA and Mexico found that removing American bullfrogs increased the size and range of frog populations. One replicated, before-and-after study in the USA found that following bullfrog removal, frogs were found out in the open more. *Assessment: likely to be beneficial (effectiveness 79%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/825>

● Remove or control invasive viperine snake

One before-and-after study in Mallorca found that numbers of Mallorcan midwife toad larvae increased after intensive, but not less intensive, removal of viperine snakes. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/830>

● Remove or control mammals

One controlled study in New Zealand found that controlling rats had no significant effect on numbers of Hochstetter's frog. Two studies, one of which was controlled, in New Zealand found that predator-proof

enclosures enabled or increased survival of frog species. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/839>

Trade-off between benefit and harms

● **Remove or control fish using Rotenone**

Three studies, including one replicated study, in Sweden, the UK and USA found that eliminating fish using rotenone increased numbers of amphibians, amphibian species and recruitment. One review in Australia, the UK and USA found that fish control that included using rotenone increased breeding success. Two replicated studies in Pakistan and the UK found that rotenone use resulted in frog deaths and negative effects on newts. *Assessment: trade-offs between benefits and harms (effectiveness 65%; certainty 60%; harms 52%).*

<http://www.conservationevidence.com/actions/828>

Unknown effectiveness (limited evidence)

● **Exclude fish with barriers**

One controlled study in Mexico found that excluding fish using a barrier increased weight gain of axolotls. *Assessment: unknown effectiveness – limited evidence (effectiveness 30%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/829>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Encourage aquatic plant growth as refuge against fish predation
- Remove or control non-native crayfish.



1.8.2 Reduce competition with other species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing competition with other species?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Reduce competition from native amphibians • Remove or control invasive Cuban tree frogs
No evidence found (no assessment)	<ul style="list-style-type: none"> • Remove or control invasive cane toads

Unknown effectiveness (limited evidence)

● Reduce competition from native amphibians

One replicated, site comparison study in the UK found that common toad control did not increase natterjack toad populations. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/821>

● Remove or control invasive Cuban tree frogs

One before-and-after study in the USA found that removal of invasive Cuban tree frogs increased numbers of native frogs. *Assessment: unknown effectiveness – limited evidence (effectiveness 65%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/822>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Remove or control invasive cane toads.

1.8.3 Reduce adverse habitat alteration by other species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing adverse habitat alteration by other species?	
Likely to be beneficial	<ul style="list-style-type: none">• Control invasive plants
No evidence found (no assessment)	<ul style="list-style-type: none">• Prevent heavy usage/exclude wildfowl from aquatic habitat

Likely to be beneficial

● Control invasive plants

One before-and-after study in the UK found that habitat and species management that included controlling swamp stonecrop, increased a population of natterjack toads. One replicated, controlled study in the USA found that more Oregon spotted frogs laid eggs in areas where invasive reed canarygrass was mown. *Assessment: likely to be beneficial (effectiveness 60%; certainty 47%; harms 0%).*

<http://www.conservationevidence.com/actions/823>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Prevent heavy usage/exclude wildfowl from aquatic habitat.

1.8.4 Reduce parasitism and disease – chytridiomycosis

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing chytridiomycosis?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Use temperature treatment to reduce infection
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Use antifungal treatment to reduce infection
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Add salt to ponds ● Immunize amphibians against infection ● Remove the chytrid fungus from ponds ● Sterilize equipment when moving between amphibian sites ● Treating amphibians in the wild or pre-release ● Use gloves to handle amphibians
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Use antibacterial treatment to reduce infection ● Use antifungal skin bacteria or peptides to reduce infection
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Use zooplankton to remove zoospores

Likely to be beneficial

● Use temperature treatment to reduce infection

Four of five studies, including four replicated, controlled studies, in Australia, Switzerland and the USA found that increasing enclosure or water temperature to 30–37°C for over 16 hours cured amphibians of chytridiomycosis. One found that treatment did not cure frogs. *Assessment: likely to be beneficial (effectiveness 60%; certainty 70%; harms 10%).*

<http://www.conservationevidence.com/actions/770>

Trade-off between benefit and harms

● Use antifungal treatment to reduce infection

Twelve of 16 studies, including four randomized, replicated, controlled studies, in Europe, Australia, Tasmania, Japan and the USA found that

antifungal treatment cured or increased survival of amphibians with chytridiomycosis. Four studies found that treatments did not cure chytridiomycosis, but did reduce infection levels or had mixed results. Six of the eight studies testing treatment with itraconazole found that it was effective at curing chytridiomycosis. One found that it reduced infection levels and one found mixed effects. Six studies found that specific fungicides caused death or other negative side effects in amphibians. *Assessment: trade-offs between benefits and harms (effectiveness 71%; certainty 70%; harms 50%).*

<http://www.conservationevidence.com/actions/882>

Unknown effectiveness (limited evidence)

● Add salt to ponds

One study in Australia found that following addition of salt to a pond containing the chytrid fungus, a population of green and golden bell frogs remained free of chytridiomycosis for over six months. *Assessment: unknown effectiveness — limited evidence (effectiveness 41%; certainty 25%; harms 50%).*

<http://www.conservationevidence.com/actions/762>

● Immunize amphibians against infection

One randomized, replicated, controlled study in the USA found that vaccinating mountain yellow-legged frogs with formalin-killed chytrid fungus did not significantly reduce chytridiomycosis infection rate or mortality. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/765>

● Remove the chytrid fungus from ponds

One before-and-after study in Mallorca found that drying out a pond and treating resident midwife toads with fungicide reduced levels of infection but did not eradicate chytridiomycosis. *Assessment: unknown effectiveness — limited evidence (effectiveness 25%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/766>

● Sterilize equipment when moving between amphibian sites

We found no evidence for the effects of sterilizing equipment when moving between amphibian sites on the spread of disease between amphibian populations or individuals. Two randomized, replicated, controlled study in Switzerland and Sweden found that Virkon S disinfectant did not affect survival, mass or behaviour of eggs, tadpoles or hatchlings. However, one of the studies found that bleach significantly reduced tadpole survival. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 30%; harms 40%).*

<http://www.conservationevidence.com/actions/768>

● Treating amphibians in the wild or pre-release

One before-and-after study in Mallorca found that treating wild toads with fungicide and drying out the pond reduced infection levels but did not eradicate chytridiomycosis. *Assessment: unknown effectiveness — limited evidence (effectiveness 27%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/767>

● Use gloves to handle amphibians

We found no evidence for the effects of using gloves on the spread of disease between amphibian populations or individuals. A review for Canada and the USA found that there were no adverse effects of handling 22 amphibian species using disposable gloves. However, three replicated studies in Australia and Austria found that deaths of tadpoles were caused by latex, vinyl and nitrile gloves for 60–100% of species tested. *Assessment: unknown effectiveness — limited evidence (effectiveness 9%; certainty 35%; harms 65%).*

<http://www.conservationevidence.com/actions/769>

Unlikely to be beneficial

● Use antibacterial treatment to reduce infection

Two studies, including one randomized, replicated, controlled study, in New Zealand and Australia found that treatment with chloramphenicol antibiotic, with other interventions in some cases, cured frogs of chytridiomycosis. One replicated, controlled study found that treatment

with trimethoprim-sulfadiazine increased survival time but did not cure infected frogs. *Assessment: unlikely to be beneficial (effectiveness 38%; certainty 45%; harms 10%).*

<http://www.conservationevidence.com/actions/763>

● Use antifungal skin bacteria or peptides to reduce infection

Three of four randomized, replicated, controlled studies in the USA found that introducing antifungal bacteria to the skin of chytrid infected amphibians did not reduce infection rate or deaths. One found that it prevented infection and death. One randomized, replicated, controlled study in the USA found that adding antifungal skin bacteria to soil significantly reduced chytridiomycosis infection rate in salamanders. One randomized, replicated, controlled study in Switzerland found that treatment with antimicrobial skin peptides before or after infection with chytridiomycosis did not increase toad survival. *Assessment: unlikely to be beneficial (effectiveness 29%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/764>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Use zooplankton to remove zoospores

1.8.5 Reduce parasitism and disease – ranaviruses

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing ranaviruses?	
No evidence found (no assessment)	• Sterilize equipment to prevent ranaviruses

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Sterilize equipment to prevent ranaviruses.

1.9 Threat: Pollution

1.9.1 Agricultural pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for agricultural pollution?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Create walls or barriers to exclude pollutants● Plant riparian buffer strips● Reduce pesticide, herbicide or fertilizer use
No evidence found (no assessment)	<ul style="list-style-type: none">● Prevent pollution from agricultural lands or sewage treatment facilities entering watercourses

Unknown effectiveness (limited evidence)

● Create walls or barriers to exclude pollutants

One controlled study in Mexico found that installing filters across canals to improve water quality and exclude fish increased weight gain in axolotls. *Assessment: unknown effectiveness – limited evidence (effectiveness 35%; certainty 29%; harms 0%).*

<http://www.conservationevidence.com/actions/771>

● Plant riparian buffer strips

One replicated, controlled study in the USA found that planting buffer strips along streams did not increase amphibian abundance or numbers of species. *Assessment: unknown effectiveness – limited evidence (effectiveness 0%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/819>

● Reduce pesticide, herbicide or fertilizer use

One study in Taiwan found that halting pesticide use, along with habitat management, increased a population of frogs. *Assessment: unknown effectiveness — limited evidence (effectiveness 71%; certainty 26%; harms 0%).*

<http://www.conservationevidence.com/actions/832>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Prevent pollution from agricultural lands or sewage treatment facilities entering watercourses

1.9.2 Industrial pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for industrial pollution?	
Trade-off between benefit and harms	● Add limestone to water bodies to reduce acidification
No evidence found (no assessment)	● Augment ponds with ground water to reduce acidification

Trade-off between benefit and harms

● Add limestone to water bodies to reduce acidification

Five before-and-after studies, including one controlled, replicated study, in the Netherlands and UK found that adding limestone to ponds resulted in establishment of one of three translocated amphibian populations, a temporary increase in breeding and metamorphosis by natterjack toads and increased egg and larval survival of frogs. One replicated, site comparison study in the UK found that habitat management that included adding limestone to ponds increased natterjack toad populations. However, two before-and-after studies, including one controlled study, in the UK found that adding limestone to ponds resulted in increased numbers of abnormal

eggs, high tadpole mortality and pond abandonment. *Assessment: trade-offs between benefits and harms (effectiveness 47%; certainty 50%; harms 50%).*

<http://www.conservationevidence.com/actions/748>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Augment ponds with ground water to reduce acidification.

1.10 Threat: Climate change and severe weather

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for climate change and severe weather?	
Beneficial	<ul style="list-style-type: none"> • Deepen ponds to prevent desiccation (deepen, de-silt or re-profile)
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Use irrigation systems for amphibian sites (artificially mist habitat)
No evidence found (no assessment)	<ul style="list-style-type: none"> • Artificially shade ponds to prevent desiccation • Protect habitat along elevational gradients • Provide shelter habitat

Create microclimate and microhabitat refuges

Studies investigating the effects of creating refuges are discussed in ‘Habitat restoration and creation’ and ‘Threat: Biological resource use – Leave coarse woody debris in forests’.

Maintain ephemeral ponds

Studies investigating the effects of regulating water levels and deepening ponds are discussed in ‘Threat: Natural system modifications – Regulate water levels’ and ‘Habitat restoration and creation – Deepen, de-silt or re-profile ponds’.



Beneficial

● Deepen ponds to prevent desiccation

Four studies, including one replicated, controlled study, in France, Denmark and the UK found that pond deepening and enlarging or re-profiling resulted in establishment or increased populations of amphibians. Four before-and-after studies in Denmark and the UK found that pond deepening, along with other interventions, maintained newt or increased toad populations. *Assessment for 'Deepen, de-silt or re-profile ponds' from 'Habitat restoration and creation' section: beneficial (effectiveness 71%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/806>

Unknown effectiveness (limited evidence)

● Use irrigation systems for amphibian sites

One before-and-after study in Tanzania found that installing a sprinkler system to mitigate against a reduction of river flow did not maintain a population of Kihansi spray toads. *Assessment for 'Artificially mist habitat to keep it damp' from 'Threat: Energy production and mining' section: unknown effectiveness — limited evidence (effectiveness 24%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/804>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Artificially shade ponds to prevent desiccation
- Protect habitat along elevational gradients
- Provide shelter habitat.

1.11 Habitat protection

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat protection?	
Trade-off between benefit and harms	<ul style="list-style-type: none">● Retain buffer zones around core habitat
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Protect habitats for amphibians● Retain connectivity between habitat patches

Trade-off between benefit and harms

● Retain buffer zones around core habitat

Two studies, including one replicated, controlled study, in Australia and the USA found that retaining unmown buffers around ponds increased numbers of frog species, but had mixed effects on tadpole mass and survival. One replicated, site comparison study in the USA found that retaining buffers along ridge tops within harvested forest increased salamander abundance, body condition and genetic diversity. However, one replicated study in the USA found that 30 m buffer zones around wetlands were not sufficient to protect marbled salamanders. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 50%; harms 25%).*

<http://www.conservationevidence.com/actions/850>



Unknown effectiveness (limited evidence)

● Protect habitats for amphibians

One replicated, site comparison study in the UK found that statutory level habitat protection helped protect natterjack toad populations. One before-and-after study in the UK found that protecting a pond during development had mixed effects on populations of amphibians. *Assessment: unknown effectiveness – limited evidence (effectiveness 51%; certainty 31%; harms 9%).*

<http://www.conservationevidence.com/actions/820>

● Retain connectivity between habitat patches

One before-and-after study in Australia found that retaining native vegetation corridors maintained populations of frogs over 20 years. *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 31%; harms 0%).*

<http://www.conservationevidence.com/actions/853>

1.12 Habitat restoration and creation

1.12.1 Terrestrial habitat

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for terrestrial habitat restoration and creation?	
Beneficial	<ul style="list-style-type: none"> ● Replant vegetation
Likely to be beneficial	<ul style="list-style-type: none"> ● Clear vegetation ● Create artificial hibernacula or aestivation sites ● Create refuges ● Restore habitat connectivity
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Change mowing regime
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Create habitat connectivity

Beneficial

● Replant vegetation

Four studies, including one replicated study, in Australia, Spain and the USA found that amphibians colonized replanted forest, reseeded grassland and seeded and transplanted upland habitat. Three of four studies, including two replicated studies, in Australia, Canada, Spain and the USA found that areas planted with trees or grass had similar amphibian abundance

or community composition to natural sites and one found similar or lower abundance compared to naturally regenerated forest. One found that wetlands within reseeded grasslands were used less than those in natural grasslands. One before-and-after study in Australia found that numbers of frog species increased following restoration that included planting shrubs and trees. *Assessment: beneficial (effectiveness 70%; certainty 63%; harms 3%).*

<http://www.conservativevidence.com/actions/849>

Likely to be beneficial

● Clear vegetation

Seven studies, including four replicated studies, in Australia, Estonia and the UK found that vegetation clearance, along with other habitat management and in some cases release of amphibians, increased or maintained amphibian populations or increased numbers of frog species. However, great crested newt populations were only maintained for six years, but not in the longer term. *Assessment: likely to be beneficial (effectiveness 60%; certainty 54%; harms 10%).*

<http://www.conservativevidence.com/actions/761>

● Create artificial hibernacula or aestivation sites

Two replicated studies in the UK found that artificial hibernacula were used by two of three amphibian species and along with other terrestrial habitat management maintained populations of great crested newts. *Assessment: likely to be beneficial (effectiveness 50%; certainty 44%; harms 0%).*

<http://www.conservativevidence.com/actions/759>

● Create refuges

Two replicated, controlled studies, one of which was randomized, in the USA and Indonesia found that adding coarse woody debris to forest floors had no effect on the number of amphibian species or overall abundance, but had mixed effects on abundance of individual species. One before-and-after study in Australia found that restoration that included reintroducing coarse woody debris to the forest floor increased frog species. Three studies, including two replicated studies, in New Zealand, the UK and USA found that artificial refugia were used by amphibians and, along with

other interventions, maintained newt populations. *Assessment: likely to be beneficial (effectiveness 45%; certainty 55%; harms 0%).*

<http://www.conservationevidence.com/actions/772>

● Restore habitat connectivity

One before-and-after study in Italy found that restoring habitat connectivity by raising a road on a viaduct significantly decreased amphibian deaths. *Assessment: likely to be beneficial (effectiveness 75%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/840>

Unknown effectiveness (limited evidence)

● Change mowing regime

One before-and-after study in Australia found that restoration that included reduced mowing increased numbers of frog species. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/783>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Create habitat connectivity.

1.12.2 Aquatic habitat

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for aquatic habitat restoration and creation?	
Beneficial	<ul style="list-style-type: none">● Create ponds (amphibians in general)● Create ponds: frogs● Create ponds: natterjack toads● Create ponds: salamanders (including newts)● Create wetlands● Deepen, de-silt or re-profile ponds● Restore wetlands



Likely to be beneficial	<ul style="list-style-type: none"> ● Create ponds: great crested newts ● Create ponds: green toads ● Create ponds: toads ● Remove specific aquatic plants (invasive species) ● Restore ponds
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Remove tree canopy to reduce pond shading
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Add nutrients to new ponds as larvae food source ● Add specific plants to aquatic habitats ● Add woody debris to ponds ● Create refuge areas in aquatic habitats

Beneficial

● Create ponds (amphibians in general)

Twenty-eight studies investigated the colonization of created ponds by amphibians in general, all of which found that amphibians used all or some of the created ponds. Five of nine studies in Australia, Canada, Spain, the UK and USA found that numbers of species were similar or higher in created compared to natural ponds. Nine studies in Europe and the USA found that amphibians established stable populations, used or reproduced in created ponds. Four found that species composition differed, and abundance, juvenile productivity or size in created ponds depended on species. One study found that numbers of species were similar or lower in created ponds. Sixteen studies in Europe and the USA found that created ponds were used or colonized by up to 15 naturally colonizing species, up to 10 species that reproduced or by captive-bred amphibians. Five studies in Europe and the USA found that pond creation, with restoration in three cases, maintained and increased populations or increased species. *Assessment: beneficial (effectiveness 80%; certainty 80%; harms 0%).*

<http://www.conservationevidence.com/actions/869>

● **Create ponds (frogs)**

Six of nine studies in Australia, Italy, Spain, the UK and USA found that frogs established breeding populations or reproduced in created ponds. One study in Denmark found that frogs colonized created ponds. One study in the Netherlands found that pond creation, along with vegetation clearance, increased frog populations. One study in the USA found that survival increased with age of created ponds. *Assessment: beneficial (effectiveness 75%; certainty 70%; harms 0%).*

<http://www.conservationevidence.com/actions/865>

● **Create ponds (natterjack toads)**

Five studies in the UK and Denmark found that pond creation, along with other interventions, maintained or increased populations at 75–100% of sites. One study in the UK found that compared to natural ponds, created ponds had lower tadpole mortality from desiccation, but higher mortality from predation by invertebrates. *Assessment: beneficial (effectiveness 75%; certainty 70%; harms 10%).*

<http://www.conservationevidence.com/actions/866>

● **Create ponds (salamanders including newts)**

Three studies in France, Germany and the USA found that alpine newts, captive-bred smooth newts and translocated spotted salamanders established stable breeding populations in 20–100% of created ponds. Three studies in France, China and the USA found that alpine newts, Chinhai salamanders and translocated spotted salamanders, but not tiger salamanders, reproduced in created ponds. *Assessment: beneficial (effectiveness 70%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/867>

● **Create wetlands**

Fifteen studies, including one review and seven replicated studies, in Australia, Kenya and the USA, investigated the effectiveness of creating wetlands for amphibians. Six studies found that created wetlands had similar amphibian abundance, numbers of species or communities as natural wetlands or in one case adjacent forest. Two of those studies found that created wetlands had fewer amphibians, amphibian species and

different communities compared to natural wetlands. One global review and two other studies combined created and restored wetlands and found that amphibian abundance and numbers of species were similar or higher compared to natural wetlands. Five of the studies found that up to 15 amphibian species used created wetlands. One study found that captive-bred frogs did not establish in a created wetland. *Assessment: beneficial (effectiveness 75%; certainty 70%; harms 0%).*

<http://www.conservationevidence.com/actions/880>

● Deepen, de-silt or re-profile ponds

Four studies, including one replicated, controlled study, in France, Denmark and the UK found that pond deepening and enlarging or re-profiling resulted in establishment or increased populations of amphibians. Four before-and-after studies in Denmark and the UK found that pond deepening, along with other interventions, maintained newt or increased toad populations. *Assessment: beneficial (effectiveness 71%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/817>

● Restore wetlands

Seventeen studies, including one review and 11 replicated studies, in Canada, Taiwan and the USA, investigated the effectiveness of wetland restoration for amphibians. Seven of ten studies found that amphibian abundance, numbers of species and species composition were similar in restored and natural wetlands. Two found that abundance or numbers of species were lower and species composition different to natural wetlands. One found mixed results. One global review found that in 89% of cases, restored and created wetlands had similar or higher amphibian abundance or numbers of species to natural wetlands. Seven of nine studies found that wetland restoration increased numbers of amphibian species, with breeding populations establishing in some cases, and maintained or increased abundance of individual species. Three found that amphibian abundance or numbers of species did not increase with restoration. Three of the studies found that restored wetlands were colonized by up to eight amphibian species. *Assessment: beneficial (effectiveness 80%; certainty 73%; harms 0%).*

<http://www.conservationevidence.com/actions/879>

Likely to be beneficial

● Create ponds (great crested newts)

Three studies in Germany and the UK found that great crested newts established breeding populations in created ponds. One systematic review in the UK found that there was no conclusive evidence that mitigation, which often included pond creation, resulted in self-sustaining populations. Four studies in the UK found that great crested newts colonized up to 88% of, or reproduced in 38% of created ponds. *Assessment: likely to be beneficial (effectiveness 60%; certainty 61%; harms 0%).*

<http://www.conservationevidence.com/actions/863>

● Create ponds (green toads)

Two studies in Denmark found that pond creation, along with other interventions, significantly increased green toad populations. One study in Sweden found that green toads used or reproduced in 41–59% of created ponds. *Assessment: likely to be beneficial (effectiveness 73%; certainty 59%; harms 0%).*

<http://www.conservationevidence.com/actions/864>

● Create ponds (toads)

Five studies in Germany, Switzerland, the UK and USA found that toads established breeding populations or reproduced in 16–100% of created ponds. Two studies in Denmark and Switzerland found that wild but not captive-bred toads colonized 29–100% of created ponds. One study in Denmark found that creating ponds, along with other interventions, increased toad populations. *Assessments: likely to be beneficial (effectiveness 70%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/868>

● Remove specific aquatic plants

One before-and-after study in the UK found that habitat and species management that included controlling swamp stoncrop, increased a population of natterjack toads. One replicated, controlled study in the USA

found that more Oregon spotted frogs laid eggs in areas where invasive reed canarygrass was mown. *Assessment for 'Control invasive plants' from 'Threat: Invasive alien and other problematic species': likely to be beneficial (effectiveness 60%; certainty 47%; harms 0%).*

<http://www.conservationevidence.com/actions/815>

● Restore ponds

Fifteen studies investigated the effectiveness of pond restoration for amphibians. Three studies, including one replicated, controlled, before-and-after study in Denmark, the UK and USA found that pond restoration did not increase or had mixed effects on population numbers and hatching success. One replicated, before-and-after study in the UK found that restoration increased pond use. One replicated study in Sweden found that only 10% of restored ponds were used for breeding. Three before-and-after studies, including one replicated, controlled study, in Denmark and Italy found that restored and created ponds were colonized by up to seven species. Eight of nine studies, including one systematic review, in Denmark, Estonia, Italy and the UK found that pond restoration, along with other habitat management, maintained or increased populations, or increased pond occupancy, ponds with breeding success or numbers of amphibian species. One found that numbers of species did not increase and one found that great crested newt populations did not establish. *Assessment: likely to be beneficial (effectiveness 60%; certainty 63%; harms 0%).*

<http://www.conservationevidence.com/actions/878>

Unknown effectiveness (limited evidence)

● Remove tree canopy to reduce pond shading

One before-and-after study in the USA found that canopy removal did not increase hatching success of spotted salamanders. One before-and-after study in Denmark found that following pond restoration that included canopy removal, translocated toads established breeding populations. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/758>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Add nutrients to new ponds as larvae food source
- Add specific plants to aquatic habitats
- Add woody debris to ponds
- Create refuge areas in aquatic habitats.

1.13 Species management

Strict protocols should be followed when carrying out these interventions to minimise potential spread of disease-causing agents such as chytrid fungi and Ranavirus.

1.13.1 Translocate amphibians

Based on the collated evidence, what is the current assessment of the effectiveness of translocations?	
Likely to be beneficial	<ul style="list-style-type: none">● Translocate amphibians (amphibians in general)● Translocate amphibians (great crested newts)● Translocate amphibians (natterjack toads)● Translocate amphibians (salamanders including newts)● Translocate amphibians (toads)● Translocate amphibians (wood frogs)
Trade-off between benefit and harms	<ul style="list-style-type: none">● Translocate amphibians (frogs)

Likely to be beneficial

● Translocate amphibians (amphibians in general)

Overall, three global reviews and one study in the USA found that 65% of amphibian translocations that could be assessed resulted in established breeding populations or substantial recruitment to the adult population. A further two translocations resulted in breeding and one in survival following release. One review found that translocations of over 1,000

animals were more successful, but that success was not related to the source of animals (wild or captive), life-stage, continent or reason for translocation. *Assessment: likely to be beneficial (effectiveness 60%; certainty 60%; harms 19%).*

<http://www.conservationevidence.com/actions/854>

● **Translocate amphibians (great crested newts)**

Four of six studies in the UK found that translocated great crested newts maintained or established breeding populations. One found that populations survived at least one year in 37% of cases, but one found that within three years breeding failed in 48% of ponds. A systematic review of 31 studies found no conclusive evidence that mitigation that included translocations resulted in self-sustaining populations. One review found that newts reproduced following 56% of translocations, in some cases along with other interventions. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/858>

● **Translocate amphibians (natterjack toads)**

Three studies in France and the UK found that translocated natterjack toad eggs, tadpoles, juveniles or adults established breeding populations at some sites, although head-started or captive-bred animals were also released at some sites. Re-establishing toads on dune or saltmarsh habitat was more successful than on heathland. One study in the UK found that repeated translocations of wild rather than captive-bred toads were more successful. *Assessment: likely to be beneficial (effectiveness 60%; certainty 56%; harms 10%).*

<http://www.conservationevidence.com/actions/859>

● **Translocate amphibians (salamanders including newts)**

Four studies in the UK and USA found that translocated eggs or adults established breeding populations of salamanders or smooth newts. One study in the USA found that one of two salamander species reproduced following translocation of eggs, tadpoles and metamorphs. One study in the USA found that translocated salamander eggs hatched and tadpoles had similar survival rates as in donor ponds. *Assessment: likely to be beneficial (effectiveness 70%; certainty 55%; harms 0%).*

<http://www.conservationevidence.com/actions/860>

● Translocate amphibians (toads)

Two of four studies in Denmark, Germany, the UK and USA found that translocating eggs and/or adults established common toad breeding populations. One found populations of garlic toads established at two of four sites and one that breeding populations of boreal toads were not established. One study in Denmark found that translocating green toad eggs to existing populations, along with habitat management, increased population numbers. Four studies in Germany, Italy, South Africa and the USA found that translocated adult toads reproduced, survived up to six or 23 years, or some metamorphs survived over winter. *Assessment: likely to be beneficial (effectiveness 60%; certainty 56%; harms 10%).*

<http://www.conservationevidence.com/actions/855>

● Translocate amphibians (wood frogs)

Two studies in the USA found that following translocation of wood frog eggs, breeding populations were established in 25–50% of created ponds. One study in the USA found that translocated eggs hatched and up to 57% survived as tadpoles in pond enclosures. *Assessment: likely to be beneficial (effectiveness 40%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/856>

Trade-off between benefit and harms

● Translocate amphibians (frogs)

Eight of ten studies in New Zealand, Spain, Sweden, the UK and USA found that translocating frog eggs, juveniles or adults established breeding populations. Two found that breeding populations went extinct within five years or did not establish. Five studies in Canada, New Zealand and the USA found that translocations of eggs, juveniles or adults resulted in little or no breeding at some sites. Five studies in Italy, New Zealand and the USA found that translocated juveniles or adults survived the winter or up to eight years. One study in the USA found that survival was lower for Oregon spotted frogs translocated as adults compared to eggs. Two studies in the USA found that 60–100% of translocated frogs left the release site and 35–73% returned to their original pond within 32 days. Two studies in

found that frogs either lost or gained weight after translocation. *Assessment: trade-offs between benefits and harms (effectiveness 58%; certainty 65%; harms 20%).*

<http://www.conservationevidence.com/actions/861>

1.13.2 Captive breeding, rearing and releases

Based on the collated evidence, what is the current assessment of the effectiveness of captive breeding, rearing and releases?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Release captive-bred individuals (amphibians in general) ● Release captive-bred individuals: frogs
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Breed amphibians in captivity: frogs ● Breed amphibians in captivity: harlequin toads ● Breed amphibians in captivity: Mallorcan midwife toad ● Breed amphibians in captivity: salamanders (including newts) ● Breed amphibians in captivity: toads ● Head-start amphibians for release ● Release captive-bred individuals: Mallorcan midwife toads ● Release captive-bred individuals: toads ● Use artificial fertilization in captive breeding ● Use hormone treatment to induce sperm and egg release
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Release captive-bred individuals: salamanders (including newts)
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Freeze sperm or eggs for future use
Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Release captive-bred individuals: green and golden bell frogs

Likely to be beneficial

● Release captive-bred individuals (amphibians in general)

One review found that 41% of release programmes of captive-bred or head-started amphibians showed evidence of breeding in the wild for multiple generations, 29% showed some evidence of breeding and 12% evidence of survival following release. *Assessment: likely to be beneficial (effectiveness 55%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/871>

● Release captive-bred individuals (frogs)

Five of six studies in Europe, Hong Kong and the USA found that captive-bred frogs released as tadpoles, juveniles or adults established breeding populations and in some cases colonized new sites. Three studies in Australia and the USA found that a high proportion of frogs released as eggs survived to metamorphosis, some released tadpoles survived the first few months, but few released froglets survived. Four studies in Australia, Italy, the UK and USA found that captive-bred frogs reproduced at 31–100% of release sites, or that breeding was limited. *Assessment: likely to be beneficial (effectiveness 60%; certainty 60%; harms 15%).*

<http://www.conservationevidence.com/actions/870>

Trade-off between benefit and harms

● Breed amphibians in captivity (frogs)

Twenty-three of 33 studies across the world found that amphibians produced eggs in captivity. Seven found mixed results, with some species or populations reproducing successfully, but with other species difficult to maintain or raise to adults. Two found that frogs did not breed successfully or died in captivity. Seventeen of the studies found that captive-bred frogs were raised successfully to hatching, tadpoles, froglets or adults in captivity. Four studies in Canada, Fiji, Hong Kong and Italy found that 30–88% of eggs hatched, or survival to metamorphosis was 75%, as froglets was 17–51% or to adults was 50–90%. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 68%; harms 30%).*

<http://www.conservationevidence.com/actions/835>

● **Breed amphibians in captivity (harlequin toads)**

Four of five studies in Colombia, Ecuador, Germany and the USA found that harlequin toads reproduced in captivity. One found that eggs were only produced by simulating a dry and wet season and one found that breeding was difficult. One found that captive-bred harlequin toads were raised successfully to metamorphosis in captivity and two found that most toads died before or after hatching. *Assessment: trade-offs between benefits and harms (effectiveness 44%; certainty 50%; harms 28%).*

<http://www.conservationevidence.com/actions/836>

● **Breed amphibians in captivity (Mallorcan midwife toad)**

Two studies in the UK found that Mallorcan midwife toads produced eggs that were raised to metamorphs or toadlets in captivity. However, clutches dropped by males were not successfully maintained artificially. One study in the UK found that toads bred in captivity for nine or more generations had slower development, reduced genetic diversity and predator defence traits. *Assessment: trade-offs between benefits and harms (effectiveness 69%; certainty 55%; harms 40%).*

<http://www.conservationevidence.com/actions/837>

● **Breed amphibians in captivity (salamanders including newts)**

Four of six studies in Japan, Germany, the UK and USA found that eggs were produced successfully in captivity. Captive-bred salamanders were raised to yearlings, larvae or adults. One review found that four of five salamander species bred successfully in captivity. Four studies in Germany, Mexico and the USA found that egg production, larval development, body condition and survival were affected by water temperature, density or enclosure type. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 50%; harms 25%).*

<http://www.conservationevidence.com/actions/838>

● **Breed amphibians in captivity (toads)**

Ten studies in Germany, Italy, Spain, the UK and USA found that toads produced eggs in captivity. Eight found that toads were raised successfully to tadpoles, toadlets or adults in captivity. Two found that most died after

hatching or metamorphosis. Two reviews found mixed results with four species of toad or 21% of captive populations of Puerto Rican crested toads breeding successfully. Four studies in Germany, Spain and the USA found that reproductive success was affected by tank location and humidity. *Assessment: trade-offs between benefits and harms (effectiveness 65%; certainty 60%; harms 25%).*

<http://www.conservationevidence.com/actions/848>

● **Head-start amphibians for release**

Twenty-two studies head-started amphibians from eggs and monitored them after release. A global review and six of 10 studies in Europe and the USA found that released head-started tadpoles, metamorphs or juveniles established breeding populations or increased existing populations. Two found mixed results with breeding populations established in 71% of studies reviewed or at 50% of sites. Two found that head-started metamorphs or adults did not establish a breeding population or prevent a population decline. An additional 10 studies in Australia, Canada, Europe and the USA measured aspects of survival or breeding success of released head-started amphibians and found mixed results. Three studies in the USA only provided results for head-starting in captivity. Two of those found that eggs could be reared to tadpoles, but only one successfully reared adults. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 60%; harms 25%).*

<http://www.conservationevidence.com/actions/881>

● **Release captive-bred individuals (Mallorcan midwife toad)**

Three studies in Mallorca found that captive-bred midwife toads released as tadpoles, toadlets or adults established breeding populations at 38–100% of sites. One study in the UK found that predator defences were maintained, but genetic diversity was reduced in a captive-bred population. *Assessment: trade-offs between benefits and harms (effectiveness 68%; certainty 58%; harms 20%).*

<http://www.conservationevidence.com/actions/873>

● **Release captive-bred individuals (toads)**

Two of three studies in Denmark, Sweden and the USA found that captive-bred toads released as tadpoles, juveniles or metamorphs established populations. The other found that populations were not established. Two studies in Puerto Rico found that survival of released captive-bred Puerto Rican crested toads was low. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 50%; harms 20%).*

<http://www.conservationevidence.com/actions/875>

● **Use artificial fertilization in captive breeding**

Three replicated studies, including two randomized studies, in Australia and the USA found that the success of artificial fertilization depended on the type and number of doses of hormones used to stimulate egg production. One replicated study in Australia found that 55% of eggs were fertilized artificially, but soon died. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 40%; harms 20%).*

<http://www.conservationevidence.com/actions/834>

● **Use hormone treatment to induce sperm and egg release**

One review and nine of 10 replicated studies, including two randomized, controlled studies, in Austria, Australia, China, Latvia, Russia and the USA found that hormone treatment of male amphibians stimulated or increased sperm production, or resulted in successful breeding. One found that hormone treatment of males and females did not result in breeding. One review and nine of 14 replicated studies, including six randomized and/or controlled studies, in Australia, Canada, China, Ecuador, Latvia and the USA found that hormone treatment of female amphibians had mixed results, with 30–71% of females producing viable eggs following treatment, or with egg production depending on the combination, amount or number of doses of hormones. Three found that hormone treatment stimulated egg production or successful breeding. Two found that treatment did not stimulate or increase egg production. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 65%; harms 30%).*

<http://www.conservationevidence.com/actions/883>

Unknown effectiveness (limited evidence)

● Release captive-bred individuals (salamanders including newts)

One study in Germany found that captive-bred great crested newts and smooth newts released as larvae, juveniles and adults established stable breeding populations. *Assessment: unknown effectiveness — limited evidence (effectiveness 70%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/874>

Unlikely to be beneficial

● Freeze sperm or eggs for future use

Ten replicated studies, including three controlled studies, in Austria, Australia, Russia, the UK and USA found that following freezing, viability of amphibian sperm, and in one case eggs, depended on species, cryoprotectant used, storage temperature or method and freezing or thawing rate. One found that sperm could be frozen for up to 58 weeks. *Assessment: unlikely to be beneficial (effectiveness 35%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/876>

Likely to be ineffective or harmful

● Release captive-bred individuals (green and golden bell frogs)

Three studies in Australia found that captive-bred green and golden bell frogs released mainly as tadpoles did not established breeding populations, or only established breeding populations in 25% of release programmes. One study in Australia found that some frogs released as tadpoles survived at least 13 months. *Assessment: likely to be ineffective or harmful (effectiveness 20%; certainty 50%; harms 20%).*

<http://www.conservationevidence.com/actions/872>

1.14 Education and awareness raising

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for education and awareness raising?	
Likely to be beneficial	<ul style="list-style-type: none">● Engage volunteers to collect amphibian data (citizen science)● Provide education programmes about amphibians● Raise awareness amongst the general public through campaigns and public information

Likely to be beneficial

● Engage volunteers to collect amphibian data (citizen science)

Five studies in Canada, the UK and USA found that amphibian data collection projects engaged up to 10,506 volunteers and were active in 16–17 states in the USA. Five studies in the UK and USA found that volunteers surveyed up to 7,872 sites, swabbed almost 6,000 amphibians and submitted thousands of amphibian records. *Assessment: likely to be beneficial (effectiveness 66%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/760>

● Provide education programmes about amphibians

One study in Taiwan found that education programmes about wetlands and amphibians, along with other interventions, doubled a population of Taipei frogs. Four studies, including one replicated study, in Germany, Mexico,



Slovenia, Zimbabwe and the USA found that education programmes increased the amphibian knowledge of students. *Assessment: likely to be beneficial (effectiveness 58%; certainty 55%; harms 0%).*

<http://www.conservationevidence.com/actions/776>

● **Raise awareness amongst the general public through campaigns and public information**

Two studies, including one replicated, before-and-after study, in Estonia and the UK found that raising public awareness, along with other interventions, increased amphibian breeding habitat and numbers of toads. One before-and-after study in Mexico found that raising awareness in tourists increased their knowledge of axolotls. However, one study in Taiwan found that holding press conferences had no effect on a frog conservation project. *Assessment: likely to be beneficial (effectiveness 60%; certainty 51%; harms 0%).*

<http://www.conservationevidence.com/actions/831>

2. BAT CONSERVATION

**Anna Berthinussen, Olivia C. Richardson, Rebecca K. Smith,
John D. Altringham & William J. Sutherland**

Expert assessors

John Altringham, University of Leeds, UK

James Aegerter, Animal and Plant Health Agency, UK

Kate Barlow, Bat Conservation Trust, UK

Anna Berthinussen, University of Leeds, UK

Fabio Bontadina, SWILD – Urban Ecology & Wildlife Research, Switzerland

David Bullock, National Trust, UK

Paul Cryan, Fort Collins Science Center, US Geological Survey

Brock Fenton, University of Western Ontario, Canada

Anita Glover, University of Leeds, UK

Joanne Hodgkins, National Trust, UK

David Jacobs, University of Cape Town, South Africa

Bradley Law, Forest Science Centre, New South Wales Department of Primary Industries, Australia

Christoph Meyer, Centre for Environmental Biology, Portugal

Kirsty Park, University of Stirling, UK

Guido Reiter, Co-ordination Centre for Bat Conservation and Research in Austria

Danilo Russo, Federico II University of Naples, Italy

Rebecca K. Smith, University of Cambridge, UK

Matt Struebig, University of Kent, UK

Christian Voigt, Freie Universität Berlin, Germany

Michael Willig, University of Connecticut, USA

Scope of assessment: for native wild bat species across the world.

Assessed: 2015.

Effectiveness measure is the median % score for effectiveness.

Certainty measure is the median % certainty of evidence for effectiveness, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects to the group of species of concern.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

2.1 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Protect brownfield sites • Provide foraging habitat in urban areas
No evidence found (no assessment)	<ul style="list-style-type: none"> • Change timing of building works • Conserve existing roosts within developments • Conserve old buildings or structures as roosting sites for bats within developments • Create alternative roosts within buildings • Maintain bridges and retain crevices for roosting • Retain or relocate access points to bat roosts • Retain or replace existing bat commuting routes within development

Unknown effectiveness (limited evidence)

● Protect brownfield sites

One study in the USA found bat activity within an urban wildlife refuge on an abandoned manufacturing site to be consistent with predictions across North America based on the availability of potential roosts. *Assessment: unknown effectiveness (effectiveness 40%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/953>

● Provide foraging habitat in urban areas

One site comparison study in the USA found higher bat activity in restored forest preserves in urban areas than in an unrestored forest preserve. One replicated, controlled, site comparison study in the UK found higher bat activity over green roofs in urban areas than conventional unvegetated roofs. *Assessment: unknown effectiveness (effectiveness 50%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/954>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Change timing of building works
- Conserve existing roosts within developments
- Conserve old buildings or structures as roosting sites for bats within developments
- Create alternative roosts within buildings
- Maintain bridges and retain crevices for roosting
- Retain or relocate access points to bat roosts
- Retain or replace existing bat commuting routes within development

2.2 Threat: Agriculture

2.2.1 Land use change

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for land use change?	
Likely to be beneficial	<ul style="list-style-type: none">● Protect or create wetlands as foraging habitat for bats
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Retain or plant trees on agricultural land to replace foraging habitat for bats
No evidence found (no assessment)	<ul style="list-style-type: none">● Conserve old buildings or structures on agricultural land as roosting sites for bats● Retain old or dead trees with hollows and cracks as roosting sites for bats on agricultural land● Retain or replace existing bat commuting routes on agricultural land

Likely to be beneficial

● Protect or create wetlands as foraging habitat for bats

We found no evidence for the effects of protecting existing wetlands. One replicated, controlled, site comparison study in the USA found higher bat activity over heliponds and drainage ditches within a pine plantation than over natural wetlands. A replicated study in Germany found high levels of bat activity over constructed retention ponds compared to nearby vineyard

sites, but comparisons were not made with natural pond sites. *Assessment: likely to be beneficial (effectiveness 60%; certainty 48%; harms 0%).*

<http://www.conservationevidence.com/actions/959>

Unknown effectiveness (limited evidence)

● Retain or plant trees on agricultural land to replace foraging habitat for bats

We found no evidence for the effects of retaining trees as foraging habitat for bats. Two site comparison studies (one replicated) in Australia found no difference in bat activity and the number of bat species in agricultural areas revegetated with native plantings and over grazing land without trees. In both studies, bat activity was lower in plantings than in original forest and woodland remnants. *Assessment: unknown effectiveness (effectiveness 20%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/958>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Conserve old buildings or structures on agricultural land as roosting sites for bats
- Retain old or dead trees with hollows and cracks as roosting sites for bats on agricultural land
- Retain or replace existing bat commuting routes on agricultural land

2.2.2 Intensive farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for intensive farming?	
Likely to be beneficial	<ul style="list-style-type: none">● Convert to organic farming● Encourage agroforestry
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Introduce agri-environment schemes

Likely to be beneficial

● Convert to organic farming

Four replicated, paired, site comparison studies on farms in the UK had inconsistent results. Two studies found higher bat abundance and activity on organic farms than conventional farms, and two studies showed no difference in bat abundance between organic and non-organic farms. *Assessment: likely to be beneficial (effectiveness 40%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/961>

● Encourage agroforestry

Four replicated, site comparison studies (three in Mexico and one in Costa Rica) found no difference in bat diversity, the number of bat species and/or bat abundance between cacao, coffee or banana agroforestry plantations and native rainforest. One replicated, site comparison study in Mexico found higher bat diversity in native forest fragments than in coffee agroforestry plantations. One replicated, randomized, site comparison study in Costa Rica found lower bat diversity in native rainforest than in cacao agroforestry plantations. A replicated, site comparison study in Mexico found that bat diversity in coffee agroforestry plantations and native rainforest was affected by the proportion of each habitat type within the landscape. Three studies found that increasing management intensity on agroforestry plantations had a negative effect on some bat species, and a positive effect on others. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/963>

Unknown effectiveness (limited evidence)

● Introduce agri-environment schemes

One replicated, paired study in Scotland, UK found lower bat activity on farms participating in agri-environment schemes than on non-participating conventional farms. *Assessment: unknown effectiveness (effectiveness 0%; certainty 18%; harms 13%).*

<http://www.conservationevidence.com/actions/962>

2.3 Threat: Energy production – wind turbines

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for wind turbines?	
Beneficial	<ul style="list-style-type: none"> ● Switch off turbines at low wind speeds to reduce bat fatalities
Likely to be beneficial	<ul style="list-style-type: none"> ● Deter bats from turbines using ultrasound
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Deter bats from turbines using radar
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Automatically switch off wind turbines when bat activity is high ● Close off nacelles on wind turbines to prevent roosting bats ● Leave a minimum distance between turbines and habitat features used by bats ● Modify turbine design to reduce bat fatalities ● Modify turbine placement to reduce bat fatalities ● Remove turbine lighting to avoid attracting bats

Beneficial

● Switch off turbines at low wind speeds to reduce bat fatalities

Three replicated, controlled studies in Canada and the USA have shown that reducing the operation of wind turbines at low wind speeds causes a

reduction in bat fatalities. *Assessment: beneficial (effectiveness 80%; certainty 70%; harms 0%).*

<http://www.conservationevidence.com/actions/970>

Likely to be beneficial

● Deter bats from turbines using ultrasound

Five field studies at wind farms or pond sites (including one replicated, randomized, before-and-after trial), and one laboratory study, have all found lower bat activity or fewer bat deaths with ultrasonic deterrents than without. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 10%).*

<http://www.conservationevidence.com/actions/968>

Unknown effectiveness (limited evidence)

● Deter bats from turbines using radar

A replicated, site comparison study in the UK found reduced bat activity in natural habitats in proximity to electromagnetic fields produced by radars. We found no evidence for the effects of installing radars on wind turbines on bats. *Assessment: unknown effectiveness (effectiveness 20%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/967>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Automatically switch off wind turbines when bat activity is high
- Close off nacelles on wind turbines to prevent roosting bats
- Leave a minimum distance between turbines and habitat features used by bats
- Modify turbine design to reduce bat fatalities
- Modify turbine placement to reduce bat fatalities
- Remove turbine lighting to avoid attracting bats

2.4 Threat: Energy production – mining

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for mining?

No evidence found (no assessment)

- Legally protect bat hibernation sites in mines from reclamation
- Provide artificial hibernacula to replace roosts lost in reclaimed mines
- Relocate bats from reclaimed mines to new hibernation sites

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Legally protect bat hibernation sites in mines from reclamation
- Provide artificial hibernacula to replace roosts lost in reclaimed mines
- Relocate bats from reclaimed mines to new hibernation sites

2.5 Threat: Transportation and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for roads?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Install underpasses as road crossing structures for bats
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Divert bats to safe crossing points with plantings or fencing ● Install bat gantries or bat bridges as road crossing structures for bats ● Install overpasses as road crossing structures for bats
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Deter bats with lighting ● Install green bridges as road crossing structures for bats ● Install hop-overs as road crossing structures for bats ● Replace or improve habitat for bats around roads

Likely to be beneficial

● Install underpasses as road crossing structures for bats

Four studies (two replicated) in Germany, Ireland and the UK found varying proportions of bats to be using existing underpasses below roads and crossing over the road above. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/976>

Unknown effectiveness (limited evidence)

● **Divert bats to safe crossing points with plantings or fencing**

We found no evidence for the effects of diverting bats to safe road crossing points. One controlled, before-and-after study in Switzerland found that a small proportion of lesser horseshoe bats within a colony flew along an artificial hedgerow to commute. *Assessment: unknown effectiveness (effectiveness 10%; certainty 10%; harms 5%).*

<http://www.conservationevidence.com/actions/981>

● **Install bat gantries or bat bridges as road crossing structures for bats**

One replicated, site comparison study in the UK found fewer bats using bat gantries than crossing the road below at traffic height. *Assessment: unknown effectiveness (effectiveness 0%; certainty 35%; harms 0%).*

<http://www.conservationevidence.com/actions/978>

● **Install overpasses as road crossing structures for bats**

One replicated, site comparison study in Ireland did not find more bats using over-motorway routes than crossing over the road below. *Assessment: unknown effectiveness (effectiveness 0%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/977>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Deter bats with lighting
- Install green bridges as road crossing structures for bats
- Install hop-overs as road crossing structures for bats
- Replace or improve habitat for bats around roads

2.6 Threat: Biological resource use

2.6.1 Hunting

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for hunting?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Educate local communities about bats and hunting• Introduce and enforce legislation to control hunting of bats• Introduce sustainable harvesting of bats

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Educate local communities about bats and hunting
- Introduce and enforce legislation to control hunting of bats
- Introduce sustainable harvesting of bats

2.6.2 Guano harvesting

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for guano harvesting?	
No evidence found (no assessment)	<ul style="list-style-type: none"> • Introduce and enforce legislation to regulate the harvesting of bat guano • Introduce sustainable harvesting of bat guano

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Introduce and enforce legislation to regulate the harvesting of bat guano
- Introduce sustainable harvesting of bat guano

2.6.3 Logging and wood harvesting

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for logging and wood harvesting?	
Likely to be beneficial	<ul style="list-style-type: none"> • Incorporate forested corridors or buffers into logged areas • Use selective harvesting/reduced impact logging instead of clearcutting • Use shelterwood cutting instead of clearcutting
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Retain residual tree patches in logged areas • Thin trees within forests
No evidence found (no assessment)	<ul style="list-style-type: none"> • Manage woodland or forest edges for bats • Replant native trees • Retain deadwood/snags within forests for roosting bats

Likely to be beneficial

● Incorporate forested corridors or buffers into logged areas

One replicated, site comparison study in Australia found no difference in the activity and number of bat species between riparian buffers in logged, regrowth or mature forest. One replicated, site comparison study in North America found higher bat activity along the edges of forested corridors than in corridor interiors or adjacent logged stands. Three replicated, site comparison studies in Australia and North America found four bat species roosting in forested corridors and riparian buffers. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/996>

● Use selective harvesting/reduced impact logging instead of clearcutting

Nine replicated, controlled, site comparison studies provide evidence for the effects of selective or reduced impact logging on bats with mixed results. One study in the USA found that bat activity was higher in selectively logged forest than in unharvested forest. One study in Italy caught fewer barbastelle bats in selectively logged forest than in unmanaged forest. Three studies in Brazil and two in Trinidad found no difference in bat abundance or species diversity between undisturbed control forest and selectively logged or reduced impact logged forest, but found differences in species composition. Two studies in Brazil found no effect of reduced impact logging on the activity of the majority of bat species, but mixed effects on the activity of four species. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/989>

● Use shelterwood cutting instead of clearcutting

One site comparison study in North America found higher or equal activity of at least five bat species in shelterwood harvests compared to unharvested control sites. One replicated, site comparison study in Australia found Gould's long eared bats selectively roosting in shelterwood harvests, but southern forest bats roosting more often in mature unlogged forest. A replicated, site comparison study in Italy found barbastelle bats favoured

unmanaged woodland for roosting and used shelterwood harvested woodland in proportion to availability. *Assessment: likely to be beneficial (effectiveness 50%; certainty 48%; harms 18%).*

<http://www.conservationevidence.com/actions/990>

Unknown effectiveness (limited evidence)

● Retain residual tree patches in logged areas

Two replicated, site comparison studies in Canada found no difference in bat activity between residual tree patch edges in clearcut blocks and edges of the remaining forest. One of the studies found higher activity of smaller bat species at residual tree patch edges than in the centre of open clearcut blocks. Bat activity was not compared to unlogged areas. *Assessment: unknown effectiveness (effectiveness 20%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/995>

● Thin trees within forests

Two replicated, site comparison studies (one paired) in North America found that bat activity was higher in thinned forest stands than in unthinned stands, and similar to that in mature forest. One replicated, site comparison study in North America found higher bat activity in thinned than in unthinned forest stands in one of the two years of the study. One replicated, site comparison study in Canada found the silver-haired bat more often in clearcut patches than unthinned forest, but found no difference in the activity of *Myotis* species. *Assessment: unknown effectiveness (effectiveness 45%; certainty 38%; harms 10%).*

<http://www.conservationevidence.com/actions/991>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Manage woodland or forest edges for bats
- Replant native trees
- Retain deadwood/snags within forests for roosting bats

2.7 Threat: Human disturbance – caving and tourism

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for caving and tourism?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Impose restrictions on cave visits
Trade-offs between benefit and harms	<ul style="list-style-type: none"> ● Use cave gates to restrict public access
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Educate the public to reduce disturbance to hibernating bats ● Legally protect bat hibernation sites ● Maintain microclimate at underground hibernation/roost sites ● Provide artificial hibernacula for bats to replace disturbed sites

Likely to be beneficial

● Impose restrictions on cave visits

Two before-and-after studies from Canada and Turkey found that bat populations within caves increased after restrictions on cave visitors were imposed. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/1002>

Trade-off between benefit and harms

● Use cave gates to restrict public access

Ten studies in Europe, North America and Australia provide evidence for the effects of cave gating on bats, with mixed results. Four of the studies (one replicated) found more or equal numbers of bats in underground systems after gating. Two of the studies (one replicated) found reduced bat populations or incidences of cave abandonment after gating. Five studies (two replicated) provide evidence for changes in flight behaviour at cave gates. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 60%; harms 50%).*

<http://www.conservationevidence.com/actions/999>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Educate the public to reduce disturbance to hibernating bats
- Legally protect bat hibernation sites
- Maintain microclimate at underground hibernation/roost sites
- Provide artificial hibernacula for bats to replace disturbed sites

2.8 Threat: Natural system modification – natural fire and fire suppression

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for natural system modification?	
Trade-offs between benefit and harms	<ul style="list-style-type: none">● Use prescribed burning

Trade-off between benefit and harms

● Use prescribed burning

Four studies in North America looked at bat activity and prescribed burning. One replicated, controlled, site comparison study found no difference in bat activity between burned and unburned forest. One replicated, site comparison study found higher activity of bat species that forage in the open in burned than unburned stands. One site comparison study found higher bat activity in forest preserves when prescribed burning was used with other restoration practices. One controlled, replicated, before-and-after study found that the home ranges of bats were closer to burned stands following fires. Four studies in North America (three replicated and one controlled) found bats roosting more often in burned areas, or equally in burned and unburned forest. *Assessment: trade-offs between benefits and harms (effectiveness 65%; certainty 50%; harms 20%).*

<http://www.conservationevidence.com/actions/1006>

2.9 Threat: Invasive species

2.9.1 Invasive species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for invasive species?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Remove invasive plant species
Likely to be ineffective or harmful	<ul style="list-style-type: none">● Translocate to predator or disease free areas
No evidence found (no assessment)	<ul style="list-style-type: none">● Control invasive predators

Unknown effectiveness (limited evidence)

● Remove invasive plant species

One site comparison study in North America found higher bat activity in forest preserves where invasive plant species had been removed alongside other restoration practices. *Assessment: unknown effectiveness (effectiveness 20%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/1008>

Likely to be ineffective or harmful

● Translocate to predator or disease free areas

Two small unreplicated studies in New Zealand and Switzerland found low numbers of bats remaining at release sites after translocation, and observed homing tendencies, disease and death. *Assessment: Likely to be ineffective or harmful (effectiveness 5%; certainty 40%; harms 80%).*

<http://www.conservationevidence.com/actions/1009>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Control invasive predators

2.9.2 White-nose syndrome

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for white-nose syndrome?	
No evidence found (no assessment)	<ul style="list-style-type: none"> • Control anthropogenic spread • Cull infected bats • Increase population resistance • Modify cave environments to increase bat survival

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Control anthropogenic spread
- Cull infected bats
- Increase population resistance
- Modify cave environments to increase bat survival

2.10 Threat: Pollution

2.10.1 Domestic and urban waste water

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for domestic and urban waste water?

Unknown effectiveness (limited evidence)

- Change effluent treatments of domestic and urban waste water

Unknown effectiveness (limited evidence)

● **Change effluent treatments of domestic and urban waste water**

We found no evidence for the effects on bats of changing effluent treatments of domestic and urban waste water discharged into rivers. One replicated, site comparison study in the UK found that foraging activity over filter bed sewage treatment works was higher than activity over active sludge systems. *Assessment: unknown effectiveness (effectiveness 40%; certainty 30%; harms 30%).*

<http://www.conservationevidence.com/actions/1014>

2.10.2 Agricultural and forestry effluents

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for agricultural and forestry effluents?	
No evidence found (no assessment)	<ul style="list-style-type: none"> • Introduce legislation to control use of fertilizers, insecticides and pesticides • Change effluent treatments used in agriculture and forestry

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Introduce legislation to control use of fertilizers, insecticides and pesticides
- Change effluent treatments used in agriculture and forestry

2.10.3 Light and noise pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for light and noise pollution?	
Likely to be beneficial	<ul style="list-style-type: none"> • Leave bat roosts, roost entrances and commuting routes unlit • Minimize excess light pollution
No evidence found (no assessment)	<ul style="list-style-type: none"> • Restrict timing of lighting • Use low pressure sodium lamps or use UV filters • Impose noise limits in proximity to roosts and bat habitats

Likely to be beneficial

● **Leave bat roosts, roost entrances and commuting routes unlit**

Two replicated studies in the UK found more bats emerging from roosts or flying along hedgerows when left unlit than when illuminated with white lights or streetlamps. *Assessment: likely to be beneficial (effectiveness 80%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/1017>

● Minimize excess light pollution

One replicated, randomized, controlled study in the UK found that bats avoided flying along hedgerows with dimmed lighting, and activity levels were lower than along unlit hedges. We found no evidence for the effects of reducing light spill using directional lighting or hoods on bats. *Assessment: likely to be beneficial (effectiveness 65%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/1018>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restrict timing of lighting
- Use low pressure sodium lamps or use UV filters
- Impose noise limits in proximity to roosts and bat habitats

2.10.4 Timber treatments

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for timber treatments?	
Beneficial	● Use mammal safe timber treatments in roof spaces
Likely to be ineffective or harmful	● Restrict timing of treatment

Beneficial

● Use mammal safe timber treatments in roof spaces

Two controlled laboratory studies in the UK found commercial timber treatments (containing lindane and pentachlorophenol) to be lethal to bats, but found alternative artificial insecticides (including permethrin) and three other fungicides did not increase bat mortality. Sealants over timber treatments had varying success. *Assessment: likely to be beneficial (effectiveness 90%; certainty 80%; harms 0%).*

<http://www.conservationevidence.com/actions/1022>

Likely to be ineffective or harmful

● Restrict timing of treatment

One controlled laboratory experiment in the UK found that treating timber with lindane and pentachlorophenol 14 months prior to exposure by bats increased survival time but did not prevent death. Bats in cages treated with permethrin survived just as long when treatments were applied two months or 14 months prior to exposure. *Assessment: Likely to be ineffective or harmful (effectiveness 5%; certainty 55%; harms 50%).*

<http://www.conservationevidence.com/actions/1023>

2.11 Providing artificial roost structures for bats

Based on the collated evidence, what is the current assessment of the effectiveness of providing artificial roost structures for bats?

Likely to be beneficial

- Provide artificial roost structures for bats

Likely to be beneficial

● Provide artificial roost structures for bats

We found 22 replicated studies of artificial roost structures from across the world. Twenty-one studies show use of artificial roosts by bats. One study in the USA found that bats did not use the bat houses provided. Fifteen studies show varying occupancy rates of bats in artificial roost structures (3–100%). Two studies in Europe found an increase in bat populations using bat boxes in forest and woodland. Eight studies looked at bat box position. Three of four studies found that box orientation and exposure to sunlight are important for occupancy. Two studies found more bats occupying bat boxes on buildings than trees. Two studies found more bats occupying bat boxes in farm forestry or pine stands than in native or deciduous forest. Eleven studies looked at bat box design, including size, number of compartments and temperature, and found varying results. *Assessment: likely to be beneficial (effectiveness 60%; certainty 60%; harms 0%)*

<http://www.conservationevidence.com/actions/1024>

2.12 Education and awareness raising

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for education and awareness raising?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Provide training to professionals• Educate homeowners about building and planning laws• Educate to improve public perception and raise awareness

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide training to professionals
- Educate homeowners about building and planning laws
- Educate to improve public perception and raise awareness.

3. BIRD CONSERVATION

David R. Williams, Matthew F. Child, Lynn V. Dicks, Nancy Ockendon, Robert G. Pople, David A. Showler, Jessica C. Walsh, Erasmus K. H. J. zu Ermgassen & William J. Sutherland

Expert assessors

Tatsuya Amano, University of Cambridge, UK

Andy Brown, Natural England, UK

Fiona Burns, Royal Society for the Protection of Birds, UK

Yohay Carmel, Israel Institute of Technology

Mick Clout, University of Auckland, New Zealand

Geoff Hilton, Wildfowl & Wetlands Trust, UK

Nancy Ockendon, University of Cambridge, UK

James Pearce-Higgins, British Trust for Ornithology, UK

Sugoto Roy, Food and Environment Research Agency, DEFRA, UK

Rebecca K. Smith, University of Cambridge, UK

William J. Sutherland, University of Cambridge, UK

Judit Szabo, Charles Darwin University, Australia

Bernie Tershy, University of California, USA

Des Thomson, Scottish Natural Heritage, UK

Stuart Warrington, National Trust, UK

David Williams, University of Cambridge, UK

Scope of assessment: for native wild bird species across the world.

Assessed: 2015.

Effectiveness measure is the median % score.

Certainty measure is the median % certainty of evidence, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects to the group of species of concern. This was not scored for section 3.11 on invasive species.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

3.1 Habitat protection

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat protection?	
Likely to be beneficial	● Legally protect habitats
Trade-offs between benefit and harms	● Provide or retain un-harvested buffer strips
Unknown effectiveness (limited evidence)	● Ensure connectivity between habitat patches

Likely to be beneficial

● Legally protect habitats for birds

Four studies from Europe found that populations increased after habitat protection and a review from China found high use of protected habitats by cranes. A replicated, randomised and controlled study from Argentina found that some, but not all bird groups had higher species richness or were at higher densities in protected habitats. *Assessment: likely to be beneficial (effectiveness 50%; certainty 52%; harms 0%).*

<http://www.conservationevidence.com/actions/158>

Trade-off between benefit and harms

● Provide or retain un-harvested buffer strips

Three replicated studies from the USA found that species richness or abundances were higher in narrow (<100 m) strips of forest, but five

replicated studies from North America found that wider strips retained a community more similar to that of uncut forest than narrow strips. Two replicated studies from the USA found no differences in productivity between wide and narrow buffers, but that predation of artificial nests was higher in buffers than in continuous forest. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 55%; harms 20%).*

<http://www.conservationevidence.com/actions/161>

Unknown effectiveness (limited evidence)

● Ensure connectivity between habitat patches

Two studies of a replicated, controlled experiment in Canadian forests found that some species (not forest specialists) were found at higher densities in forest patches connected to continuous forest, compared to isolated patches and that some species used corridors more than clearcuts between patches. *Assessment: unknown effectiveness — limited evidence (effectiveness 38%; certainty 38%; harms 0%).*

<http://www.conservationevidence.com/actions/160>

3.2 Education and awareness raising

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for education and awareness raising?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Raise awareness amongst the general public through campaigns and public information
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Provide bird feeding materials to families with young children
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Enhance bird taxonomy skills through higher education and training ● Provide training to conservationists and land managers on bird ecology and conservation

Likely to be beneficial

- **Raise awareness amongst the general public through campaigns and public information**

A literature review from North America found that education was not sufficient to change behaviour, but that it was necessary for the success of economic incentives and law enforcement. *Assessment: likely to be beneficial (effectiveness 45%; certainty 48%; harms 0%).*

<http://www.conservationevidence.com/actions/162>

Unknown effectiveness (limited evidence)

● **Provide bird feeding materials to families with young children**

A single replicated, paired study from the USA found that most children involved in a programme providing families with bird food increased their knowledge of birds, but did not significantly change their environmental attitudes. *Assessment: unknown effectiveness – limited evidence (effectiveness 42%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/163>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Enhance bird taxonomy skills through higher education and training
- Provide training to conservationists and land managers on bird ecology and conservation

3.3 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Angle windows to reduce bird collisions• Mark windows to reduce bird collisions

Unknown effectiveness (limited evidence)

● Angle windows to reduce bird collisions

A single randomised, replicated and controlled experiment in the USA found that fewer birds collided with windows angled away from the vertical. *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/166>

● Mark windows to reduce bird collisions

Two randomised, replicated and controlled studies found that marking windows did not appear to reduce bird collisions. However, when windows were largely covered with white cloth, or tinted, fewer birds flew towards or collided with them. A third randomised, replicated and controlled study found that fewer birds collided with tinted windows than

Bird Conservation

with un-tinted ones, although the authors noted that the poor reflective quality of the glass could have influenced the results. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/167>

3.4 Threat: Agriculture

3.4.1 All farming systems

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for all farming systems?	
Beneficial	<ul style="list-style-type: none"> ● Plant wild bird seed or cover mixture ● Provide (or retain) set-aside areas in farmland
Likely to be beneficial	<ul style="list-style-type: none"> ● Create uncultivated margins around intensive arable or pasture fields ● Increase the proportion of natural/semi-natural habitat in the farmed landscape ● Manage ditches to benefit wildlife ● Pay farmers to cover the costs of conservation measures ● Plant grass buffer strips/margins around arable or pasture fields ● Plant nectar flower mixture/wildflower strips ● Leave refuges in fields during harvest ● Reduce conflict by deterring birds from taking crops: use bird scarers ● Relocate nests at harvest time to reduce nestling mortality ● Use mowing techniques to reduce mortality
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Control scrub on farmland ● Offer per clutch payment for farmland birds ● Manage hedges to benefit wildlife ● Plant new hedges ● Reduce conflict by deterring birds from taking crops: use repellents ● Take field corners out of management

Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Mark bird nests during harvest or mowing
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Cross compliance standards for all subsidy payments ● Food labelling schemes relating to biodiversity-friendly farming ● Manage stone-faced hedge banks to benefit birds ● Plant in-field trees ● Protect in-field trees ● Reduce field size (or maintain small fields) ● Support or maintain low-intensity agricultural systems ● Tree pollarding, tree surgery

Beneficial

● Plant wild bird seed or cover mixture

Seven of 41 studies found that fields or farms with wild bird cover had higher diversity than other sites, or that wild bird cover held more species than other habitats. Thirty-two studies found that populations, or abundances of some or all species were higher on wild bird cover than other habitats, or that wild bird cover was used more than other habitats. Four of these studies investigated several interventions at once. Thirteen studies found that bird populations or densities were similar on wild bird cover and other habitats that some species were not associated with wild bird cover, or that birds rarely used wild bird cover. Three studies found higher productivities of birds on wild bird cover than other habitats. Two found no differences for some or all species studied. Two studies found that survival of grey partridge or artificial nests increased on wild bird cover; one found lower partridge survival in farms with wild bird cover than other farms. Five studies from the UK found that some wild bird cover crops were used more than others. A study and a review found that the arrangement of wild bird cover in the landscape affected its use by birds. *Assessment: beneficial (effectiveness 81%; certainty 81%; harms 0%).*

<http://www.conservationevidence.com/actions/187>

● Provide (or retain) set-aside areas in farmland

Four out of 23 studies from Europe and North America found more species on set-aside than on crops. One study found fewer. Twenty-one studies found that some species were at higher densities on set-aside than other habitats, or that they used set-aside more often. Four found that some species were found at lower densities on set-aside than other habitats. Three studies found that waders and Eurasian skylarks had higher productivities on set-aside than other crops. One study found that skylarks on set-aside had lower similar or lower productivities than on crops. One study from the UK found that rotational set-aside was used more than non-rotational set-aside, another found no difference. A review from North America and Europe found that naturally regenerated set-aside held more birds and more species than sown set-aside. *Assessment: beneficial (effectiveness 70%; certainty 75%; harms 0%).*

<http://www.conservationevidence.com/actions/175>

Likely to be beneficial

● Create uncultivated margins around intensive arable or pasture fields

One of eight studies found that three sparrow species found on uncultivated margins on a site in the USA were not found on mown field edges. A replicated study from Canada found fewer species in uncultivated margins than in hedges or trees. Three studies found that some bird species were associated with uncultivated margins, or that birds were more abundant on margins than other habitats. One study found that these effects were very weak and four studies of three experiments found that uncultivated margins contained similar numbers of birds as other habitats in winter, or that several species studied did not show associations with margins. A study from the UK found that yellowhammers used uncultivated margins more than crops in early summer. Use fell in uncut margins later in the year. A study from the UK found that grey partridge released on uncultivated margins had high survival. *Assessment: likely to be beneficial (effectiveness 45%; certainty 55%; harms 0%).*

<http://www.conservationevidence.com/actions/190>

● **Increase the proportion of natural/semi-natural habitat in the farmed landscape**

Two studies from Switzerland and Australia, of the five we captured, found that areas with plantings of native species, or areas under a scheme designed to increase semi-natural habitats (the Swiss Ecological Compensation Areas scheme), held more bird species than other areas. One study from Switzerland found that populations of three bird species increased in areas under the Ecological Compensation Areas scheme. A third Swiss study found that some habitats near Ecological Compensation Areas held more birds than habitats further away, but the overall amount of Ecological Compensation Area had no effect on bird populations. A study from the UK found no effect of habitat-creation on grey partridge populations. *Assessment: likely to be beneficial (effectiveness 45%; certainty 44%; harms 0%).*

<http://www.conservationevidence.com/actions/171>

● **Manage ditches to benefit wildlife**

One study of four from the UK found that bunded ditches were visited more often by birds than non-bunded ditches. Three studies found that some birds responded positively to ditches managed for wildlife, but that other species did not respond to management, or responded negatively. *Assessment: likely to be beneficial (effectiveness 40%; certainty 49%; harms 14%).*

<http://www.conservationevidence.com/actions/180>

● **Pay farmers to cover the costs of conservation measures**

Three out of 31 studies found national population increases in three species after payment schemes targeted at their conservation. One found that many other species continued declining. Twenty-two studies found that at least some species were found at higher densities on sites with agri-environment schemes; some differences were present only in summer or only in winter. Fifteen studies found some species at similar densities on agri-environment schemes and non-agri-environment scheme sites or appeared to respond negatively to agri-environment schemes. One study found that grey partridge survival was higher in some years on agri-environment scheme sites. Two studies found higher productivity on agri-environment scheme sites for some species, one found no effect of agri-environment schemes. A review found that some agri-environment schemes options were not being used enough to benefit many species of bird. A study from the UK found

that there was no difference in the densities of seed-eating birds in winter between two agri-environment scheme designations. *Assessment: likely to be beneficial (effectiveness 56%; certainty 80%; harms 0%).*

<http://www.conservationevidence.com/actions/172>

● **Plant grass buffer strips/margins around arable or pasture fields**

One of 15 studies found more bird species in fields in the USA that were bordered by grass margins than in unbordered fields. Two studies from the UK found no effect of margins on species richness. One study found that more birds used grass strips in fields than used crops. Even more used grass margins. Nine studies from the USA and UK found that sites with grass margins had more positive population trends or higher populations for some birds, or that some species showed strong habitat associations with grass margins. Three studies found no such effect for some or all species. Two studies found that species used margins more than other habitats and one found that birds used cut margins more than uncut during winter, but less than other habitats during summer. A study from the UK found that grey partridge broods were smaller on grass margins than other habitat types. *Assessment: likely to be beneficial (effectiveness 47%; certainty 54%; harms 0%).*

<http://www.conservationevidence.com/actions/191>

● **Plant nectar flower mixture/wildflower strips**

Three of seven studies found that birds used wildflower strips more than other habitats; two found strips were not used more than other habitats. A study from Switzerland found that Eurasian skylarks were more likely to nest in patches sown with annual weeds than in crops and were less likely to abandon nests. A study from the UK found that management of field margins affected their use more than the seed mix used. *Assessment: likely to be beneficial (effectiveness 55%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/189>

● **Leave refuges in fields during harvest**

One study found that fewer gamebirds came into contact with mowing machinery when refuges were left in fields. A study from the UK found that Eurasian skylarks did not nest at higher densities in uncut refuges than

in the rest of the field. *Assessment: likely to be beneficial (effectiveness 50%; certainty 41%; harms 0%).*

<http://www.conservationevidence.com/actions/193>

● **Reduce conflict by deterring birds from taking crops (using bird scarers)**

A controlled paired study in the USA found reduced levels of damage to almond orchards when American crow distress calls were broadcast. A study in Pakistan found that four pest species were less abundant when reflector ribbons were hung above crops compared to where ribbons were not used. *Assessment: likely to be beneficial (effectiveness 66%; certainty 44%; harms 0%).*

<http://www.conservationevidence.com/actions/199>

● **Relocate nests at harvest time to reduce nestling mortality**

A study from Spain found that Montagu's harrier clutches had higher hatching and fledging rates when they were temporarily moved during harvest than control nests that were not moved. *Assessment: likely to be beneficial (effectiveness 55%; certainty 42%; harms 0%).*

<http://www.conservationevidence.com/actions/195>

● **Use mowing techniques to reduce mortality**

One of three studies from the UK found a large increase in the national population of corncrakes after a scheme to delay mowing and promote corncrake-friendly mowing techniques. Two studies found lower levels of corncrake and Eurasian skylark mortality when wildlife-friendly mowing techniques were used. *Assessment: likely to be beneficial (effectiveness 85%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/192>

Unknown effectiveness (limited evidence)

● **Control scrub on farmland**

A study from the UK found farms with a combined intervention that included scrub control had lower numbers of young grey partridge per

adult. *Assessment: unknown effectiveness — limited evidence (effectiveness 7%; certainty 9%; harms 1%).*

<http://www.conservationevidence.com/actions/197>

● Offer per clutch payment for farmland birds

One of two studies from the Netherlands found slightly higher breeding densities of waders on farms with per clutch payment schemes but this and another study found no higher numbers overall. One study found higher hatching success on farms with payment schemes. *Assessment: unknown effectiveness — limited evidence (effectiveness 43%; certainty 35%; harms 0%).*

<http://www.conservationevidence.com/actions/196>

● Manage hedges to benefit wildlife

One of seven studies found no differences in the number of species in a UK site with wildlife-friendly hedge management and sites without. Seven studies found that some species increased in managed hedges or were more likely to be found in them than other habitats. One investigated several interventions at the same time. Four studies found that some species responded negatively or not at all to hedge management or that effects varied across regions of the UK. *Assessment: unknown effectiveness — limited evidence (effectiveness 39%; certainty 38%; harms 3%).*

<http://www.conservationevidence.com/actions/177>

● Plant new hedges

A study from the USA found that populations of northern bobwhites increased following several interventions including the planting of new hedges. *Assessment: unknown effectiveness — limited evidence (effectiveness 23%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/178>

● Reduce conflict by deterring birds from taking crops (using repellents)

A replicated, randomised and controlled *ex situ* study in the USA found that dickcissels consumed less rice if it was treated with two repellents compared to controls. *Assessment: unknown effectiveness — limited evidence (effectiveness 29%; certainty 27%; harms 0%).*

<http://www.conservationevidence.com/actions/200>

● Take field corners out of management

A study from the UK found that overwinter survival of grey partridge was positively correlated with taking field corners out of management, but this relationship was only significant in one of three winters. There was no relationship with measures of productivity (brood size, young: adult). *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/198>

Likely to be ineffective or harmful

● Mark bird nests during harvest or mowing

A study from the Netherlands found that fewer northern lapwing nests were destroyed when they were marked with bamboo poles than when they were unmarked. *Assessment: likely to be ineffective or harmful (effectiveness 30%; certainty 45%; harms 20%).*

<http://www.conservationevidence.com/actions/148>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Cross compliance standards for all subsidy payments
- Food labelling schemes relating to biodiversity-friendly farming
- Manage stone-faced hedge banks to benefit birds
- Plant in-field trees
- Protect in-field trees
- Reduce field size (or maintain small fields)
- Support or maintain low-intensity agricultural systems
- Tree pollarding, tree surgery

3.4.2 Arable farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for arable farming systems?	
Likely to be beneficial	<ul style="list-style-type: none"> • Create 'skylark plots' • Leave overwinter stubbles • Leave uncropped cultivated margins or fallow land (includes lapwing and stone curlew plots) • Sow crops in spring rather than autumn • Undersow spring cereals, with clover for example
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Reduce tillage
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Implement mosaic management • Increase crop diversity to benefit birds • Plant more than one crop per field (intercropping)
Unlikely to be beneficial	<ul style="list-style-type: none"> • Create beetle banks
Likely to be ineffective or harmful	<ul style="list-style-type: none"> • Plant cereals in wide-spaced rows • Revert arable land to permanent grassland
No evidence found (no assessment)	<ul style="list-style-type: none"> • Add 1% barley into wheat crop for corn buntings • Create corn bunting plots • Leave unharvested cereal headlands within arable fields • Plant nettle strips

Likely to be beneficial

● Create 'skylark plots' (undrilled patches in cereal fields)

One study of seven found that the Eurasian skylark population on a farm increased after skylark plots were provided. Another found higher skylark densities on fields with plots in. Two studies from the UK found that skylark productivity was higher for birds with skylark plots in their territories, a study from Switzerland found no differences. Two studies from Denmark

and Switzerland found that skylarks used plots more than expected, but a study from the UK found that seed-eating songbirds did not. *Assessment: likely to be beneficial (effectiveness 65%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/214>

● **Leave overwinter stubbles**

Three of fourteen studies report positive population-level changes in two species after winter stubble provision. All investigated several interventions at once. Eight studies found that some farmland birds were found on stubbles or were positively associated with them, three investigated several interventions and one found no more positive associations than expected by chance. A study from the UK found that most species did not preferentially use stubble, compared to cover crops and another found that a greater area of stubble in a site meant lower grey partridge brood size. Five studies from the UK found that management of stubbles influenced their use by birds. One study found that only one species was more common on stubbles under agri-environment schemes. *Assessment: likely to be beneficial (effectiveness 40%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/203>

● **Leave uncropped cultivated margins or fallow land (includes lapwing and stone curlew plots)**

Three of nine studies report that the UK population of Eurasian thick-knees increased following a scheme to promote lapwing plots (and other interventions). A study from the UK found that plots did not appear to influence grey partridge populations. Four studies from the UK found that at least one species was associated with lapwing plots, or used them for foraging or nesting. One study found that 11 species were not associated with plots, another that fewer used plots than used crops in two regions of the UK. Two studies found that nesting success was higher on lapwing plots and fallow than in crops. A third found fewer grey partridge chicks per adult on sites with lots of lapwing plots. *Assessment: likely to be beneficial (effectiveness 59%; certainty 55%; harms 15%).*

<http://www.conservationevidence.com/actions/213>

● Sow crops in spring rather than autumn

One study from Sweden, of three examining the effects of spring-sown crops, found that more birds were found on areas with spring, rather than autumn-sown crops. A study from the UK found that several species used the study site for the first time after spring-sowing was started. All three studies found that some populations increased after the start of spring sowing. A study from the UK found that some species declined as well. A study from Sweden found that hatching success of songbirds and northern lapwing was lower on spring-sown, compared with autumn-sown crops. *Assessment: likely to be beneficial (effectiveness 55%; certainty 67%; harms 10%).*

<http://www.conservationevidence.com/actions/207>

● Undersow spring cereals, with clover for example

Four of five studies from the UK found that bird densities were higher on undersown fields or margins than other fields, or that use of fields increased if they were undersown. Two studies of the same experiment found that not all species nested at higher densities in undersown habitats. A study from the UK found that grey partridge populations were lower on sites with large amounts of undersown cereal. *Assessment: likely to be beneficial (effectiveness 60%; certainty 45%; harms 10%).*

<http://www.conservationevidence.com/actions/208>

Trade-off between benefit and harms

● Reduce tillage

Six of ten studies found that some or all bird groups had higher species richness or diversity on reduced-tillage fields, compared to conventional fields in some areas. Two studies found that some groups had lower diversity on reduced-tillage sites, or that there was no difference between treatments. Nine studies found that some species were found at higher densities on reduced tillage fields, six found that some species were at similar or lower densities. Three studies found evidence for higher productivities on reduced-tillage fields. One found that not all measures of productivity were higher. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 48%; harms 51%).*

<http://www.conservationevidence.com/actions/211>

Unknown effectiveness (limited evidence)

● Implement mosaic management

One of two studies from the Netherlands found that northern lapwing population trends, but not those of three other waders, became more positive following the introduction of mosaic management. The other found that black-tailed godwit productivity was higher under mosaic management than other management types. *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 33%; harms 0%).*

<http://www.conservationevidence.com/actions/130>

● Increase crop diversity to benefit birds

A study from the UK found that more barnacle geese used a site after the amount of land under cereals was decreased and several other interventions were used. *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/201>

● Plant more than one crop per field (intercropping)

A study from the USA found that 35 species of bird used fields with intercropping, with four nesting, but that productivity from the fields was very low. *Assessment: unknown effectiveness – limited evidence (effectiveness 30%; certainty 36%; harms 18%).*

<http://www.conservationevidence.com/actions/209>

Unlikely to be beneficial

● Create beetle banks

Two of six studies from the UK found that some bird populations were higher on sites with beetle banks. Both investigated several interventions at once. Two studies found no relationships between bird species abundances or populations and beetle banks. Two studies (including a review) from the

UK found that three bird species used beetle banks more than expected, one used them less than expected. *Assessment: unlikely to be beneficial (effectiveness 30%; certainty 41%; harms 0%).*

<http://www.conservationevidence.com/actions/217>

Likely to be ineffective or harmful

● Plant cereals in wide-spaced rows

One of three studies from the UK found that fields with wide-spaced rows held more Eurasian skylark nests than control fields. One study found that fields with wide-spaced rows held fewer nests. Both found that fields with wide-spaced rows held fewer nests than fields with skylark plots. A study from the UK found that skylark chicks in fields with wide-spaced rows had similar diets to those in control fields. *Assessment: likely to be ineffective or harmful (effectiveness 20%; certainty 44%; harms 20%).*

<http://www.conservationevidence.com/actions/216>

● Revert arable land to permanent grassland

All five studies looking at the effects of reverting arable land to grassland found no clear benefit to birds. The studies monitored birds in winter or grey partridges in the UK and wading birds in Denmark. They included three replicated controlled trials. *Assessment: likely to be ineffective or harmful (effectiveness 0%; certainty 64%; harms 10%).*

<http://www.conservationevidence.com/actions/210>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Add 1% barley into wheat crop for corn buntings
- Create corn bunting plots
- Leave unharvested cereal headlands within arable fields
- Plant nettle strips

3.4.3 Livestock farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for livestock farming systems?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Delay mowing date on grasslands ● Leave uncut rye grass in silage fields ● Maintain species-rich, semi-natural grassland ● Maintain traditional water meadows ● Mark fencing to avoid bird mortality ● Plant cereals for whole crop silage ● Reduce grazing intensity ● Reduce management intensity of permanent grasslands
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Exclude livestock from semi-natural habitat
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Create open patches or strips in permanent grassland ● Maintain upland heath/moor ● Protect nests from livestock to reduce trampling ● Provide short grass for waders ● Raise mowing height on grasslands
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Use traditional breeds of livestock
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Maintain lowland heathland ● Maintain rush pastures ● Maintain wood pasture and parkland ● Plant Brassica fodder crops ● Use mixed stocking

Likely to be beneficial

● Delay mowing date on grasslands

Two of five studies (both reviews) found that the UK corncrake populations increased following two schemes to encourage farmers to delay mowing. A study from the Netherlands found no evidence that waders and other birds were more abundant in fields with delayed mowing. Another study from

the Netherlands found that fields with delayed mowing held more birds than other fields, but differences were present before the scheme began and population trends did not differ between treatments. A study from the USA found that fewer nests were destroyed by machinery in late-cut fields, compared with early-cut fields. *Assessment: likely to be beneficial (effectiveness 45%; certainty 52%; harms 0%).*

<http://www.conservationevidence.com/actions/223>

● **Leave uncut rye grass in silage fields**

All four studies from the UK (including two reviews) found that seed-eating birds were benefited by leaving uncut (or once-cut) rye grass in fields, or that seed-eating species were more abundant on uncut plots. Three studies found that seed-eating birds were more abundant on uncut and ungrazed plots than on uncut and grazed plots. A study from the UK found that the responses of non-seed-eating birds were less certain than seed-eating species, with some species avoiding uncut rye grass. *Assessment: likely to be beneficial (effectiveness 67%; certainty 56%; harms 8%).*

<http://www.conservationevidence.com/actions/224>

● **Maintain species-rich, semi-natural grassland**

One of two studies found that the populations of five species increased in an area of the UK after the start of management designed to maintain unimproved grasslands. A study from Switzerland found that wetland birds nested at greater densities on managed hay meadows than expected, but birds of open farmland used hay meadows less. *Assessment: likely to be beneficial (effectiveness 41%; certainty 44%; harms 0%).*

<http://www.conservationevidence.com/actions/218>

● **Maintain traditional water meadows**

One of four studies (from the UK) found that the populations of two waders increased on reserves managed as water meadows. Two studies from the Netherlands found that there were more waders or birds overall on specially managed meadows or 12.5 ha plots, but one found that these differences were present before management began, the other found no differences between individual fields under different management. Two studies from the UK and Netherlands found that wader populations were

no different between specially and conventionally managed meadows, or that wader populations decreased on specially-managed meadows. A study from the UK found that northern lapwing productivity was not high enough to maintain populations on three of four sites managed for waders. *Assessment: likely to be beneficial (effectiveness 50%; certainty 52%; harms 0%).*

<http://www.conservationevidence.com/actions/229>

● **Mark fencing to avoid bird mortality**

A study from the UK found that fewer birds collided with marked sections of deer fences, compared to unmarked sections. *Assessment: likely to be beneficial (effectiveness 65%; certainty 46%; harms 0%).*

<http://www.conservationevidence.com/actions/238>

● **Plant cereals for whole crop silage**

Three studies of one experiment found that seed-eating birds used cereal-based wholecrop silage crops more than other crops in summer and winter. Insect-eating species used other crops and grassland more often. *Assessment: likely to be beneficial (effectiveness 55%; certainty 43%; harms 0%).*

<http://www.conservationevidence.com/actions/225>

● **Reduce grazing intensity**

Nine of eleven studies from the UK and USA found that the populations of some species were higher on fields with reduced grazing intensity, compared to conventionally-grazed fields, or found that birds used these fields more. Three studies investigated several interventions at once. Five studies from Europe found that some or all species were no more numerous, or were less abundant on fields with reduced grazing. A study from the UK found that black grouse populations increased at reduced grazing sites (whilst they declined elsewhere). However, large areas with reduced grazing had low female densities. A study from the USA found that the number of species on plots with reduced grazing increased over time. A study from four European countries found no differences in the number of species on sites with low- or high-intensity grazing. *Assessment: likely to be beneficial (effectiveness 46%; certainty 55%; harms 0%).*

<http://www.conservationevidence.com/actions/220>

● Reduce management intensity of permanent grasslands

Seven of eight European studies found that some or all birds studied were more abundant on grasslands with reduced management intensity, or used them more than other habitats for foraging. Five studies of four experiments found that some or all species were found at lower or similar abundances on reduced-management grasslands, compared to intensively-managed grasslands. *Assessment: likely to be beneficial (effectiveness 65%; certainty 46%; harms 0%).*

<http://www.conservationevidence.com/actions/219>

Trade-off between benefit and harms

● Exclude livestock from semi-natural habitat

Two studies from the USA, out of 11 overall, found higher species richness on sites with grazers excluded. A study from Argentina found lower species richness and one from the USA found no difference. Seven studies from the USA found that overall bird abundance, or the abundances of some species were higher in sites with grazers excluded. Seven studies from the USA and Argentina found that overall abundance or the abundance of some species were lower on sites without grazers, or did not differ. Three studies found that productivities were higher on sites with grazers excluded. In one, the difference was only found consistently in comparison with improved pastures, not unimproved. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 57%; harms 30%).*

<http://www.conservationevidence.com/actions/236>

Unknown effectiveness (limited evidence)

● Create open patches or strips in permanent grassland

A study from the UK found that Eurasian skylarks used fields with open strips in, but that variations in skylark numbers were too great to draw conclusions from this finding. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/239>

● **Maintain upland heath/moor**

A study from the UK found that bird populations in one region were increasing with agri-environment guidelines on moor management. There were some problems with overgrazing, burning and scrub encroachment. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/230>

● **Protect nests from livestock to reduce trampling**

One of two studies found that a population of Chatham Island oystercatchers increased following several interventions including the erection of fencing around individual nests. A study from Sweden found that no southern dunlin nests were trampled when protected by cages; some unprotected nests were destroyed. *Assessment: unknown effectiveness — limited evidence (effectiveness 56%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/237>

● **Provide short grass for waders**

A study from the UK found that common starlings and northern lapwing spent more time foraging on areas with short swards, compared to longer swards. *Assessment: unknown effectiveness — limited evidence (effectiveness 41%; certainty 32%; harms 0%).*

<http://www.conservationevidence.com/actions/221>

● **Raise mowing height on grasslands**

One of two studies from the UK found that no more foraging birds were attracted to plots with raised mowing heights, compared to plots with shorter grass. A review from the UK found that Eurasian skylarks had higher productivity on sites with raised mowing heights, but this increase was not enough to maintain local populations. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 36%; harms 0%).*

<http://www.conservationevidence.com/actions/222>

Unlikely to be beneficial

● Use traditional breeds of livestock

A study from four countries in Europe found no differences in bird abundances in areas grazed with traditional or commercial breeds. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 44%; harms 0%).*

<http://www.conservationevidence.com/actions/233>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain lowland heathland
- Maintain rush pastures
- Maintain wood pasture and parkland
- Plant Brassica fodder crops
- Use mixed stocking

3.4.4 Perennial, non-timber crops

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for perennial, non-timber crops?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Maintain traditional orchards
No evidence found (no assessment)	<ul style="list-style-type: none"> • Manage perennial bioenergy crops to benefit wildlife

Unknown effectiveness (limited evidence)

● Maintain traditional orchards

Two site comparison studies from the UK and Switzerland found that traditional orchards offer little benefit to birds. In Switzerland only one

breeding bird species was associated with traditional orchards. In the UK, the population density of circl bunting was negatively related to the presence of orchards. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 24%; harms 0%).*

<http://www.conservationevidence.com/actions/240>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Manage perennial bioenergy crops to benefit wildlife

3.4.5 Aquaculture

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for aquaculture?	
Likely to be beneficial	<ul style="list-style-type: none"> • Deter birds from landing on shellfish culture gear suspend oyster bags under water • Deter birds from landing on shellfish culture gear use spikes on oyster cages • Disturb birds at roosts • Provide refuges for fish within ponds • Use electric fencing to exclude fish-eating birds • Use ‘mussel socks’ to prevent birds from attacking shellfish • Use netting to exclude fish-eating birds
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Increase water turbidity to reduce fish predation by birds • Translocate birds away from fish farms • Use in-water devices to reduce fish loss from ponds
Unlikely to be beneficial	<ul style="list-style-type: none"> • Disturb birds using foot patrols • Spray water to deter birds from ponds
Likely to be ineffective or harmful	<ul style="list-style-type: none"> • Scare birds from fish farms

Likely to be beneficial

● Deter birds from landing on shellfish culture gear

A study from Canada found that fewer birds landed on oyster cages fitted with spikes than control cages. The same study found that fewer birds landed on oyster bags suspended 6 cm, but not 3 cm, underwater, compared to bags on the surface. *Assessment for using spikes on oyster cages: likely to be beneficial (effectiveness 60%; certainty 43%; harms 0%). Assessment for suspending oyster bags under water: likely to be beneficial (effectiveness 55%; certainty 43%; harms 0%).*

<http://www.conservationevidence.com/actions/257>

<http://www.conservationevidence.com/actions/256>

● Disturb birds at roosts

One study from the USA found reduced fish predation after fish-eating birds were disturbed at roosts. Five studies from the USA and Israel found that birds foraged less near disturbed roosts, or left the area after being disturbed. One found the effects were only temporary. *Assessment: likely to be beneficial (effectiveness 67%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/245>

● Provide refuges for fish within ponds

A study from the UK found that cormorants caught fewer fish in a pond with fish refuges in, compared to a control pond. *Assessment: likely to be beneficial (effectiveness 65%; certainty 43%; harms 0%).*

<http://www.conservationevidence.com/actions/253>

● Use electric fencing to exclude fish-eating birds

Two before-and-after trials from the USA found lower use of fish ponds by herons after electric fencing was installed. *Assessment: likely to be beneficial (effectiveness 60%; certainty 49%; harms 0%).*

<http://www.conservationevidence.com/actions/247>

● Use ‘mussel socks’ to prevent birds from attacking shellfish

A study from Canada found that mussel socks with protective sleeves lost fewer medium-sized mussels (but not small or large mussels), compared to unprotected mussel socks. *Assessment: likely to be beneficial (effectiveness 50%; certainty 41%; harms 0%).*

<http://www.conservationevidence.com/actions/250>

● Use netting to exclude fish-eating birds

Two studies from Germany and the USA, and a review, found that netting over ponds reduced the loss of fish to predatory birds. Two studies from the USA and the Netherlands found that birds still landed on ponds with netting, but that they altered their behaviour, compared to open ponds. Two studies from Germany and Israel found that some birds became entangled in netting over ponds. *Assessment: likely to be beneficial (effectiveness 60%; certainty 59%; harms 15%).*

<http://www.conservationevidence.com/actions/248>

Unknown effectiveness (limited evidence)

● Increase water turbidity to reduce fish predation by birds

An *ex situ* study from France found that egret foraging efficiency was reduced in more turbid water. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/252>

● Translocate birds away from fish farms

A study from the USA found that translocating birds appeared to reduce bird numbers at a fish farm. A study from Belgium found that it did not. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 33%; harms 0%).*

<http://www.conservationevidence.com/actions/251>

● Use in-water devices to reduce fish loss from ponds

A study from the USA found that fewer cormorants used two ponds after underwater ropes were installed; a study from Australia found that

no fewer cormorants used ponds with gill nets in. *Assessment: unknown effectiveness — limited evidence (effectiveness 34%; certainty 35%; harms 0%).*

<http://www.conservationevidence.com/actions/254>

Unlikely to be beneficial

● Disturb birds using foot patrols

Two replicated studies from Belgium and Australia found that using foot patrols to disturb birds from fish farms did not reduce the number of birds present or fish consumption. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/249>

● Spray water to deter birds from ponds

A study from Sweden found that spraying water deterred birds from fish ponds, but that some birds became habituated to the spray. *Assessment: unlikely to be beneficial (effectiveness 31%; certainty 43%; harms 0%).*

<http://www.conservationevidence.com/actions/255>

Likely to be ineffective or harmful

● Scare birds from fish farms

One study from Israel found a population increase in fish-eating birds after efforts to scare them from fish farms, possibly due to lower persecution. One of two studies found evidence for reduced loss of fish when birds were scared from farms. Two studies from Australia and Belgium found that disturbing birds using foot patrols was not effective. Ten of 11 studies from across the world found some effects for acoustic deterrents, five of seven found that visual deterrents were effective. In both cases some studies found that results were temporary, birds became habituated or that some deterrents were effective, whilst others were not. One study found that trained raptors were effective, one found little evidence for the effectiveness of helicopters or light aircraft. *Assessment: likely to be ineffective or harmful (effectiveness 36%; certainty 64%; harms 0%).*

<http://www.conservationevidence.com/actions/244>

3.5 Threat: Energy production and mining

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for energy production and mining?

Unknown effectiveness (limited evidence)

- Paint wind turbines to increase their visibility

Unknown effectiveness (limited evidence)

● **Paint wind turbines to increase their visibility**

A single, controlled *ex situ* experiment found that thick black stripes running across a wind turbine's blades made them more conspicuous to an American kestrel *Falco sparverius* than control (unpatterned) blades. Other designs were less visible or indistinguishable from controls. *Assessment: unknown effectiveness – limited evidence (effectiveness 16%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/258>

3.6 Threat: Transportation and service corridors

3.6.1 Verges and airports

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for verges and airports?	
Likely to be beneficial	• Scare or otherwise deter birds from airports
Unknown effectiveness (limited evidence)	• Mow roadside verges
No evidence found (no assessment)	• Sow roadside verges

Likely to be beneficial

● Scare or otherwise deter birds from airports

Two replicated studies in the UK and USA found that fewer birds used areas of long grass at airports, but no data were provided on the effect of long grass on strike rates or bird mortality. *Assessment: likely to be beneficial (effectiveness 50%; certainty 44%; harms 0%).*

<http://www.conservationevidence.com/actions/261>

Unknown effectiveness (limited evidence)

● Mow roadside verges

A single replicated, controlled trial in the USA found that mowed roadside verges were less attractive to ducks as nesting sites, but had higher nesting

success after four years. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 30%; harms 9%).*

<http://www.conservationevidence.com/actions/259>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Sow roadside verges

3.6.2 Power lines and electricity pylons

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for power lines and electricity pylons?	
Beneficial	<ul style="list-style-type: none">• Mark power lines
Likely to be beneficial	<ul style="list-style-type: none">• Bury or isolate power lines• Insulate electricity pylons• Remove earth wires from power lines• Use perch-deterrents to stop raptors perching on pylons
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Thicken earth wires
Unlikely to be beneficial	<ul style="list-style-type: none">• Add perches to electricity pylons• Reduce electrocutions by using plastic, not metal, leg rings to mark birds• Use raptor models to deter birds from power lines

Beneficial

● Mark power lines

A total of eight studies and two literature reviews from across the world found that marking power lines led to significant reductions in bird collision mortalities. Different markers had different impacts. *Assessment: beneficial (effectiveness 81%; certainty 85%; harms 0%).*

<http://www.conservationevidence.com/actions/265>



Likely to be beneficial

● Bury or isolate power lines

A single before-and-after study in Spain found a dramatic increase in juvenile eagle survival following the burial or isolation of dangerous power lines. *Assessment: likely to be beneficial (effectiveness 60%; certainty 44%; harms 0%).*

<http://www.conservationevidence.com/actions/262>

● Insulate electricity pylons

A single before-and-after study in the USA found that insulating power pylons significantly reduced the number of Harris's hawks electrocuted. *Assessment: likely to be beneficial (effectiveness 60%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/268>

● Remove earth wires from power lines

Two before-and-after studies from Norway and the USA describe significant reductions in bird collision mortalities after earth wires were removed from sections of power lines. *Assessment: likely to be beneficial (effectiveness 90%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/263>

● Use perch-deterrents to stop raptors perching on pylons

A single controlled study in the USA found that significantly fewer raptors were found near perch-deterrent lines, compared to controls, but no information on electrocutions was provided. *Assessment: likely to be beneficial (effectiveness 50%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/269>

Unknown effectiveness (limited evidence)

● Thicken earth wires

A single paired sites trial in the USA found no reduction in crane species collision rates in a wire span with an earth wire three times thicker than

normal. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/264>

Unlikely to be beneficial

● Add perches to electricity pylons

A single before-and-after study in Spain found that adding perches to electricity pylons did not reduce electrocutions of Spanish imperial eagles. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 42%; harms 0%).*

<http://www.conservationevidence.com/actions/267>

● Reduce electrocutions by using plastic, not metal, leg rings to mark birds

A single replicated and controlled study in the USA found no evidence that using plastic leg rings resulted in fewer raptors being electrocuted. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 42%; harms 0%).*

<http://www.conservationevidence.com/actions/270>

● Use raptor models to deter birds from power lines

A single paired sites trial in Spain found that installing raptor models near power lines had no impact on bird collision mortalities. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 43%; harms 0%).*

<http://www.conservationevidence.com/actions/266>

3.7 Threat: Biological resource use

3.7.1 Reducing exploitation and conflict

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing exploitation and conflict?	
Beneficial	<ul style="list-style-type: none"> ● Use legislative regulation to protect wild populations
Likely to be beneficial	<ul style="list-style-type: none"> ● Use wildlife refuges to reduce hunting disturbance
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Employ local people as 'biomonitors' ● Increase 'on-the-ground' protection to reduce unsustainable levels of exploitation ● Introduce voluntary 'maximum shoot distances' ● Mark eggs to reduce their appeal to collectors ● Move fish-eating birds to reduce conflict with fishermen ● Promote sustainable alternative livelihoods ● Provide 'sacrificial grasslands' to reduce conflict with farmers ● Relocate nestlings to reduce poaching ● Use education programmes and local engagement to help reduce persecution or exploitation of species
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Use alerts during shoots to reduce mortality of non-target species

Scare fish-eating birds from areas to reduce conflict

Studies investigating scaring fish from fishing areas are discussed in 'Threat: Agriculture — Aquaculture'.

Beneficial

● Use legislative regulation to protect wild populations

Five out of six studies from Europe, Asia, North America and across the world, found evidence that stricter legislative protection was correlated with increased survival, lower harvests or increased populations. The sixth, a before-and-after study from Australia, found that legislative protection did not reduce harvest rates. *Assessment: beneficial (effectiveness 65%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/271>

Likely to be beneficial

● Use wildlife refuges to reduce hunting disturbance

Three studies from the USA and Europe found that more birds used refuges where hunting was not allowed, compared to areas with hunting, and more used the refuges during the open season. However, no studies examined the population-level effects of refuges. *Assessment: likely to be beneficial (effectiveness 45%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/278>

Unknown effectiveness (limited evidence)

● Employ local people as 'biomonitors'

A single replicated study in Venezuela found that poaching of parrot nestlings was significantly lower in years following the employment of five local people as 'biomonitors'. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/275>

● Increase 'on-the-ground' protection to reduce unsustainable levels of exploitation

Two before-and-after studies from Europe and Central America found increases in bird populations and recruitment following stricter



anti-poaching methods or the stationing of a warden on the island in question. However, the increases in Central America were only short-term, and were lost when the intensive effort was reduced. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/272>

● **Introduce voluntary ‘maximum shoot distances’**

A single study from Denmark found a significant reduction in the injury rates of pink-footed geese following the implementation of a voluntary maximum shooting distance. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/279>

● **Mark eggs to reduce their appeal to collectors**

A single before-and-after study in Australia found increased fledging success of raptor eggs in a year they were marked with a permanent pen. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 35%; harms 0%).*

<http://www.conservationevidence.com/actions/276>

● **Move fish-eating birds to reduce conflict with fishermen**

A single before-and-after study in the USA found that Caspian tern chicks had a lower proportion of commercial fish in their diet following the movement of the colony away from an important fishery. *Assessment: unknown effectiveness — limited evidence (effectiveness 32%; certainty 24%; harms 0%).*

<http://www.conservationevidence.com/actions/281>

● **Promote sustainable alternative livelihoods**

A single before-and-after study in Costa Rica found that a scarlet macaw population increased following several interventions including the promotion of sustainable, macaw-based livelihoods. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/273>

● **Provide ‘sacrificial grasslands’ to reduce conflict with farmers**

Two UK studies found that more geese used areas of grassland managed for them, but that this did not appear to attract geese from outside the study site and therefore was unlikely to reduce conflict with farmers. *Assessment: unknown effectiveness — limited evidence (effectiveness 18%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/280>

● **Relocate nestlings to reduce poaching**

A single replicated study in Venezuela found a significant reduction in poaching rates and an increase in fledging rates of yellow-shouldered amazons when nestlings were moved into police premises overnight. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/277>

● **Use education programmes and local engagement to help reduce persecution or exploitation of species**

Six out of seven studies from across the world found increases in bird populations or decreases in mortality following education programmes, whilst one study from Venezuela found no evidence that poaching decreased following an educational programme. In all but one study reporting successes, other interventions were also used, and a literature review from the USA and Canada argues that education was not sufficient to change behaviour, although a Canadian study found that there was a significant shift in local peoples’ attitudes to conservation and exploited species following educational programmes. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/274>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use alerts during shoots to reduce mortality of non-target species

3.7.2 Reducing fisheries bycatch

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing fisheries bycatch?	
Beneficial	<ul style="list-style-type: none"> ● Use streamer lines to reduce seabird bycatch on longlines
Likely to be beneficial	<ul style="list-style-type: none"> ● Mark trawler warp cables to reduce seabird collisions ● Reduce seabird bycatch by releasing offal overboard when setting longlines ● Weight baits or lines to reduce longline bycatch of seabirds
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Set lines underwater to reduce seabird bycatch ● Set longlines at night to reduce seabird bycatch
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Dye baits to reduce seabird bycatch ● Thaw bait before setting lines to reduce seabird bycatch ● Turn deck lights off during night-time setting of longlines to reduce bycatch ● Use a sonic scarer when setting longlines to reduce seabird bycatch ● Use acoustic alerts on gillnets to reduce seabird bycatch ● Use bait throwers to reduce seabird bycatch ● Use bird exclusion devices such as 'Brickle curtains' to reduce seabird mortality when hauling longlines ● Use high visibility mesh on gillnets to reduce seabird bycatch ● Use shark liver oil to deter birds when setting lines
Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Use a line shooter to reduce seabird bycatch
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Reduce bycatch through seasonal or area closures ● Reduce 'ghost fishing' by lost/discarded gear ● Reduce gillnet deployment time to reduce seabird bycatch ● Set longlines at the side of the boat to reduce seabird bycatch

	<ul style="list-style-type: none">● Tow buoys behind longlining boats to reduce seabird bycatch● Use a water cannon when setting longlines to reduce seabird bycatch● Use high-visibility longlines to reduce seabird bycatch● Use larger hooks to reduce seabird bycatch on longlines
--	---

Beneficial

● Use streamer lines to reduce seabird bycatch on longlines

Ten studies from coastal and pelagic fisheries across the globe found strong evidence for reductions in bycatch when streamer lines were used. Five studies from the South Atlantic, New Zealand and Australia were inconclusive, uncontrolled or had weak evidence for reductions. One study from the sub-Antarctic Indian Ocean found no evidence for reductions. Three studies from around the world found that bycatch rates were lower when two streamers were used compared to one, and one study found rates were lower still with three streamers. *Assessment: beneficial (effectiveness 65%; certainty 75%; harms 0%).*

<http://www.conservationevidence.com/actions/285>

Likely to be beneficial

● Mark trawler warp cables to reduce seabird collisions

A single replicated and controlled study in Argentina found lower seabird mortality (from colliding with warp cables) when warp cables were marked with orange traffic cones. *Assessment: likely to be beneficial (effectiveness 54%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/305>

● Reduce seabird bycatch by releasing offal overboard when setting longlines

Two replicated and controlled studies in the South Atlantic and sub-Antarctic Indian Ocean found significantly lower seabird bycatch rates



when offal was released overboard as lines were being set. *Assessment: likely to be beneficial (effectiveness 51%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/299>

● **Weight baits or lines to reduce longline bycatch of seabirds**

Three replicated and controlled studies from the Pacific found lower bycatch rates of some seabird species on weighted longlines. An uncontrolled study found low bycatch rates with weighted lines but that weights only increased sink rates in small sections of the line. Some species were found to attack weighted lines more than control lines. *Assessment: likely to be beneficial (effectiveness 46%; certainty 45%; harms 15%).*

<http://www.conservationevidence.com/actions/296>

Trade-off between benefit and harms

● **Set lines underwater to reduce seabird bycatch**

Five studies in Norway, South Africa and the North Pacific found lower seabird bycatch rates on longlines set underwater. However, results were species-specific, with shearwaters and possibly albatrosses continuing to take baits set underwater. *Assessment: trade-offs between benefits and harms (effectiveness 61%; certainty 50%; harms 24%).*

<http://www.conservationevidence.com/actions/288>

● **Set longlines at night to reduce seabird bycatch**

Six out of eight studies from around the world found lower bycatch rates when longlines were set at night, but the remaining two found higher bycatch rates (of northern fulmar in the North Pacific and white-chinned petrels in the South Atlantic, respectively). Knowing whether bycatch species are night- or day-feeding is therefore important in reducing bycatch rates. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 70%; harms 48%).*

<http://www.conservationevidence.com/actions/283>

Unknown effectiveness (limited evidence)

● Dye baits to reduce seabird bycatch

A single randomised, replicated and controlled trial in Hawaii, USA, found that albatrosses attacked baits at significantly lower rates when baits were dyed blue. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/293>

● Thaw bait before setting lines to reduce seabird bycatch

A study from Australia found that longlines set using thawed baits caught significantly fewer seabirds than controls. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/298>

● Turn deck lights off during night-time setting of longlines to reduce bycatch

A single replicated and controlled study in the South Atlantic found lower seabird bycatch rates on night-set longlines when deck lights were turned off. *Assessment: unknown effectiveness — limited evidence (effectiveness 51%; certainty 21%; harms 0%).*

<http://www.conservationevidence.com/actions/284>

● Use a sonic scarer when setting longlines to reduce seabird bycatch

A single study from the South Atlantic found that seabirds only temporarily changed behaviour when a sonic scarer was used, and seabird bycatch rates did not appear to be lower on lines set with a scarer. *Assessment: unknown effectiveness — limited evidence (effectiveness 2%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/295>

● Use acoustic alerts on gillnets to reduce seabird bycatch

A randomised, replicated and controlled trial in a coastal fishery in the USA found that fewer guillemots (common murre) but not rhinoceros



auklets were caught in gillnets fitted with sonic alerts. *Assessment: unknown effectiveness — limited evidence (effectiveness 44%; certainty 21%; harms 0%).*

<http://www.conservationevidence.com/actions/301>

● **Use bait throwers to reduce seabird bycatch**

A single analysis found significantly lower seabird bycatch on Australian longliners when a bait thrower was used to set lines. *Assessment: unknown effectiveness — limited evidence (effectiveness 46%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/291>

● **Use bird exclusion devices such as ‘Brickle curtains’ to reduce seabird mortality when hauling longlines**

A single replicated study found that Brickle curtains reduced the number of seabirds caught, when compared to an exclusion device using only a single boom. Using purse seine buoys as well as the curtain appeared to be even more effective, but sample sizes did not allow useful comparisons. *Assessment: unknown effectiveness — limited evidence (effectiveness 48%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/302>

● **Use high visibility mesh on gillnets to reduce seabird bycatch**

A single randomised, replicated and controlled trial in a coastal fishery in the USA found that fewer guillemots (common murre) and rhinoceros auklets were caught in gillnets with higher percentages of brightly coloured netting. However, such netting also reduced the catch of the target salmon. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/303>

● **Use shark liver oil to deter birds when setting lines**

Two out of three replicated and controlled trials in New Zealand found that fewer birds followed boats or dived for baits when non-commercial shark oil was dripped off the back of the boat. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/297>

Likely to be ineffective or harmful

● Use a line shooter to reduce seabird bycatch

Two randomised, replicated and controlled trials found that seabird bycatch rates were higher (in the North Pacific) or the same (in Norway) on longlines set using line shooters, compared to those set without a shooter. *Assessment: likely to be ineffective or harmful (effectiveness 0%; certainty 50%; harms 40%).*

<http://www.conservationevidence.com/actions/290>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce bycatch through seasonal or area closures
- Reduce 'ghost fishing' by lost/discarded gear
- Reduce gillnet deployment time to reduce seabird bycatch
- Set longlines at the side of the boat to reduce seabird bycatch
- Tow buoys behind longlining boats to reduce seabird bycatch
- Use a water cannon when setting longlines to reduce seabird bycatch
- Use high-visibility longlines to reduce seabird bycatch
- Use larger hooks to reduce seabird bycatch on longlines

3.8 Threat: Human intrusions and disturbance

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for human intrusions and disturbance?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Provide paths to limit disturbance ● Start educational programmes for personal watercraft owners ● Use signs and access restrictions to reduce disturbance at nest sites ● Use voluntary agreements with local people to reduce disturbance
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Habituate birds to human visitors ● Use nest covers to reduce the impact of research on predation of ground-nesting seabirds
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Reduce visitor group sizes ● Set minimum distances for approaching birds (buffer zones)

Likely to be beneficial

● Provide paths to limit disturbance

A study from the UK found that two waders nested closer to a path, or at higher densities near the path, following resurfacing, which resulted in far fewer people leaving the path. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/311>

● **Start educational programmes for personal watercraft owners**

A before-and-after study in the USA found that common tern reproduction increased, and rates of disturbance decreased, following a series of educational programmes aimed at recreational boat users. *Assessment: likely to be beneficial (effectiveness 40%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/314>

● **Use signs and access restrictions to reduce disturbance at nest sites**

Six studies from across the world found increased numbers of breeders, higher reproductive success or lower levels of disturbance in waders and terns following the start of access restrictions or the erection of signs near nesting areas. Two studies from Europe and Antarctica found no effect of access restrictions on reproductive success in eagles and penguins, respectively. *Assessment: likely to be beneficial (effectiveness 59%; certainty 55%; harms 10%).*

<http://www.conservationevidence.com/actions/309>

● **Use voluntary agreements with local people to reduce disturbance**

A before-and-after trial in the USA found significantly lower rates of waterfowl disturbance following the establishment of a voluntary waterfowl avoidance area, despite an overall increase in boat traffic. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/313>

Unknown effectiveness (limited evidence)

● **Habituate birds to human visitors**

A study from Australia found that bridled terns from heavily disturbed sites had similar or higher reproductive success compared with less-disturbed sites, possibly suggesting that habituation had occurred. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/315>



● **Use nest covers to reduce the impact of research on predation of ground-nesting seabirds**

A before-and-after study from Canada found that hatching success of Caspian terns was significantly higher when researchers protected nests after disturbing adults from them. *Assessment: unknown effectiveness – limited evidence (effectiveness 41%; certainty 35%; harms 19%).*

<http://www.conservationevidence.com/actions/316>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce visitor group sizes
- Set minimum distances for approaching birds (buffer zones)

3.9 Threat: Natural system modifications

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for natural system modifications?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Create scrapes and pools in wetlands and wet grasslands ● Provide deadwood/snags in forests: use ring-barking, cutting or silvicides ● Use patch retention harvesting instead of clearcutting
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Clear or open patches in forests ● Employ grazing in artificial grassland/pastures ● Employ grazing in natural grasslands ● Employ grazing in non-grassland habitats ● Manage water level in wetlands ● Manually control or remove midstorey and ground-level vegetation: forests ● Manually control or remove midstorey and ground-level vegetation: mow or cut natural grasslands ● Manually control or remove midstorey and ground-level vegetation: mow or cut semi-natural grasslands/pastures ● Manually control or remove midstorey and ground-level vegetation: shrubland ● Raise water levels in ditches or grassland ● Thin trees within forests



	<ul style="list-style-type: none"> ● Use prescribed burning: grasslands ● Use prescribed burning: pine forests ● Use prescribed burning: savannahs ● Use prescribed burning: shrublands ● Use selective harvesting/logging instead of clearcutting
<p>Unknown effectiveness (limited evidence)</p>	<ul style="list-style-type: none"> ● Clearcut and re-seed forests ● Coppice trees ● Fertilise grasslands ● Manage woodland edges for birds ● Manually control or remove midstorey and ground-level vegetation: reedbeds ● Manually control or remove midstorey and ground-level vegetation: savannahs ● Plant trees to act as windbreaks ● Plough habitats ● Provide deadwood/snags in forests: add woody debris to forests ● Remove coarse woody debris from forests ● Replace non-native species of tree/shrub ● Re-seed grasslands ● Use environmentally sensitive flood management ● Use fire suppression/control ● Use greentree reservoir management ● Use prescribed burning: Australian sclerophyll forest ● Use shelterwood cutting instead of clearcutting ● Use variable retention management during forestry operations
<p>Likely to be ineffective or harmful</p>	<ul style="list-style-type: none"> ● Apply herbicide to mid- and understorey vegetation ● Treat wetlands with herbicides ● Use prescribed burning: coastal habitats ● Use prescribed burning: deciduous forests
<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Protect nest trees before burning

Likely to be beneficial

● Create scrapes and pools in wetlands and wet grasslands

Four out of six studies from the UK and North America found that more birds used sites, or breeding populations on sites increased, after ponds or scrapes were created. A study from the USA found that some duck species used newly created ponds and others used older ponds. A study from the UK found that northern lapwing chicks foraged in newly created features and that chick condition was higher in sites with a large number of footdrains. *Assessment: likely to be beneficial (effectiveness 75%; certainty 60%; harms 0%).*

<http://www.conservationevidence.com/actions/359>

● Provide deadwood/snags in forests (use ring-barking, cutting or silvicides)

One of five studies found that forest plots provided with snags had higher bird diversity and abundance than plots without snags. Three of four studies from the USA and UK found that species used artificially-created snags for nesting and foraging. One study from the USA found that use increased with how long a snag had been dead. *Assessment: likely to be beneficial (effectiveness 45%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/343>

● Use patch retention harvesting instead of clearcutting

One of two studies (from the USA) found that areas under patch retention harvesting contained more birds of more species than clearcut areas, retaining similar numbers to unharvested areas. Two studies found that forest specialist species were found more frequently in patch retention plots than under other management. Habitat generalists declined on patch retention sites compared to other managements. *Assessment: likely to be beneficial (effectiveness 70%; certainty 46%; harms 0%).*

<http://www.conservationevidence.com/actions/330>



Trade-off between benefit and harms

● Clear or open patches in forests

Seven out of nine studies from the UK and USA found that early-successional species increased in clearcut areas of forests, compared to other management. Two studies found that mature-forest species declined. One study found no differences in species richness between treatments, another found no consistent differences. A study from the USA found that a mosaic of cut and uncut areas supported a variety of species. *Assessment: trade-offs between benefits and harms (effectiveness 55%; certainty 60%; harms 30%).*

<http://www.conservationevidence.com/actions/326>

● Employ grazing in artificial grasslands/pastures

Five studies from the UK and USA found use or nesting densities were higher in grazed compared to ungrazed areas. A study from Canada found an increase in duck populations following the start of grazing along with other interventions. Eight studies from the UK, Canada and the USA found species richness, community composition, abundances, use, nesting densities, nesting success or productivity were similar or lower on grazed compared with ungrazed areas. One found that several species were excluded by grazing. *Assessment: trade-offs between benefits and harms (effectiveness 43%; certainty 65%; harms 45%).*

<http://www.conservationevidence.com/actions/349>

● Employ grazing in natural grasslands

Five of 12 studies from the USA and Canada found that densities of some species were higher on grazed than ungrazed sites. Eight studies from the USA, Canada and France found that some or all species studied were found at similar or lower densities on grazed compared to ungrazed sites or those under other management. Two controlled studies from the USA and Canada found that nesting success was higher on grazed than ungrazed sites. Five studies from the USA and Canada found that nesting success was similar or lower on grazed sites. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 60%; harms 50%).*

<http://www.conservationevidence.com/actions/348>

● **Employ grazing in non-grassland habitats**

One of eight studies found more bird species on grazed than unmanaged sites, apart from in drought years. A study from the Netherlands found the number of species in a mixed habitat wetland site declined with increased grazing. Three studies in Sweden, the Netherlands and Kenya found that the overall abundance or densities of some species were higher in grazed than ungrazed sites. Four studies in Europe and Kenya found that some species were absent or at lower densities on grazed compared to ungrazed sites or those under different management. Five studies from across the world found no differences in abundances or densities of some or all species between grazed sites and those that were ungrazed or under different management. Two studies from the UK found that productivity was lower in grazed than ungrazed sites. A study from the UK found that songbirds and invertebrate-eating species, but not crows were more common on rough-grazed habitats than intensive pasture. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 67%; harms 40%).*

<http://www.conservationevidence.com/actions/350>

● **Manage water level in wetlands**

Three studies (of six) from the USA, UK and Canada found that different species were more abundant at different water heights. One found that diversity levels also changed. One study found that great bitterns in the UK established territories earlier when deep water levels were maintained, but productivity did not vary. A study from Spain found that water management successfully retained water near a greater flamingo nesting area, but did not measure the effects on productivity or survival. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 41%; harms 35%).*

<http://www.conservationevidence.com/actions/355>

● **Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (forests)**

Seven studies from Europe and the USA found that species richness, total density or densities of some species were higher in areas with mid- or understorey management compared to areas without management. Four studies also used other interventions. Seven studies from the USA and



Canada found that species richness, densities, survival or competition for nest sites were similar or lower in areas with mid- or understorey control. Two studies investigated several interventions at once. Two studies from Canada found higher nest survival in forests with removal of deciduous trees compared to controls. One study found that chicks foraging success was higher in areas with cleared understorey vegetation compared to burned areas, but lower than under other managements. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 75%; harms 40%).*

<http://www.conservationevidence.com/actions/335>

● **Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (mowing or cutting natural grasslands)**

Two of six studies found higher densities of birds or nests on mown grasslands compared to unmanaged or burned areas. Two studies found lower densities or nests of some species and two found no differences in nesting densities or community composition on mown compared to unmown areas. One study from the USA found that grasshopper sparrow nesting success was higher on mown than grazed areas. One study from the USA found that duck nesting success was similar on cut and uncut areas. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 50%; harms 39%).*

<http://www.conservationevidence.com/actions/338>

● **Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (mowing or cutting semi-natural grasslands/pastures)**

One of four studies found that wader populations increased following annual cutting of semi-natural grasslands. One study from the UK found that ducks grazed at higher densities on cut areas. Another study in the UK found that goose grazing densities were unaffected by cutting frequency. One study from the USA found that Henslow's sparrows were more likely to be recaptured on unmown than mown grasslands. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 40%; harms 20%).*

<http://www.conservationevidence.com/actions/339>

- **Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (shrublands)**

One of seven studies found that overall bird diversity and bird density was similar between chained areas, burned areas and controls. One found that overall diversity and abundance was lower on mown sites than controls, but that grassland-specialist species were present on managed sites. Five studies from the USA and Europe found that some species were at greater densities or abundances on sites with mechanical vegetation control than on sites with burning or no management. Three studies from the USA found that some species were less abundant on sites with mechanical vegetation removal. One study from the USA found no differences between areas cut in winter and summer. *Assessment: trade-offs between benefits and harms (effectiveness 43%; certainty 54%; harms 30%).*

<http://www.conservationevidence.com/actions/337>

- **Raise water levels in ditches or grassland**

One of seven studies found that three waders were found to have recolonised a UK site or be found at very high densities after water levels were raised. Three studies from Europe found that raising water levels on grassland provided habitat for waders. A study from Denmark found that oystercatchers did not nest at higher densities on sites with raised water levels. A study from the UK found that birds visited sites with raised water levels more frequently than other fields, but another UK study found that feeding rates did not differ between sites with raised water levels and those without. A study from the USA found that predation rates on seaside sparrow nests increased as water levels were raised. *Assessment: trade-offs between benefits and harms (effectiveness 65%; certainty 55%; harms 25%).*

<http://www.conservationevidence.com/actions/354>

- **Thin trees within forests**

One study of 14 (from the USA) found higher bird species richness in sites with tree thinning and several other interventions, compared to unmanaged sites. Three studies from the UK and USA found no such differences. Seven studies (four investigating multiple interventions) found that overall bird abundance or the abundance of some species was higher in thinned



plots, compared to those under different management. Five studies found that abundances were similar, or that some species were less abundant in areas with thinning. Two studies from the USA found no effect of thinning on wood thrushes, a species thought to be sensitive to it. A study from the USA found that a higher proportion of nests were in nest boxes in a thinned site, compared to a control. A study from the USA found no differences in bird abundances between burned sites with high-retention thinning, compared to low-retention sites. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 60%; harms 30%).*

<http://www.conservationevidence.com/actions/328>

● Use prescribed burning (grasslands)

Four of 21 studies found that overall species richness and community composition did not vary between burned and unburned sites. Nine studies from across the world found that at least some species were more abundant or at higher densities in burned than unburned areas or areas under different management. Fourteen studies found that at least one species was at similar or lower abundances on burned areas. Responses varied depending on how soon after fires monitoring occurred. One study from the USA found that Florida grasshopper sparrow had significantly higher reproductive success soon after burns, whilst another found that dickcissel reproductive success was higher in patch-burned than burned and grazed areas. *Assessment: trade-offs between benefits and harms (effectiveness 45%; certainty 60%; harms 40%).*

<http://www.conservationevidence.com/actions/322>

● Use prescribed burning (pine forests)

Four of 28 studies in the USA found higher species richness, densities or abundances in sites with prescribed burning, tree thinning and in one case mid- or understorey control compared to controls. Fourteen studies found that some species were more abundant, or had higher productivities or survival in burned or burned and thinned areas than control areas. One study found that effects varied with geography and habitat. Fifteen studies found no differences in species richness or densities, community composition, productivity, behaviour or survival between sites with prescribed burning or burning and thinning, and controls or sites with

other management. One study found that foraging success of chicks was lower in burned areas. Three studies found effects did not vary with burn season. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 77%; harms 35%).*

<http://www.conservationevidence.com/actions/318>

● **Use prescribed burning (savannahs)**

One of five studies found that burned areas of savannah tended to have more birds and species than control or grazed areas, although burned sites showed significant annual variation unlike grazed sites. A study from Australia found that effects on bird abundances depended on burn season and habitat type. Two studies in the USA found that some open country species were more common in burned areas than unburned. A study from the USA found that two eastern bluebirds successfully raised chicks after a local prescribed burn. *Assessment: trade-offs between benefits and harms (effectiveness 40%; certainty 50%; harms 35%).*

<http://www.conservationevidence.com/actions/320>

● **Use prescribed burning (shrublands)**

One of eight studies found that overall bird densities were similar between burned and unburned areas, whilst another found that species numbers and densities did not vary between areas burned in summer or winter. Three studies found that some species were more abundant on areas that were burned. Four found that species densities were similar or lower on burned compared to control areas or those under different management. One study found that sage sparrows chose different nest sites before and after burning. Another found no differences in greater sage grouse movement between burned and unburned areas. *Assessment: trade-offs between benefits and harms (effectiveness 43%; certainty 50%; harms 45%).*

<http://www.conservationevidence.com/actions/321>

● **Use selective harvesting/logging instead of clearcutting**

Six of seven studies from the USA and Canada found that some species were more, and other less, abundant in selectively logged forests compared to unlogged stands, or those under other management. One study found that differences between treatments were not consistent. A study from

the USA found that species richness of cavity-nesting birds was lower in selectively logged forests than in clearcuts. One study from the USA found that brood parasitism was higher in selectively logged forests for two species and lower for two others, compared to control stands. *Assessment: trade-offs between benefits and harms (effectiveness 65%; certainty 60%; harms 30%).*

<http://www.conservationevidence.com/actions/331>

Unknown effectiveness (limited evidence)

● Clearcut and re-seed forests

One of two studies from the USA found that stands of pines replanted with native species held more species typical of scrub habitats than stands under different management. The other study found similar bird densities in clearcut and re-seeded sites and those under different management. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 35%; harms 0%).*

<http://www.conservationevidence.com/actions/327>

● Coppice trees

One of three studies found a population increase in European nightjars on a UK site after the introduction of coppicing and other interventions. Two studies from the UK and USA found that the use of coppices by some bird species declined over time. A UK study found that species richness decreased with the age of a coppice, but that some species were more abundant in older stands. *Assessment: unknown effectiveness — limited evidence (effectiveness 34%; certainty 30%; harms 30%).*

<http://www.conservationevidence.com/actions/329>

● Fertilise grasslands

All four studies captured (all from the UK) found that more geese grazed on fertilised areas of grass more than control areas. Two investigated cutting and fertilizing at the same time. One study found that fertilised areas were used less than re-seeded areas. One study found that fertilisation had an effect at applications of 50 kg N/ha, but not at 18 kg N/ha. Another found that the effects of fertilisation did not increase at applications over 80 kg N/ha.

Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 35%; harms 7%).

<http://www.conservationevidence.com/actions/353>

● **Manage woodland edges for birds**

One of three studies found that a local population of European nightjars increased at a UK site following the start of a management regime that included the management of woodland edges for birds. Two studies of an experiment in the USA found that bird abundance (but not species richness or nesting success) was higher in woodland edges managed for wildlife than unmanaged edges. *Assessment: unknown effectiveness — limited evidence (effectiveness 55%; certainty 39%; harms 30%).*

<http://www.conservationevidence.com/actions/334>

● **Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (reedbeds)**

One of three studies found that warblers nested at lower densities in cut areas of reeds. Productivity and success did not vary between treatments. A study from Denmark found that geese grazed at the highest densities on reedbeds cut 5–12 years previously. One study in the UK found that cutting reeds and changing water levels did not affect great bittern breeding productivity, but did delay territory establishment. *Assessment: unknown effectiveness — limited evidence (effectiveness 15%; certainty 36%; harms 14%).*

<http://www.conservationevidence.com/actions/340>

● **Manually control or remove midstorey and ground-level vegetation (including mowing, chaining, cutting etc.) (savannahs)**

A study in Argentina found that in summer, but not overall, bird abundance and species richness was lower in an area where shrubs were removed compared to a control. Community composition also differed between treatments. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 10%; harms 30%).*

<http://www.conservationevidence.com/actions/336>



● Plant trees to act as windbreaks

One of two studies found that a population of European nightjars increased at a UK site after multiple interventions including the planting of windbreak trees. A study from the USA found that such trees appeared to disrupt lekking behaviour in greater prairie chickens. *Assessment: unknown effectiveness — limited evidence (effectiveness 12%; certainty 25%; harms 20%).*

<http://www.conservationevidence.com/actions/351>

● Plough habitats

One of four studies found that bird densities were higher on ploughed wetlands in the USA than unploughed ones. Three studies of one experiment in the UK found that few whimbrels nested on areas of heathland ploughed and re-seeded, but that they were used for foraging in early spring. There were no differences in chick survival between birds that used ploughed and re-seeded heathland and those that did not. *Assessment: unknown effectiveness — limited evidence (effectiveness 25%; certainty 36%; harms 10%).*

<http://www.conservationevidence.com/actions/358>

● Provide deadwood/snags in forests (adding woody debris to forests)

One study from Australia found that brown treecreeper numbers were higher in plots with large amounts of dead wood added compared to plots with less or no debris added. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 29%; harms 0%).*

<http://www.conservationevidence.com/actions/344>

● Remove coarse woody debris from forests

Two studies from the USA found that some species increased in sites with woody debris removal. One found that overall breeding bird abundance and diversity were lower in removal plots; the other that survival of black-chinned hummingbird nests was lower. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 33%; harms 60%).*

<http://www.conservationevidence.com/actions/345>

● **Replace non-native species of tree/shrub**

A study from the USA found that the number of black-chinned hummingbird nests increased after fuel reduction and the planting of native species, but that the increase was smaller than at sites without planting. *Assessment: unknown effectiveness — limited evidence (effectiveness 5%; certainty 18%; harms 0%).*

<http://www.conservationevidence.com/actions/341>

● **Re-seed grasslands**

One of two studies from the UK found that geese grazed at higher densities on re-seeded grasslands than on control or fertilised grasslands. Another study from the UK found that geese grazed at higher densities on areas sown with clover, rather than grass seed. *Assessment: unknown effectiveness — limited evidence (effectiveness 35%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/352>

● **Use environmentally sensitive flood management**

One of two studies found more bird territories on a stretch of river in the UK with flood beams, compared to a channelized river. The other found that 13 out of 20 species of bird increased at sites in the USA where a river's hydrological dynamics were restored. *Assessment: unknown effectiveness — limited evidence (effectiveness 41%; certainty 26%; harms 0%).*

<http://www.conservationevidence.com/actions/356>

● **Use fire suppression/control**

All three studies we captured, from the USA, UK and Australia, found that some bird species increased after fire suppression, and in one case that woodland species appeared in a site. Two studies (from the UK and USA) found that some species declined following fire suppression. The USA study identified open country species as being negatively affected. *Assessment: unknown effectiveness — limited evidence (effectiveness 35%; certainty 34%; harms 30%).*

<http://www.conservationevidence.com/actions/324>



● Use greentree reservoir management

A study from the USA found that fewer mid- and under-storey birds were found at a greentree reservoir site than at a control site. Canopy-nesting species were not affected. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 10%; harms 40%).*

<http://www.conservationevidence.com/actions/357>

● Use prescribed burning (Australian sclerophyll forest)

Two of three studies from Australia found no differences in bird species richness in burned sites compared to unburned areas. All three found differences in species assemblages, with some species lost and others gained from areas after fire. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 31%; harms 30%).*

<http://www.conservationevidence.com/actions/319>

● Use shelterwood cutting instead of clearcutting

A study from the USA found that bird community composition differed between shelterwood stands and those under other forestry practices: some species were more abundant, others less so. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 20%; harms 40%).*

<http://www.conservationevidence.com/actions/333>

● Use variable retention management during forestry operations

A study from the USA found that nine species were more abundant and five less so in stands under variable retention management, compared to unmanaged stands. *Assessment: unknown effectiveness — limited evidence (effectiveness 45%; certainty 20%; harms 25%).*

<http://www.conservationevidence.com/actions/332>

Likely to be ineffective or harmful

● Apply herbicide to mid- and understorey vegetation

One of seven studies from North America found that bird species richness in a forest declined after deciduous trees were treated with herbicide. Three studies found increases in total bird densities, or those of some species, after herbicide treatment, although one found no differences between treatment and control areas. One study found that densities of one species decreased and another remained steady after treatment. Three studies found that nest survival was lower in herbicide-treated areas and one found lower nesting densities. One study found that northern bobwhite chicks higher had foraging success in forest areas treated with herbicide compared to under other managements. *Assessment: likely to be ineffective or harmful (effectiveness 20%; certainty 50%; harms 60%).*

<http://www.conservationevidence.com/actions/346>

● Treat wetlands with herbicides

All four studies from the USA found higher densities of birds in wetlands sprayed with herbicide, compared with unsprayed areas. Two found that some species were at lower densities compared to unsprayed areas or those under other management. *Assessment: likely to be ineffective or harmful (effectiveness 30%; certainty 42%; harms 40%).*

<http://www.conservationevidence.com/actions/347>

● Use prescribed burning (coastal habitats)

One study from the USA found that breeding seaside sparrow numbers decreased the year a site was burned, but were higher than on an unburned site the following year. One study in Argentina found that tall-grass specialist species were lost from burned areas in the year of burning, but that some habitats recovered by the following year. One study from the USA found no differences in nest predation rates between burned and unburned areas for two years after burning. *Assessment: likely to be ineffective or harmful (effectiveness 20%; certainty 40%; harms 30%).*

<http://www.conservationevidence.com/actions/323>



● Use prescribed burning (deciduous forests)

One of four studies found that bird species richness was similar in burned and unburned aspen forests, although relative abundances of some species changed. A study in the USA found no changes in community composition in oak and hickory forests following burning. One study in the USA found no differences in wood thrush nest survival in burned and unburned areas. Another study in the USA found a reduction in black-chinned hummingbird nests following fuel reduction treatments including burning. *Assessments: likely to be ineffective or harmful (effectiveness 32%; certainty 60%; harms 30%).*

<http://www.conservationevidence.com/actions/317>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Protect nest trees before burning

3.10 Habitat restoration and creation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat restoration and creation?	
Beneficial	<ul style="list-style-type: none"> ● Restore or create forests ● Restore or create wetlands and marine habitats: restore or create inland wetlands
Likely to be beneficial	<ul style="list-style-type: none"> ● Restore or create grassland ● Restore or create traditional water meadows ● Restore or create wetlands and marine habitats: restore or create coastal and intertidal wetlands
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Restore or create shrubland ● Restore or create wetlands and marine habitats: restore or create kelp forests ● Restore or create wetlands and marine habitats: restore or create lagoons
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Restore or create savannahs ● Revegetate gravel pits

Beneficial

● Restore or create forests

Thirteen of 15 studies from across the world found that restored forests were similar to in-tact forests, that species returned to restored sites, that species recovered significantly better at restored than unrestored sites or that bird species richness, diversity or abundances in restored forest sites



increased over time. One study also found that restoration techniques themselves improved over time. Nine studies found that some species did not return to restored forests or were less common and a study found that territory densities decreased over time. A study from the USA found that no more birds were found in restored sites, compared with unrestored. One study investigated productivity and found it was similar between restored and intact forests. A study from the USA found that planting fast-growing species appeared to provide better habitat than slower-growing trees. *Assessment: beneficial (effectiveness 65%; certainty 76%; harms 0%).*

<http://www.conservationevidence.com/actions/360>

● Restore or create wetlands and marine habitats (inland wetlands)

All eleven studies from the USA and Canada found that birds used restored or created wetlands. Two found that rates of use and species richness were similar or higher than on natural wetlands. One found that use was higher than on unrestored wetlands. Three studies from the USA and Puerto Rico found that restored wetlands held lower densities and fewer species or had similar productivity compared to natural wetlands. Two studies in the USA found that semi-permanent restored and larger wetlands were used more than temporary or seasonal or smaller ones. *Assessment: beneficial (effectiveness 70%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/366>

Likely to be beneficial

● Restore or create grassland

Three of 23 studies found that species richness on restored grasslands was higher than unrestored habitats, or similar to remnant grassland, and three found that target species used restored grassland. Two studies from the USA found that diversity or species richness fell after restoration or was lower than unrestored sites. Seven studies from the USA and UK found high use of restored sites, or that such sites held a disproportionate proportion of the local population of birds. Two studies found that densities or abundances were lower on restored than unrestored sites, potentially due to drought conditions in one case. Five studies found that at least

some bird species had higher productivities in restored sites compared to unrestored; had similar or higher productivities than natural habitats; or had high enough productivities to sustain populations. Three studies found that productivities were lower in restored than unrestored areas, or that productivities on restored sites were too low to sustain populations. A study from the USA found that older restored fields held more nests, but fewer species than young fields. Three studies found no differences between restoration techniques; two found that sowing certain species increased the use of sites by birds. *Assessment: likely to be beneficial (effectiveness 45%; certainty 70%; harms 0%).*

<http://www.conservationevidence.com/actions/361>

● **Restore or create traditional water meadows**

Four out of five studies found that the number of waders or wildfowl on UK sites increased after the restoration of traditional water meadows. One study from Sweden found an increase in northern lapwing population after an increase in meadow management. One study found that lapwing productivity was higher on meadows than some habitats, but not others. *Assessment: likely to be beneficial (effectiveness 65%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/363>

● **Restore or create wetlands and marine habitats (coastal and intertidal wetlands)**

All six studies from the USA and UK found that bird species used restored or created wetlands. Two found that numbers and/or diversity were similar to in natural wetlands and one that numbers were higher than in unrestored sites. Three found that bird numbers on wetlands increased over time. Two studies from the UK found that songbirds and waders decreased following wetland restoration, whilst a study from the USA found that songbirds were more common on unrestored sites than restored wetlands. *Assessment: likely to be beneficial (effectiveness 65%; certainty 55%; harms 3%).*

<http://www.conservationevidence.com/actions/367>



Unknown effectiveness (limited evidence)

● Restore or create shrubland

Three studies from the UK, USA and the Azores found local bird population increases after shrubland restoration. Two studies investigated multiple interventions and one found an increase from no birds to one or two pairs. One study from the UK found that several interventions, including shrubland restoration, were negatively related to the number of young grey partridges per adult bird on sites. *Assessment: unknown effectiveness – limited evidence (effectiveness 25%; certainty 20%; harms 3%).*

<http://www.conservationevidence.com/actions/364>

● Restore or create wetlands and marine habitats (kelp forests)

One study in the USA found that the densities of five of the nine bird species increased following kelp forest restoration. *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/368>

● Restore or create wetlands and marine habitats (lagoons)

One study in the UK found that large numbers of bird species used and bred in a newly-created lagoon. *Assessment: unknown effectiveness – limited evidence (effectiveness 61%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/369>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restore or create savannahs
- Revegetate gravel pits

3.11 Threat: Invasive alien and other problematic species

This assessment method for this chapter is described in Walsh, J. C., Dicks, L. V. & Sutherland, W. J. (2015) The effect of scientific evidence on conservation practitioners' management decisions. *Conservation Biology*, 29: 88–98. No harms were assessed for sections 3.11.1, 3.11.2, 3.11.3 and 3.11.4.

3.11.1 Reduce predation by other species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing predation by other species?	
Beneficial	<ul style="list-style-type: none"> • Control mammalian predators on islands • Remove or control predators to enhance bird populations and communities
Likely to be beneficial	<ul style="list-style-type: none"> • Control avian predators on islands
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Control invasive ants on islands • Reduce predation by translocating predators
Evidence not assessed	<ul style="list-style-type: none"> • Control predators not on islands



Beneficial

● Control mammalian predators on islands

Of the 33 studies from across the world, 16 described population increases or recolonisations in at least some of the sites studied and 18 found higher reproductive success or lower mortality (on artificial nests in one case). Two studies that investigated population changes found only partial increases, in black oystercatchers *Haematopus bachmani* and two gamebird species, respectively. Eighteen of the studies investigated rodent control; 12 cat *Felis catus* control and 6 various other predators including pigs *Sus scrofa* and red foxes *Vulpes*. The two that found only partial increases examined cat, fox and other larger mammal removal. *Assessment: beneficial (effectiveness 81%; certainty 78%)*.

<http://www.conservationevidence.com/actions/373>

● Remove or control predators to enhance bird populations and communities

Both a meta-analysis and a systematic review (both global) found that bird reproductive success increased with predator control and that either post-breeding or breeding-season populations increased. The systematic review found that post-breeding success increased with predator control on mainland, but not islands. *Assessment: beneficial (effectiveness 66%; certainty 71%)*.

<http://www.conservationevidence.com/actions/371>

Likely to be beneficial

● Control avian predators on islands

Seven out of ten studies from North America, Australia and Europe found that controlling avian predators led to increased population sizes, reduced mortality, increased reproductive success or successful translocation of seabirds on islands. Two controlled studies on European islands found little effect of controlling crows on reproductive success in raptors or gamebirds. One study in the UK found that numbers of terns and small gulls on gravel islands declined despite the attempted control of large gulls. *Assessment: likely to be beneficial (effectiveness 50%; certainty 45%)*.

<http://www.conservationevidence.com/actions/372>

Unknown effectiveness (limited evidence)

● Control invasive ants on islands

A single study in the USA found that controlling the invasive tropical fire ant *Solenopsis geminata*, but not the big-headed ant *Pheidole megacephala*, led to lower rates of injuries and temporarily higher fledging success than on islands without ant control. The authors note that very few chicks were injured by *P. megacephala* on either experimental or control islands. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 15%).*

<http://www.conservationevidence.com/actions/383>

● Reduce predation by translocating predators

Two studies from France and the USA found local population increases or reduced predation following the translocation of predators away from an area. *Assessment: unknown effectiveness — limited evidence (effectiveness 27%; certainty 20%).*

<http://www.conservationevidence.com/actions/393>

Evidence not assessed

● Control predators not on islands

A study from the UK found higher bird community breeding densities and fledging success rates in plots with red fox *Vulpes vulpes* and carrion crow *Corvus corone* control. Of the 25 taxa-specific studies, only five found evidence for population increases with predator control, whilst one found a population decrease (with other interventions also used); one found lower or similar survival, probably because birds took bait. Nineteen studies found some evidence for increased reproductive success or decreased predation with predator control, with three studies (including a meta-analysis) finding no evidence for higher reproductive success or predation with predator control or translocation from the study site. One other study found evidence for increases in only three of six species studied. Most studies studied the removal of a number of different mammals, although several also removed bird predators, mostly carrion crows and gulls *Larus* spp. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/384>

3.11.2 Reduce incidental mortality during predator eradication or control

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing incidental mortality during predator eradication or control predation	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Distribute poison bait using dispensers ● Use coloured baits to reduce accidental mortality during predator control ● Use repellents on baits
Evidence not assessed	<ul style="list-style-type: none"> ● Do birds take bait designed for pest control?

Unknown effectiveness (limited evidence)

● Distribute poison bait using dispensers

A study from New Zealand found that South Island robin survival was higher when bait for rats and mice was dispensed from feeders, compared to being scattered. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 25%).*

<http://www.conservationevidence.com/actions/157>

● Use coloured baits to reduce accidental mortality during predator control

Two out of three studies found that dyed baits were consumed at lower rates by songbirds and kestrels. An *ex situ* study from Australia found that dyeing food did not reduce its consumption by bush thick-knees. *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 30%).*

<http://www.conservationevidence.com/actions/182>

● Use repellents on baits

A study in New Zealand found that repellents reduced the rate of pecking at baits by North Island robins. A study from the USA found that treating bait with repellents did not reduce consumption by American kestrels. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 10%).*

<http://www.conservationevidence.com/actions/159>

Evidence not assessed

● **Do birds take bait designed for pest control?**

Two studies from New Zealand and Australia, one *ex situ*, found no evidence that birds took bait meant for pest control. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/395>

3.11.3 Reduce nest predation by excluding predators from nests or nesting areas

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing nest predation by excluding predators from nests or nesting areas	
Likely to be beneficial	<ul style="list-style-type: none"> ● Physically protect nests from predators using non-electric fencing ● Physically protect nests with individual enclosures/barriers or provide shelters for chicks ● Protect bird nests using electric fencing ● Use artificial nests that discourage predation
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Guard nests to prevent predation ● Plant nesting cover to reduce nest predation ● Protect nests from ants ● Use multiple barriers to protect nests ● Use naphthalene to deter mammalian predators ● Use snakeskin to deter mammalian nest predators
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Play spoken-word radio programs to deter predators ● Use 'cat curfews' to reduce predation ● Use lion dung to deter domestic cats ● Use mirrors to deter nest predators ● Use ultrasonic devices to deter cats
Evidence not assessed	<ul style="list-style-type: none"> ● Can nest protection increase nest abandonment? ● Can nest protection increase predation of adults and chicks?



Likely to be beneficial

● **Physically protect nests from predators using non-electric fencing**

Two of four studies from the UK and the USA found that fewer nests failed or were predated when predator exclusion fences were erected. Two studies found that nesting and fledging success was no higher when fences were used, one found that hatching success was higher. *Assessment: likely to be beneficial (effectiveness 45%; certainty 48%).*

<http://www.conservationevidence.com/actions/183>

● **Physically protect nests with individual enclosures/ barriers or provide shelters for chicks**

Nine of 23 studies found that fledging rates or productivity were higher for nests protected by individual barriers than for unprotected nests. Two found no higher productivity. Fourteen studies found that hatching rates or survival were higher, or that predation was lower for protected nests. Two found no differences between protected and unprotected nests and one found that adults were harassed by predators at protected nests. One study found that chick shelters were not used much and a review found that some enclosure designs were more effective than others. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%).*

<http://www.conservationevidence.com/actions/397>

<http://www.conservationevidence.com/actions/398>

<http://www.conservationevidence.com/actions/399>

<http://www.conservationevidence.com/actions/400>

● **Protect bird nests using electric fencing**

Two of six studies found increased numbers of terns or tern nests following the erection of an electric fence around colonies. Five studies found higher survival or productivity of waders or seabirds when electric fences were used and one found lower predation by mammals inside electric fences. One study found that predation by birds was higher inside electric fences. *Assessment: likely to be beneficial (effectiveness 60%; certainty 59%).*

<http://www.conservationevidence.com/actions/188>

● Use artificial nests that discourage predation

Three out of five studies from North America found lower predation rates or higher nesting success for wildfowl in artificial nests, compared with natural nests. An *ex situ* study found that some nest box designs prevented raccoons from entering. A study found that wood ducks avoided anti-predator nest boxes but only if given the choice of unaltered nest boxes. *Assessment: likely to be beneficial (effectiveness 59%; certainty 54%).*

<http://www.conservationevidence.com/actions/402>

Unknown effectiveness (limited evidence)

● Guard nests to prevent predation

Nest guarding can be used as a response to a range of threats and is therefore discussed in 'General responses to small/declining populations — Guard nests'. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%).*

<http://www.conservationevidence.com/actions/411>

● Plant nesting cover to reduce nest predation

Studies relevant to this intervention are discussed in 'Threat: Agriculture'. *Assessment: unknown effectiveness — limited evidence (effectiveness 28%; certainty 30%).*

<http://www.conservationevidence.com/actions/405>

● Protect nests from ants

A study from the USA found that vireo nests protected from ants with a physical barrier and a chemical repellent had higher fledging success than unprotected nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 45%; certainty 17%).*

<http://www.conservationevidence.com/actions/410>

● Use multiple barriers to protect nests

One of two studies found that plover fledging success in the USA was no higher when an electric fence was erected around individual nest enclosures, compared to when just the enclosures were present. A study



from the USA found that predation on chicks was lower when one of two barriers around nests was removed early, compared to when it was left for three more days. *Assessment: unknown effectiveness – limited evidence (effectiveness 7%; certainty 17%).*

<http://www.conservationevidence.com/actions/404>

● Use naphthalene to deter mammalian predators

A study from the USA found that predation rates on artificial nests did not differ when naphthalene moth balls were scattered around them. *Assessment: unknown effectiveness – limited evidence (effectiveness 0%; certainty 10%).*

<http://www.conservationevidence.com/actions/408>

● Use snakeskin to deter mammalian nest predators

A study from the USA found that flycatcher nests were predated less frequently if they had a snakeskin wrapped around them. *Assessment: unknown effectiveness – limited evidence (effectiveness 33%; certainty 15%).*

<http://www.conservationevidence.com/actions/406>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Play spoken-word radio programmes to deter predators
- Use 'cat curfews' to reduce predation
- Use lion dung to deter domestic cats
- Use mirrors to deter nest predators
- Use ultrasonic devices to deter cats

Evidence not assessed

● Can nest protection increase nest abandonment?

One of four studies (from the USA) found an increase in abandonment after nest enclosures were used. Two studies from the USA and Sweden found no increases in abandonment when enclosures were used and a review from

the USA found that some designs were more likely to cause abandonment than others. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/401>

● **Can nest protection increase predation of adults and chicks?**

Four of five studies from the USA and Sweden found that predation on chicks and adults was higher when exclosures were used. One of these found that adults were harassed when exclosures were installed and the chicks rapidly predated when they were removed. One study from Sweden found that predation was no higher when exclosures were used. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/403>

3.11.4 Reduce mortality by reducing hunting ability or changing predator behaviour

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing mortality by reducing hunting ability or changing predator behaviour	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Reduce predation by translocating nest boxes● Use collar-mounted devices to reduce predation● Use supplementary feeding of predators to reduce predation
Unlikely to be beneficial	<ul style="list-style-type: none">● Use aversive conditioning to reduce nest predation

Unknown effectiveness (limited evidence)

● **Reduce predation by translocating nest boxes**

Two European studies found that predation rates were lower for translocated nest boxes than for controls. *Assessment: unknown effectiveness – limited evidence (effectiveness 48%; certainty 25%).*

<http://www.conservationevidence.com/actions/420>



● Use collar-mounted devices to reduce predation

Two replicated randomised and controlled studies in the UK and Australia found that fewer birds were returned by cats wearing collars with anti-hunting devices, compared to cats with control collars. No differences were found between different devices. *Assessment: unknown effectiveness – limited evidence (effectiveness 48%; certainty 35%).*

<http://www.conservationevidence.com/actions/416>

● Use supplementary feeding to reduce predation

One of three studies found that fewer grouse chicks were taken to harrier nests when supplementary food was provided to the harriers, but no effect on grouse adult survival or productivity was found. One study from the USA found reduced predation on artificial nests when supplementary food was provided. Another study from the USA found no such effect. *Assessment: unknown effectiveness – limited evidence (effectiveness 13%; certainty 20%).*

<http://www.conservationevidence.com/actions/417>

Unlikely to be beneficial

● Use aversive conditioning to reduce nest predation

Nine out of 12 studies found no evidence for aversive conditioning or reduced nest predation after aversive conditioning treatment stopped. Ten studies found reduced consumption of food when it was treated with repellent chemicals, i.e. during the treatment. Three, all studying avian predators, found some evidence for reduced consumption after treatment but these were short-lived trials or the effect disappeared within a year. *Assessment: unlikely to be beneficial (effectiveness 9%; certainty 60%).*

<http://www.conservationevidence.com/actions/418>

<http://www.conservationevidence.com/actions/419>

3.11.5 Reduce competition with other species for food and nest sites

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing competition with other species for food and nest sites?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Reduce inter-specific competition for food by removing or controlling competitor species
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Protect nest sites from competitors ● Reduce competition between species by providing nest boxes ● Reduce inter-specific competition for nest sites by modifying habitats to exclude competitor species ● Reduce inter-specific competition for nest sites by removing competitor species: ground nesting seabirds ● Reduce inter-specific competition for nest sites by removing competitor species: songbirds ● Reduce inter-specific competition for nest sites by removing competitor species: woodpeckers

Likely to be beneficial

● Reduce inter-specific competition for food by removing or controlling competitor species

Three out of four studies found that at least some of the target species increased following the removal or control of competitor species. Two studies found that some or all target species did not increase, or that there was no change in kleptoparasitic behaviour of competitor species after control efforts. *Assessment: likely to be beneficial (effectiveness 44%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/428>



Unknown effectiveness (limited evidence)

● Protect nest sites from competitors

Two studies from the USA found that red-cockaded woodpecker populations increased after the installation of 'restrictor plates' around nest holes to prevent larger woodpeckers from enlarging them. Several other interventions were used at the same time. A study from Puerto Rico found lower competition between species after nest boxes were altered. A study from the USA found weak evidence that exclusion devices prevented house sparrows from using nest boxes and another study from the USA found that fitting restrictor plates to red-cockaded woodpecker holes reduced the number that were enlarged by other woodpeckers. *Assessment: unknown effectiveness — limited evidence (effectiveness 39%; certainty 24%; harms 5%).*

<http://www.conservationevidence.com/actions/426>

● Reduce competition between species by providing nest boxes

A study from the USA found that providing extra nest boxes did not reduce the rate at which common starlings usurped northern flickers from nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 16%; harms 0%).*

<http://www.conservationevidence.com/actions/427>

● Reduce inter-specific competition for nest sites by modifying habitats to exclude competitor species

A study from the USA found that clearing midstorey vegetation did not reduce the occupancy of red-cockaded woodpecker nesting holes by southern flying squirrels. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 12%; harms 0%).*

<http://www.conservationevidence.com/actions/425>

● **Reduce inter-specific competition for nest sites by removing competitor species (ground nesting seabirds)**

Four studies from Canada and the UK found increased tern populations following the control or exclusion of gulls, and in two cases with many additional interventions. Two studies from the UK and Canada found that controlling large gulls had no impact on smaller species. Two studies from the USA and UK found that exclusion devices successfully reduced the numbers of gulls at sites, although one found that they were only effective at small colonies and the other found that methods varied in their effectiveness and practicality. *Assessment: unknown effectiveness — limited evidence (effectiveness 41%; certainty 31%; harms 14%).*

<http://www.conservationevidence.com/actions/422>

● **Reduce inter-specific competition for nest sites by removing competitor species (songbirds)**

Two studies from Australia found increases in bird populations and species richness after control of noisy miners. A study from Italy found that blue tits nested in more nest boxes when hazel dormice were excluded from boxes over winter. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 22%; harms 0%).*

<http://www.conservationevidence.com/actions/424>

● **Reduce inter-specific competition for nest sites by removing competitor species (woodpeckers)**

Two studies in the USA found red-cockaded woodpecker populations increased following the removal of southern flying squirrels, in one case along with other interventions. A third found that red-cockaded woodpecker reintroductions were successful when squirrels were controlled. One study found fewer holes were occupied by squirrels following control efforts, but that occupancy by red-cockaded woodpeckers was no higher. *Assessment: unknown effectiveness — limited evidence (effectiveness 34%; certainty 28%; harms 0%).*

<http://www.conservationevidence.com/actions/423>



3.11.6 Reduce adverse habitat alteration by other species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing adverse habitat alteration by other species?	
Likely to be beneficial	<ul style="list-style-type: none"> • Control or remove habitat-altering mammals • Reduce adverse habitat alterations by excluding problematic species (terrestrial species)
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Reduce adverse habitat alterations by excluding problematic species (aquatic species) • Remove problematic vegetation • Use buffer zones to reduce the impact of invasive plant control

Likely to be beneficial

● Control or remove habitat-altering mammals

Four out of five studies from islands in the Azores and Australia found that seabird populations increased after rabbits or other species were removed, although three studied several interventions at the same time. Two studies from Australia and Madeira found that seabird productivity increased after rabbit and house mouse eradication. *Assessment: likely to be beneficial (effectiveness 61%; certainty 41%; harms 0%).*

<http://www.conservationevidence.com/actions/431>

● Reduce adverse habitat alterations by excluding problematic species (terrestrial species)

Three studies from the USA and the UK found higher numbers of certain songbird species and higher species richness in these groups when deer were excluded from forests. Intermediate canopy-nesting species in the USA and common nightingales in the UK were the species to benefit. A study from Hawaii found mixed effects of grazer exclusion. *Assessment: likely to be beneficial (effectiveness 48%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/429>

Unknown effectiveness (limited evidence)

● Reduce adverse habitat alterations by excluding problematic species (aquatic species)

A study in the USA found that waterbirds preferentially used wetland plots from which grass carp were excluded but moved as these became depleted over the winter. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 14%; harms 0%).*

<http://www.conservationevidence.com/actions/430>

● Remove problematic vegetation

One of four studies (from Japan) found an increase in a bird population following the removal of an invasive plant. One study from the USA found lower bird densities in areas where a problematic native species was removed. One study from Australia found the Gould's petrel productivity was higher following the removal of native bird-lime trees, and a study from New Zealand found that Chatham Island oystercatchers could nest in preferable areas of beaches after invasive marram grass was removed. *Assessment: unknown effectiveness — limited evidence (effectiveness 43%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/432>

● Use buffer zones to reduce the impact of invasive plant control

A study from the USA found that no snail kite nests (built above water in cattail and bulrush) were lost during herbicide spraying when buffer zones were established around nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/433>



3.11.7 Reduce parasitism and disease

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing parasitism and disease?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Remove/control adult brood parasites
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Remove/treat endoparasites and diseases
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Alter artificial nest sites to discourage brood parasitism ● Exclude or control 'reservoir species' to reduce parasite burdens ● Remove brood parasite eggs from target species' nests ● Remove/treat ectoparasites to increase survival or reproductive success: reduce nest ectoparasites by providing beneficial nesting material ● Remove/treat ectoparasites to increase survival or reproductive success: remove ectoparasites from feathers ● Use false brood parasite eggs to discourage brood parasitism
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Remove/treat ectoparasites to increase survival or reproductive success: remove ectoparasites from nests

Likely to be beneficial

● Remove/control adult brood parasites

One of 12 studies, all from the Americas, found that a host species population increased after control of the parasitic cowbird, two studies found no effect. Five studies found higher productivities or success rates when cowbirds were removed, five found that some or all measures of productivity were no different. Eleven studies found that brood parasitism rates were lower after cowbird control. *Assessment: likely to be beneficial (effectiveness 48%; certainty 61%; harms 0%).*

<http://www.conservationevidence.com/actions/441>

Trade-off between benefit and harms

● Remove/treat endoparasites and diseases

Two out of five studies found that removing endoparasites increased survival in birds and one study found higher productivity in treated birds. Two studies found no evidence, or uncertain evidence, for increases in survival with treatment and one study found lower parasite burdens, but also lower survival in birds treated with antihelmintic drugs. *Assessment: trade-offs between benefits and harms (effectiveness 48%; certainty 51%; harms 37%).*

<http://www.conservationevidence.com/actions/434>

Unknown effectiveness (limited evidence)

● Alter artificial nest sites to discourage brood parasitism

A replicated trial from Puerto Rico found that brood parasitism levels were extremely high across all nest box designs tested. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/446>

● Exclude or control 'reservoir species' to reduce parasite burdens

One of two studies found increased chick production in grouse when hares (carriers of louping ill virus) were culled in the area, although a comment on the paper disputes this finding. A literature review found no compelling evidence for the effects of hare culling on grouse populations. *Assessment: unknown effectiveness — limited evidence (effectiveness 13%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/435>

● Remove brood parasite eggs from target species' nests

One of two studies found lower rates of parasitism when cowbird eggs were removed from host nests. One study found that nests from which cowbird eggs were removed had lower success than parasitised nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 24%; certainty 20%; harms 21%).*

<http://www.conservationevidence.com/actions/443>



- **Remove/treat ectoparasites to increase survival or reproductive success (provide beneficial nesting material)**

A study in Canada found lower numbers of some, but not all, parasites in nests provided with beneficial nesting material, but that there was no effect on fledging rates or chick condition. *Assessment: unknown effectiveness — limited evidence (effectiveness 15%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/439>

- **Remove/treat ectoparasites to increase survival or reproductive success (remove ectoparasites from feathers)**

A study in the UK found that red grouse treated with spot applications had lower tick and disease burdens and higher survival than controls, whilst birds with impregnated tags had lower tick burdens only. A study in Hawaii found that CO₂ was the most effective way to remove lice from feathers, although lice were not killed. *Assessment: unknown effectiveness — limited evidence (effectiveness 42%; certainty 16%; harms 0%).*

<http://www.conservationevidence.com/actions/437>

- **Use false brood parasite eggs to discourage brood parasitism**

A study from the USA found that parasitism rates were lower for red-winged blackbird nests with false or real cowbird eggs placed in them, than for control nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 35%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/444>

Unlikely to be beneficial

- **Remove/treat ectoparasites to increase survival or reproductive success (remove ectoparasites from nests)**

Six of the seven studies found lower infestation rates in nests treated for ectoparasites, one (that used microwaves to treat nests) did not find fewer parasites. Two studies from the USA found higher survival or lower abandonment in nests treated for ectoparasites, whilst seven studies from across the world found no differences in survival, fledging rates or productivity between nests treated for ectoparasites and controls. Two of

six studies found that chicks from nests treated for ectoparasites were in better condition than those from control nests. *Assessment: unlikely to be beneficial (effectiveness 25%; certainty 58%; harms 0%).*

<http://www.conservationevidence.com/actions/438>

3.11.8 Reduce detrimental impacts of other problematic species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for reducing detrimental impacts of other problematic species?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Use copper strips to exclude snails from nests

Unknown effectiveness (limited evidence)

● Use copper strips to exclude snails from nests

A study from Mauritius found no mortality from snails invading echo parakeet nests after the installation of copper strips around nest trees. Before installation, four chicks were killed by snails. *Assessment: unknown effectiveness — limited evidence (effectiveness 47%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/447>

3.12 Threat: Pollution

3.12.1 Industrial pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for industrial pollution?	
Likely to be beneficial	<ul style="list-style-type: none">• Use visual and acoustic ‘scarers’ to deter birds from landing on pools polluted by mining or sewage
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Relocate birds following oil spills• Use repellents to deter birds from landing on pools polluted by mining
Unlikely to be beneficial	<ul style="list-style-type: none">• Clean birds after oil spills

Likely to be beneficial

- **Use visual and acoustic ‘scarers’ to deter birds from landing on pools polluted by mining or sewage**

Two studies from Australia and the USA found that deterrent systems reduced bird mortality on toxic pools. Four of five studies from the USA and Canada found that fewer birds landed on pools when deterrents were used, one found no effect. Two studies found that radar-activated systems were more effective than randomly-activated systems. One study found that loud noises were more effective than raptor models. *Assessment: likely to be beneficial (effectiveness 50%; certainty 46%; harms 0%).*

<http://www.conservationevidence.com/actions/452>

Unknown effectiveness (limited evidence)

● Relocate birds following oil spills

A study from South Africa found that a high percentage of penguins relocated following an oil spill returned to and bred at their old colony. More relocated birds bred than oiled-and-cleaned birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 39%; certainty 10%; harms 5%).*

<http://www.conservationevidence.com/actions/449>

● Use repellents to deter birds from landing on pools polluted by mining

An *ex situ* study from the USA found that fewer common starlings consumed contaminated water laced with chemicals, compared to untreated water. *Assessment: unknown effectiveness — limited evidence (effectiveness 51%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/453>

Unlikely to be beneficial

● Clean birds after oil spills

Three studies from South Africa and Australia found high survival of oiled-and-cleaned penguins and plovers, but a large study from the USA found low survival of cleaned common guillemots. Two studies found that cleaned birds bred and had similar success to un-oiled birds. After a second spill, one study found that cleaned birds were less likely to breed. Two studies found that cleaned birds had lower breeding success than un-oiled birds. *Assessment: unlikely to be beneficial (effectiveness 30%; certainty 45%; harms 5%).*

<http://www.conservationevidence.com/actions/448>

3.12.2 Agricultural pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for agricultural pollution?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Leave headlands in fields unsprayed (conservation headlands) ● Provide food for vultures to reduce mortality from diclofenac ● Reduce pesticide, herbicide and fertiliser use generally
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Reduce chemical inputs in permanent grassland management ● Restrict certain pesticides or other agricultural chemicals
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Make selective use of spring herbicides ● Provide buffer strips along rivers and streams ● Provide unfertilised cereal headlands in arable fields ● Use buffer strips around in-field ponds ● Use organic rather than mineral fertilisers

Likely to be beneficial

● **Leave headlands in fields unsprayed (conservation headlands)**

Three studies from Europe found that several species were strongly associated with conservation headlands; two of these found that other species were not associated with them. A review from the UK found larger grey partridge populations on sites with conservation headlands. Three studies found higher grey partridge adult or chick survival on sites with conservation headlands, one found survival did not differ. Four studies found higher grey partridge productivity on sites with conservation headlands, two found similar productivities and one found a negative relationship between conservation headlands and the number of chicks per adult partridge. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/461>

● Provide food for vultures to reduce mortality from diclofenac

A before-and-after trial in Pakistan found that oriental white-backed vulture mortality rates were significantly lower when supplementary food was provided, compared to when it was not. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<http://www.conservationevidence.com/actions/456>

● Reduce pesticide, herbicide and fertiliser use generally

One of nine studies found that the populations of some species increased when pesticide use was reduced and other interventions used. Three studies found that some or all species were found at higher densities on reduced-input sites. Five found that some of all species were not at higher densities. A study from the UK found that grey partridge chicks had higher survival on sites with reduced pesticide input. Another found that partridge broods were smaller on such sites and there was no relationship between reduced inputs and survival or the ratio of young to old birds. *Assessment: likely to be beneficial (effectiveness 55%; certainty 55%; harms 3%).*

<http://www.conservationevidence.com/actions/454>

Unknown effectiveness (limited evidence)

● Reduce chemical inputs in permanent grassland management

A study from the UK found that no more foraging birds were attracted to pasture plots with no fertiliser, compared to control plots. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/459>

● Restrict certain pesticides or other agricultural chemicals

A before-and-study from Spain found an increase in the regional griffon vulture population following the banning of strychnine, amongst several other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/455>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Make selective use of spring herbicides
- Provide buffer strips along rivers and streams
- Provide unfertilised cereal headlands in arable fields
- Use buffer strips around in-field ponds
- Use organic rather than mineral fertilisers

3.12.3 Air-borne pollutants

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for air-borne pollutants?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Use lime to reduce acidification in lakes

Unknown effectiveness (limited evidence)

● **Use lime to reduce acidification in lakes**

A study from Sweden found no difference in osprey productivity during a period of extensive liming of acidified lakes compared to two periods without liming. *Assessment: unknown effectiveness – limited evidence (effectiveness 0%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/465>

3.12.4 Excess energy

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for excess energy?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Shield lights to reduce mortality from artificial lights● Turning off lights to reduce mortality from artificial lights● Use flashing lights to reduce mortality from artificial lights● Use lights low in spectral red to reduce mortality from artificial lights
No evidence found (no assessment)	<ul style="list-style-type: none">● Reduce the intensity of lighthouse beams● Using volunteers to collect and rehabilitate downed birds

Unknown effectiveness (limited evidence)

● **Shield lights to reduce mortality from artificial lights**

A study from the USA found that fewer shearwaters were downed when security lights were shielded, compared to nights with unshielded lights. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/469>

● **Turning off lights to reduce mortality from artificial lights**

A study from the UK found that fewer seabirds were downed when artificial (indoor and outdoor) lighting was reduced at night, compared to nights with normal lighting. *Assessment: unknown effectiveness — limited evidence (effectiveness 49%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/467>



● Use flashing lights to reduce mortality from artificial lights

A study from the USA found that fewer dead birds were found beneath aviation control towers with only flashing lights, compared to those with both flashing and continuous lights. *Assessment: unknown effectiveness – limited evidence (effectiveness 54%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/470>

● Use lights low in spectral red to reduce mortality from artificial lights

Two studies from Europe found that fewer birds were attracted to low-red lights (including green and blue lights), compared with the number expected, or the number attracted to white or red lights. *Assessment: unknown effectiveness – limited evidence (effectiveness 56%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/471>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce the intensity of lighthouse beams
- Using volunteers to collect and rehabilitate downed birds

3.13 Threat: Climate change, extreme weather and geological events

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for climate change, extreme weather and geological events?

Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Replace nesting habitats when they are washed away by storms● Water nesting mounds to increase incubation success in malleefowl
---	--

Unknown effectiveness (limited evidence)

- **Replace nesting habitats when they are washed away by storms**

A before-and-after study found that a common tern colony increased following the replacement of nesting habitats, whilst a second found that a colony decreased. In both cases, several other interventions were used at the same time, making it hard to examine the effect of habitat provision. *Assessment: unknown effectiveness — limited evidence (effectiveness 8%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/474>



● **Water nesting mounds to increase incubation success in malleefowl**

A single small trial in Australia found that watering malleefowl nests increased their internal temperature but that a single application of water did not prevent the nests drying out and being abandoned during a drought. *Assessment: unknown effectiveness — limited evidence (effectiveness 9%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/473>

3.14 General responses to small/declining populations

3.14.1 Inducing breeding, rehabilitation and egg removal

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for inducing breeding, rehabilitation and egg removal?

Unknown effectiveness (limited evidence)

- Rehabilitate injured birds
- Remove eggs from wild nests to increase reproductive output
- Use artificial visual and auditory stimuli to induce breeding in wild populations

Unknown effectiveness (limited evidence)

● **Rehabilitate injured birds**

Two studies of four studies from the UK and USA found that 25–40% of injured birds taken in by centres were rehabilitated and released. Three studies from the USA found that rehabilitated birds appeared to have high survival. One found that mortality rates were higher for owls than raptors. *Assessment: unknown effectiveness — limited evidence (effectiveness 36%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/476>



● **Remove eggs from wild nests to increase reproductive output**

A study from Canada found that whooping crane reproductive success was higher for nests with one or two eggs removed than for controls. A study from the USA found that removing bald eagle eggs did not appear to affect the wild population and a replicated study from Mauritius found that removing entire Mauritius kestrel clutches appeared to increase productivity more than removing individual eggs as they were laid. *Assessment: unknown effectiveness – limited evidence (effectiveness 24%; certainty 25%; harms 5%).*

<http://www.conservationevidence.com/actions/477>

● **Use artificial visual and auditory stimuli to induce breeding in wild populations**

A small study from the British Virgin Islands found an increase in breeding behaviour after the introduction of visual and auditory stimulants. *Assessment: unknown effectiveness – limited evidence (effectiveness 19%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/475>

3.14.2 Provide artificial nesting sites

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for providing artificial nesting sites?	
Beneficial	<ul style="list-style-type: none"> ● Provide artificial nests: falcons ● Provide artificial nests: owls ● Provide artificial nests: songbirds ● Provide artificial nests: wildfowl
Likely to be beneficial	<ul style="list-style-type: none"> ● Clean artificial nests to increase occupancy or reproductive success ● Provide artificial nests: burrow-nesting seabirds ● Provide artificial nests: divers/loons ● Provide artificial nests: ground- and tree-nesting seabirds ● Provide artificial nests: oilbirds ● Provide artificial nests: raptors ● Provide artificial nests: wildfowl – artificial/ floating islands

Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Artificially incubate eggs or warm nests● Guard nests● Provide artificial nests: gamebirds● Provide artificial nests: grebes● Provide artificial nests: ibises and flamingos● Provide artificial nests: parrots● Provide artificial nests: pigeons● Provide artificial nests: rails● Provide artificial nests: rollers● Provide artificial nests: swifts● Provide artificial nests: trogons● Provide artificial nests: waders● Provide artificial nests: woodpeckers● Provide nesting habitat for birds that is safe from extreme weather● Provide nesting material for wild birds● Remove vegetation to create nesting areas● Repair/support nests to support breeding● Use differently-coloured artificial nests
---	---

Beneficial

● Provide artificial nests (falcons)

Four studies from the USA and Europe found that local populations of falcons increased following the installation of artificial nesting sites. However, a study from Canada found no increase in the local population of falcons following the erection of nest boxes. Eight studies from across the world found that the success and productivity of falcons in nest boxes was higher than or equal to those in natural nests. Four studies from across the world found that productivity in nest boxes was lower than in natural nests, or that some falcons were evicted from their nests by owls. Four studies from across the world found no differences in productivity between nest box designs or positions, whilst two from Spain and Israel found that productivity in boxes varied between designs and habitats. Twenty-one studies from across the world found nest boxes were used by falcons, with one in the UK finding that nest boxes were not used at



all. Seven studies found that position or design affected use, whilst three found no differences between design or positioning. *Assessment: beneficial (effectiveness 65%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/489>

● Provide artificial nests (owls)

Three studies from the UK appeared to show increases in local populations of owls following the installation of artificial nests. Another UK study found that providing nesting sites when renovating buildings maintained owl populations, whilst they declined at sites without nests. Four studies from the USA and the UK found high levels of breeding success in artificial nests. Two studies from the USA and Hungary found lower productivity or fledgling survival from breeding attempts in artificial nests, whilst a study from Finland found that artificial nests were only successful in the absence of larger owls. Four studies from the USA and Europe found that artificial nests were used as frequently as natural sites. Five studies from across the world found that owls used artificial nests. Seven studies found that nest position or design affected occupancy or productivity. However four studies found occupancy and/or productivity did not differ between different designs of nest box. *Assessment: beneficial (effectiveness 65%; certainty 66%; harms 5%).*

<http://www.conservationevidence.com/actions/490>

● Provide artificial nests (songbirds)

Only three out of 66 studies from across the world found low rates of nest box occupancy in songbirds. Low rates of use were seen in thrushes, crows, swallows and New World warblers. Thrushes, crows, finches, swallows, wrens, tits, Old World and tyrant flycatchers, New World blackbirds, sparrows, waxbills, starlings and ovenbirds all used nest boxes. Five studies from across the world found higher population densities or growth rates, and one study from the USA found higher species richness, in areas with nest boxes. Twelve studies from across the world found that productivity in nest boxes was higher than or similar to natural nests. One study found there were more nesting attempts in areas with more nest boxes, although a study from Canada found no differences in productivity between areas with different nest box densities. Two studies from Europe found lower predation of species using nest boxes but three studies from the USA found

low production in nest boxes. Thirteen studies from across the world found that use, productivity or usurpation rate varied with nest box design, whilst seven found no difference in occupation rates or success between different designs. Similarly, fourteen studies found different occupation or success rates depending on the position of artificial nest sites but two studies found no such differences. *Assessment: beneficial (effectiveness 67%; certainty 85%; harms 0%).*

<http://www.conservationevidence.com/actions/498>

● **Provide artificial nests (wildfowl)**

Six studies from North America and Europe found that wildfowl populations increased with the provision of artificial nests, although one study from Finland found no increase in productivity in areas with nest boxes. Nine out of twelve studies from North America found that productivity was high in artificial nests. Two studies found that success for some species in nest boxes was lower than for natural nests. Nineteen studies from across the world found that occupancy rates varied from no use to 100% occupancy. Two studies found that occupancy rates were affected by design or positioning. Three studies from North America found that nest boxes could have other impacts on reproduction and behaviour. *Assessment: beneficial (effectiveness 62%; certainty 76%; harms 0%).*

<http://www.conservationevidence.com/actions/482>

Likely to be beneficial

● **Clean artificial nests to increase occupancy or reproductive success**

Five out of ten studies from North America and Europe found that songbirds preferentially nested in cleaned nest boxes or those sterilised using microwaves, compared to used nest boxes. One study found that the preference was not strong enough for birds to switch nest boxes after they were settled. One study found that birds avoided heavily-soiled nest boxes. Two studies birds had a preference for used nest boxes and one found no preference for cleaned or uncleaned boxes. None of the five studies that examined it found any effect of nest box cleanliness on nesting success or



parasitism levels. *Assessment: likely to be beneficial (effectiveness 40%; certainty 40%; harms 15%).*

<http://www.conservationevidence.com/actions/499>

● Provide artificial nests (burrow-nesting seabirds)

Four studies from across the world found population increases or population establishment following the provision of nest boxes. In two cases this was combined with other interventions. Six studies from across the world found high occupancy rates for artificial burrows by seabirds but three studies from across the world found very low occupancy rates for artificial burrows used by petrels. Eight studies from across the world found that the productivity of birds in artificial burrows was high although two studies from the USA and the Galapagos found low productivity in petrels. *Assessment: likely to be beneficial (effectiveness 60%; certainty 71%; harms 5%).*

<http://www.conservationevidence.com/actions/481>

● Provide artificial nests (divers/loons)

Three studies from the UK and the USA found increases in loon productivity on lakes provided with nesting rafts. A study in the UK found that usage of nesting rafts varied between sites. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/478>

● Provide artificial nests (ground- and tree-nesting seabirds)

Three studies from the UK and the Azores found increases in gull and tern populations following the provision of rafts/islands or nest boxes alongside other interventions. Five studies from Canada and Europe found that terns used artificial nesting sites. A study from the USA found that terns had higher nesting success on artificial rafts in some years and a study from Japan found increased nesting success after provision of nesting substrate. Design of nesting structure should be considered. *Assessment: likely to be beneficial (effectiveness 60%; certainty 49%; harms 0%).*

<http://www.conservationevidence.com/actions/480>

● Provide artificial nests (oilbirds)

A study in Trinidad and Tobago found an increase in the size of an oilbird colony after the creation of artificial nesting lodges. *Assessment: likely to be beneficial (effectiveness 50%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/491>

● Provide artificial nests (raptors)

Nine studies from North America and Spain found that raptors used artificial nesting platforms. Two studies from the USA found increases in populations or densities following the installation of platforms. Three studies describe successful use of platforms but three found lower productivity or failed nesting attempts, although these studies only describe a single nesting attempt. *Assessment: likely to be beneficial (effectiveness 55%; certainty 55%; harms 0%).*

<http://www.conservationevidence.com/actions/488>

● Provide artificial nests (wildfowl – artificial/floating islands)

Two studies from North America found that wildfowl used artificial islands and floating rafts and had high nesting success. A study in the UK found that wildfowl preferentially nested on vegetated rather than bare islands. *Assessment: likely to be beneficial (effectiveness 45%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/483>

Unknown effectiveness (limited evidence)

● Artificially incubate eggs or warm nests

One of two studies found that no kakapo chicks or eggs died of cold when they were artificially warmed when females left the nest. A study from the UK found that great tits were less likely to interrupt their laying sequence if their nest boxes were warmed, but there was no effect on egg or clutch size. *Assessment: unknown effectiveness – limited evidence (effectiveness 26%; certainty 16%; harms 0%).*

<http://www.conservationevidence.com/actions/503>



● **Guard nests**

We captured four studies describing the effects of guarding nests. One, from Costa Rica, found an increase in scarlet macaw population after nest monitoring and several other interventions. Two studies from Puerto Rico and New Zealand found that nest success was higher, or mortality lower, when nests were monitored. A study from New Zealand found that nest success was high overall when nests were monitored. *Assessment: unknown effectiveness – limited evidence (effectiveness 41%; certainty 24%; harms 0%).*

<http://www.conservationevidence.com/actions/506>

● **Provide artificial nests (gamebirds)**

A study in China found that approximately 40% of the local population of Cabot's tragopans used nesting platforms. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/484>

● **Provide artificial nests (grebes)**

A study from the UK found that grebes used nesting rafts in some areas but not others. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 9%; harms 0%).*

<http://www.conservationevidence.com/actions/479>

● **Provide artificial nests (ibises and flamingos)**

A study from Turkey found that ibises moved to a site with artificial breeding ledges. A study from Spain and France found that large numbers of flamingos used artificial nesting islands. *Assessment: unknown effectiveness – limited evidence (effectiveness 42%; certainty 31%; harms 0%).*

<http://www.conservationevidence.com/actions/487>

● **Provide artificial nests (parrots)**

A study from Costa Rica found that the local population of scarlet macaws increased following the installation of nest boxes along with several other interventions. Five studies from South and Central America and Mauritius found that nest boxes were used by several species of parrots. One study from Peru found that blue-and-yellow macaws only used modified palms, not 'boxes', whilst another study found that scarlet macaws used both PVC

and wooden boxes. Four studies from Venezuela and Columbia found that several species rarely, if ever, used nest boxes. Six studies from Central and South America found that parrots nested successfully in nest boxes, with two species showing higher levels of recruitment into the population following nest box erection and another finding that success rates for artificial nests were similar to natural nests. Three studies from South America found that artificial nests had low success rates, in two cases due to poaching. *Assessment: unknown effectiveness — limited evidence (effectiveness 25%; certainty 38%; harms 11%).*

<http://www.conservationevidence.com/actions/497>

● **Provide artificial nests (pigeons)**

Two studies from the USA and the Netherlands found high use rates and high nesting success of pigeons and doves using artificial nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 16%; harms 0%).*

<http://www.conservationevidence.com/actions/492>

● **Provide artificial nests (rails)**

A study from the UK found that common moorhens and common coot readily used artificial nesting islands. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/485>

● **Provide artificial nests (rollers)**

A study from Spain found that the use of nest boxes by rollers increased over time and varied between habitats. Another study from Spain found no difference in success rates between new and old nest boxes. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/494>

● **Provide artificial nests (swifts)**

A study from the USA found that Vaux's swifts successfully used nest boxes provided. *Assessment: unknown effectiveness — limited evidence (effectiveness 25%; certainty 16%; harms 0%).*

<http://www.conservationevidence.com/actions/495>



● Provide artificial nests (trogons)

A small study from Guatemala found that at least one resplendent quetzal nested in nest boxes provided. *Assessment: unknown effectiveness – limited evidence (effectiveness 19%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/493>

● Provide artificial nests (waders)

Two studies from the USA and the UK found that waders used artificial islands and nesting sites. *Assessment: unknown effectiveness – limited evidence (effectiveness 25%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/486>

● Provide artificial nests (woodpeckers)

Four studies from the USA found local increases in red-cockaded woodpecker populations or the successful colonisation of new areas following the installation of ‘cavity inserts’. One study also found that the productivity of birds using the inserts was higher than the regional average. Two studies from the USA found that red-cockaded woodpeckers used cavity inserts, in one case more frequently than making their own holes or using natural cavities. One study from the USA found that woodpeckers roosted, but did not nest, in nest boxes. Five studies from the USA found that some woodpeckers excavated holes in artificial snags but only roosted in excavated holes or nest boxes. *Assessment: unknown effectiveness – limited evidence (effectiveness 35%; certainty 39%; harms 0%).*

<http://www.conservationevidence.com/actions/496>

● Provide nesting habitat for birds that is safe from extreme weather

Two of three studies found that nesting success of waders and terns was no higher on raised areas of nesting substrate, with one finding that similar numbers were lost to flooding. The third study found that Chatham Island oystercatchers used raised nest platforms, but did not report on nesting success. *Assessment: unknown effectiveness – limited evidence (effectiveness 28%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/504>

● **Provide nesting material for wild birds**

One of two studies found that wild birds took nesting material provided; the other found only very low rates of use. *Assessment: unknown effectiveness — limited evidence (effectiveness 11%; certainty 9%; harms 0%).*

<http://www.conservationevidence.com/actions/501>

● **Remove vegetation to create nesting areas**

Two out of six studies found increases in population sizes at seabird and wader colonies after vegetation was cleared and a third found that an entire colony moved to a new site that was cleared of vegetation. Two of these studies found that several interventions were used at once. Two studies found that gulls and terns used plots cleared of vegetation, one of these found that nesting densities were higher on partially-cleared plots than totally cleared, or uncleared, plots. One study found that tern nesting success was higher on plots after they were cleared of vegetation and other interventions were used. *Assessment: unknown effectiveness — limited evidence (effectiveness 45%; certainty 28%; harms 10%).*

<http://www.conservationevidence.com/actions/505>

● **Repair/support nests to support breeding**

A study from Puerto Rico found that no chicks died from chilling after nine nests were repaired to prevent water getting in. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/502>

● **Use differently-coloured artificial nests**

A study from the USA found that two bird species (a thrush and a pigeon) both showed colour preferences for artificial nests, but that these preferences differed between species. In each case, clutches in the preferred colour nest were less successful than those in the other colour. *Assessment: unknown effectiveness — limited evidence (effectiveness 3%; certainty 9%; harms 0%).*

<http://www.conservationevidence.com/actions/500>



3.14.3 Foster chicks in the wild

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for fostering chicks in the wild?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Foster eggs or chicks with wild conspecifics: raptors ● Foster eggs or chicks with wild non-conspecifics (cross-fostering): songbirds
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Foster eggs or chicks with wild conspecifics: bustards ● Foster eggs or chicks with wild conspecifics: cranes ● Foster eggs or chicks with wild conspecifics: gannets and boobies ● Foster eggs or chicks with wild conspecifics: owls ● Foster eggs or chicks with wild conspecifics: parrots ● Foster eggs or chicks with wild conspecifics: vultures ● Foster eggs or chicks with wild conspecifics: waders ● Foster eggs or chicks with wild conspecifics: woodpeckers ● Foster eggs or chicks with wild non-conspecifics (cross-fostering): cranes ● Foster eggs or chicks with wild non-conspecifics (cross-fostering): ibises ● Foster eggs or chicks with wild non-conspecifics (cross-fostering): petrels and shearwaters ● Foster eggs or chicks with wild non-conspecifics (cross-fostering): waders

Likely to be beneficial

● **Foster eggs or chicks with wild conspecifics (raptors)**

Ten out of 11 studies from across the world found that fostering raptor chicks to wild conspecifics had high success rates. A single study from the USA found that only one of six eggs fostered to wild eagle nests hatched and was raised. A study from Spain found that Spanish imperial eagle chicks were no more likely to survive to fledging if they were transferred to foster nests from three chick broods (at high risk from siblicide). A study

from Spain found that young (15–20 day old) Montagu's harrier chicks were successfully adopted, but three older (27–29 day old) chicks were rejected. *Assessment: likely to be beneficial (effectiveness 70%; certainty 60%; harms 10%).*

<http://www.conservationevidence.com/actions/510>

● **Foster eggs or chicks with wild non-conspecifics (cross-fostering) (songbirds)**

A study from the USA found that the survival of cross-fostered yellow warbler chicks was lower than previously-published rates for the species. A study from Norway found that the success of cross-fostering small songbirds varied depending on the species of chick and foster birds but recruitment was the same or higher than control chicks. The pairing success of cross-fostered chicks varied depending on species of chick and foster birds. *Assessment: likely to be beneficial (effectiveness 45%; certainty 45%; harms 10%).*

<http://www.conservationevidence.com/actions/520>

Unknown effectiveness (limited evidence)

● **Foster eggs or chicks with wild conspecifics (bustards)**

A small study in Saudi Arabia found that a captive-bred egg was successfully fostered to a female in the wild. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 5%; harms 0%).*

<http://www.conservationevidence.com/actions/513>

● **Foster eggs or chicks with wild conspecifics (cranes)**

A small study in Canada found high rates of fledging for whooping crane eggs fostered to first time breeders. *Assessment: unknown effectiveness — limited evidence (effectiveness 26%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/512>

● **Foster eggs or chicks with wild conspecifics (gannets and boobies)**

A small study in Australia found that gannet chicks were lighter, and hatching and fledging success lower in nests which had an extra egg or chick added. However, overall productivity was non-significantly higher



in experimental nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 9%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/507>

● **Foster eggs or chicks with wild conspecifics (owls)**

A study in the USA found high fledging rates for barn owl chicks fostered to wild pairs. A study from Canada found that captive-reared burrowing owl chicks fostered to wild nests did not have lower survival or growth rates than wild chicks. *Assessment: unknown effectiveness — limited evidence (effectiveness 35%; certainty 21%; harms 0%).*

<http://www.conservationevidence.com/actions/511>

● **Foster eggs or chicks with wild conspecifics (parrots)**

A study from Venezuela found that yellow-shouldered Amazon chicks had high fledging rates when fostered to conspecific nests in the wild. A second study from Venezuela found lower poaching rates of yellow-shouldered Amazons when chicks were moved to foster nests closer to a field base. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 14%; harms 0%).*

<http://www.conservationevidence.com/actions/515>

● **Foster eggs or chicks with wild conspecifics (vultures)**

Two small studies in Italy and the USA found that single chicks were successfully adopted by foster conspecifics, although in one case this led to the death of one of the foster parents' chicks. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 15%; harms 41%).*

<http://www.conservationevidence.com/actions/509>

● **Foster eggs or chicks with wild conspecifics (waders)**

Two small trials in North America found that piping plovers accepted chicks introduced into their broods, although in one case the chick died. A study from New Zealand found that survival of fostered black stilts was higher for birds fostered to conspecifics rather than a closely related species. *Assessment: unknown effectiveness — limited evidence (effectiveness 29%; certainty 9%; harms 0%).*

<http://www.conservationevidence.com/actions/508>

● **Foster eggs or chicks with wild conspecifics (woodpeckers)**

Three studies from the USA found that red-cockaded woodpecker chicks fostered to conspecifics had high fledging rates. One small study found that fostered chicks survived better than chicks translocated with their parents. *Assessment: unknown effectiveness — limited evidence (effectiveness 41%; certainty 29%; harms 0%).*

<http://www.conservationevidence.com/actions/514>

● **Foster eggs or chicks with wild non-conspecifics (cross-fostering) (cranes)**

Two studies from the USA found low fledging success for cranes fostered to non-conspecifics' nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 14%; certainty 35%; harms 10%).*

<http://www.conservationevidence.com/actions/519>

● **Foster eggs or chicks with wild non-conspecifics (cross-fostering) (ibises)**

A 2007 literature review describes attempting to foster northern bald ibis chicks with cattle egrets as unsuccessful. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/518>

● **Foster eggs or chicks with wild non-conspecifics (cross-fostering) (petrels and shearwaters)**

A study from Hawaii found that Newell's shearwater eggs fostered to wedge-tailed shearwater nests had high fledging rates. *Assessment: unknown effectiveness — limited evidence (effectiveness 45%; certainty 6%; harms 0%).*

<http://www.conservationevidence.com/actions/516>

● **Foster eggs or chicks with wild non-conspecifics (cross-fostering) (waders)**

A study from the USA found that killdeer eggs incubated and raised by spotted sandpipers had similar fledging rates to parent-reared birds. A study from New Zealand found that cross-fostering black stilt chicks to black-winged stilt nests increased nest success, but cross-fostered chicks



had lower success than chicks fostered to conspecifics' nests. *Assessment: unknown effectiveness – limited evidence (effectiveness 35%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/517>

3.14.4 Provide supplementary food

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for providing supplementary food?	
Beneficial	<ul style="list-style-type: none"> ● Provide supplementary food to increase adult survival: songbirds
Likely to be beneficial	<ul style="list-style-type: none"> ● Place feeders close to windows to reduce collisions ● Provide calcium supplements to increase survival or reproductive success ● Provide supplementary food to increase adult survival: cranes ● Provide supplementary food to increase reproductive success: gulls, terns and skuas ● Provide supplementary food to increase reproductive success: owls ● Provide supplementary food to increase reproductive success: raptors ● Provide supplementary food to increase reproductive success: songbirds
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Provide perches to improve foraging success ● Provide supplementary food through the establishment of food populations ● Provide supplementary food to allow the rescue of a second chick ● Provide supplementary food to increase adult survival: gamebirds ● Provide supplementary food to increase adult survival: gulls, terns and skuas ● Provide supplementary food to increase adult survival: hummingbirds ● Provide supplementary food to increase adult survival: nectar-feeding songbirds

	<ul style="list-style-type: none">● Provide supplementary food to increase adult survival: pigeons● Provide supplementary food to increase adult survival: raptors● Provide supplementary food to increase adult survival: vultures● Provide supplementary food to increase adult survival: waders● Provide supplementary food to increase adult survival: wildfowl● Provide supplementary food to increase adult survival: woodpeckers● Provide supplementary food to increase reproductive success: auks● Provide supplementary food to increase reproductive success: gamebirds● Provide supplementary food to increase reproductive success: gannets and boobies● Provide supplementary food to increase reproductive success: ibises● Provide supplementary food to increase reproductive success: kingfishers● Provide supplementary food to increase reproductive success: parrots● Provide supplementary food to increase reproductive success: petrels● Provide supplementary food to increase reproductive success: pigeons● Provide supplementary food to increase reproductive success: rails and coots● Provide supplementary food to increase reproductive success: vultures● Provide supplementary food to increase reproductive success: waders● Provide supplementary food to increase reproductive success: wildfowl● Provide supplementary water to increase survival or reproductive success
--	--



Beneficial

● Provide supplementary food to increase adult survival (songbirds)

Seven studies from Europe and the USA found higher densities or larger populations of songbird species in areas close to supplementary food. Six studies from Europe, Canada and Japan found that population trends or densities were no different between fed and unfed areas. Four studies from around the world found that birds had higher survival when supplied with supplementary food. However, in two studies this was only apparent in some individuals or species and one study from the USA found that birds with feeding stations in their territories had lower survival. Six studies from Europe and the USA found that birds supplied with supplementary food were in better physical condition than unfed birds. However, in four studies this was only true for some individuals, species or seasons. Two studies investigated the effect of feeding on behaviours: one in the USA found that male birds spent more time singing when supplied with food and one in Sweden found no behavioural differences between fed and unfed birds. Thirteen studies from the UK, Canada and the USA investigated use of feeders. Four studies from the USA and the UK found high use of supplementary food, with up to 21% of birds' daily energy needs coming from feeders. However, another UK study found very low use of food. The timing of peak feeder use varied. Two trials from the UK found that the use of feeders increased with distance to houses and decreased with distance to cover. Two studies in Canada and the UK, found that preferences for feeder locations and positions varies between species. *Assessment: beneficial (effectiveness 65%; certainty 75%; harms 0%).*

<http://www.conservationevidence.com/actions/552>

Likely to be beneficial

● Place feeders close to windows to reduce collisions

A randomised, replicated and controlled study in the USA found that fewer birds hit windows, and fewer were killed, when feeders were placed close to windows, compared to when they were placed further away. *Assessment: likely to be beneficial (effectiveness 44%; certainty 43%; harms 0%).*

<http://www.conservationevidence.com/actions/557>

- **Provide calcium supplements to increase survival or reproductive success**

Eight of 13 studies (including a literature review) from across the world found some positive effects of calcium provisioning on birds' productivities (six studies) or health (two studies). Six studies (including the review) found no evidence for positive effects on some of the species studied. One study from Europe found that birds at polluted sites took more calcium supplement than those at cleaner sites. *Assessment: likely to be beneficial (effectiveness 55%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/559>

- **Provide supplementary food to increase adult survival (cranes)**

A study from Japan and a global literature review found that local crane populations increased after the provision of supplementary food. *Assessment: likely to be beneficial (effectiveness 40%; certainty 40%; harms 15%).*

<http://www.conservationevidence.com/actions/547>

- **Provide supplementary food to increase reproductive success (gulls, terns and skuas)**

Four studies of three experiments from Europe and Alaska found that providing supplementary food increased fledging success or chick survival in two gull species, although a study from the UK found that this was only true for one of two islands. One study from the Antarctic found no effect of feeding parent skuas on productivity. One study from Alaska found increased chick growth when parents were fed but a study from the Antarctic found no such increase. *Assessment: likely to be beneficial (effectiveness 42%; certainty 41%; harms 0%).*

<http://www.conservationevidence.com/actions/525>

- **Provide supplementary food to increase reproductive success (owls)**

Two replicated, controlled trials from Europe and the USA found that owls supplied with supplementary food had higher hatching and fledging rates. The European study, but not the American, also found that fed pairs laid



earlier and had larger clutches. The study in the USA also found that owls were no more likely to colonise nest boxes provided with supplementary food. *Assessment: likely to be beneficial (effectiveness 50%; certainty 42%; harms 0%).*

<http://www.conservationevidence.com/actions/533>

● **Provide supplementary food to increase reproductive success (raptors)**

A small study in Italy described a small increase in local kite populations following the installation of a feeding station. Four European studies found that kestrels and Eurasian sparrowhawks laid earlier than control birds when supplied with supplementary food. Three studies from the USA and Europe found higher chick survival or condition when parents were supplied with food, whilst three from Europe found fed birds laid larger clutches and another found that fed male hen harriers bred with more females than control birds. Four studies from across the world found no evidence that feeding increased breeding frequency, clutch size, laying date, eggs size or hatching or fledging success. A study from Mauritius found uncertain effects of feeding on Mauritius kestrel reproduction. There was some evidence that the impact of feeding was lower in years with peak numbers of prey species. *Assessment: likely to be beneficial (effectiveness 55%; certainty 52%; harms 0%).*

<http://www.conservationevidence.com/actions/532>

● **Provide supplementary food to increase reproductive success (songbirds)**

Two studies from the USA found evidence for higher population densities of magpies and American blackbirds in areas provided with supplementary food, whilst two studies from the UK and Canada found that population densities were not affected by feeding. Twelve studies from across the world found that productivity was higher for fed birds than controls. Eleven studies from Europe and the USA found that fed birds had the same, or even lower, productivity or chick survival than control birds. Nine studies from Europe and North America found that the eggs of fed birds were larger or heavier, or that the chicks of fed birds were in better physical condition. However, eight studies from across the world found no evidence for better

condition or increased size in the eggs or chicks of fed birds. Six studies from across the world found that food-supplemented pairs laid larger clutches, whilst 14 studies from Europe and North America found that fed birds did not lay larger clutches. Fifteen studies from across the world found that birds supplied with supplementary food began nesting earlier than controls, although in two cases only certain individuals, or those in particular habitats, laid earlier. One study found that fed birds had shorter incubations than controls whilst another found that fed birds re-nested quicker and had shorter second incubations. Four studies from the USA and Europe found that fed birds did not lay any earlier than controls. Seven studies from across the world found that fed parent birds showed positive behavioural responses to feeding. However, three studies from across the world found neutral or negative responses to feeding. *Assessment: likely to be beneficial (effectiveness 51%; certainty 85%; harms 6%).*

<http://www.conservationevidence.com/actions/537>

Unknown effectiveness (limited evidence)

● **Provide perches to improve foraging success**

One of four studies, from Sweden, found that raptors used clearcuts provided with perches more than clearcuts without perches. Two studies found that birds used perches provided, but a controlled study from the USA found that shrikes did not alter foraging behaviour when perches were present. *Assessment: unknown effectiveness — limited evidence (effectiveness 45%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/556>

● **Provide supplementary food through the establishment of food populations**

One of four studies that established prey populations found that wildfowl fed on specially-planted rye grass. Two studies found that cranes in the USA and owls in Canada did not respond to established prey populations. A study from Sweden found that attempts to increase macroinvertebrate numbers for wildfowl did not succeed. *Assessment: unknown effectiveness — limited evidence (effectiveness 9%; certainty 26%; harms 0%).*

<http://www.conservationevidence.com/actions/555>



- **Provide supplementary food to allow the rescue of a second chick**

A study from Spain found that second chicks from lammergeier nests survived longer if nests were provided with food, in one case allowing a chick to be rescued. *Assessment: unknown effectiveness — limited evidence (effectiveness 15%; certainty 14%; harms 0%).*

<http://www.conservationevidence.com/actions/541>

- **Provide supplementary food to increase adult survival (gamebirds)**

Two European studies found increased numbers of birds in fed areas, compared to unfed areas. There was only an increase in the overall population in the study area in one of these studies. Of four studies in the USA on northern bobwhites, one found that birds had higher overwinter survival in fed areas, one found lower survival, one found fed birds had higher body fat percentages and a literature review found no overall effect of feeding. *Assessment: unknown effectiveness — limited evidence (effectiveness 49%; certainty 38%; harms 0%).*

<http://www.conservationevidence.com/actions/544>

- **Provide supplementary food to increase adult survival (gulls, terns and skuas)**

A study in the Antarctic found that fed female south polar skuas lost more weight whilst feeding two chicks than unfed birds. There was no difference for birds with single chicks, or male birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 20%; harms 10%).*

<http://www.conservationevidence.com/actions/548>

- **Provide supplementary food to increase adult survival (hummingbirds)**

Four studies from the USA found that three species of hummingbird preferred higher concentrations of sucrose, consuming more and visiting feeders more frequently. A study from the USA found that hummingbirds preferentially fed on sugar solutions over artificial sweeteners, and that the viscosity of these solutions did not affect their consumption. Two studies from Mexico and Argentina found that four species showed preferences for

sucrose over fructose or glucose and sucrose over a sucrose-glucose mix, but no preference for sucrose over a glucose-fructose mix. A study from the USA found that birds showed a preference for red-dyed sugar solutions over five other colours. A study from the USA found that rufous hummingbirds preferentially fed on feeders that were placed higher. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 24%; harms 0%).*

<http://www.conservationevidence.com/actions/550>

● **Provide supplementary food to increase adult survival (nectar-feeding songbirds)**

Two studies from Australia and New Zealand found that ten species of honeyeaters and stitchbirds readily used feeders supplying sugar solutions, with seasonal variations varying between species. A series of *ex situ* trials using southern African birds found that most species preferred sucrose solutions over glucose or fructose. One study found that sunbirds and sugarbirds only showed such a preference at low concentrations. Two studies found that two species showed preferences for sucrose when comparing 20% solutions, although a third species did not show this preference. All species rejected solutions with xylose added. A final study found that sucrose preferences were only apparent at equicaloric concentrations high enough for birds to subsist on. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/553>

● **Provide supplementary food to increase adult survival (pigeons)**

The first of two studies of a recently-released pink pigeon population on Mauritius found that fewer than half the birds took supplementary food. However, the later study found that almost all birds used supplementary feeders. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/549>

● **Provide supplementary food to increase adult survival (raptors)**

Two studies in the USA found that nesting northern goshawks were significantly heavier in territories supplied with supplementary food,



compared with those from unfed territories. *Assessment: unknown effectiveness— limited evidence (effectiveness 30%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/546>

● **Provide supplementary food to increase adult survival (vultures)**

A study from Spain found a large increase in griffon vulture population in the study area following multiple interventions including supplementary feeding. Two studies from the USA and Israel found that vultures fed on the carcasses provided for them. In the study in Israel vultures were sometimes dominated by larger species at a feeding station supplied twice a month, but not at one supplied every day. *Assessment: unknown effectiveness — limited evidence (effectiveness 18%; certainty 18%; harms 0%).*

<http://www.conservationevidence.com/actions/545>

● **Provide supplementary food to increase adult survival (waders)**

A study in Northern Ireland found that waders fed on millet seed when provided, but were dominated by other ducks when larger seeds were provided. *Assessment: unknown effectiveness — limited evidence (effectiveness 22%; certainty 9%; harms 0%).*

<http://www.conservationevidence.com/actions/543>

● **Provide supplementary food to increase adult survival (wildfowl)**

Two studies from Canada and Northern Ireland found that five species of wildfowl readily consumed supplementary grains and seeds. The Canadian study found that fed birds were heavier and had larger hearts or flight muscles or more body fat than controls. *Assessment: unknown effectiveness — limited evidence (effectiveness 14%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/542>

● **Provide supplementary food to increase adult survival (woodpeckers)**

One replicated, controlled study from the USA found that 12 downy woodpeckers supplied with supplementary food had higher nutritional

statuses than unfed birds. However, two analyses of a replicated, controlled study of 378 downy woodpeckers from the USA found that they did not have higher survival rates or nutritional statuses than unfed birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 30%; harms 0%).*

<http://www.conservationevidence.com/actions/551>

- **Provide supplementary food to increase reproductive success (auks)**

Two replicated studies from the UK found that Atlantic puffin chicks provided with supplementary food were significantly heavier than control chicks, but fed chicks fledged at the same time as controls. A randomised, replicated and controlled study from Canada found that tufted puffin chicks supplied with supplementary food fledged later than controls and that fed chicks had faster growth by some, but not all, metrics. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 38%; harms 0%).*

<http://www.conservationevidence.com/actions/524>

- **Provide supplementary food to increase reproductive success (gamebirds)**

A controlled study in Tibet found that Tibetan eared pheasants fed supplementary food laid significantly larger eggs and clutches than control birds. Nesting success and laying dates were not affected. *Assessment: unknown effectiveness — limited evidence (effectiveness 23%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/527>

- **Provide supplementary food to increase reproductive success (gannets and boobies)**

A small controlled study in Australia found that Australasian gannet chicks were significantly heavier if they were supplied with supplementary food, but only in one of two years. Fledging success of fed nests was also higher, but not significantly so. A randomised replicated and controlled study in the Galapagos Islands found that fed female Nazca boobies were more likely to produce two-egg clutches, and that second eggs were significantly



heavier. *Assessment: unknown effectiveness — limited evidence (effectiveness 33%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/523>

● **Provide supplementary food to increase reproductive success (ibises)**

A study from China found that breeding success of crested ibis was correlated with the amount of supplementary food provided, although no comparison was made with unfed nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 25%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/530>

● **Provide supplementary food to increase reproductive success (kingfishers)**

A controlled study in the USA found that belted kingfishers supplied with food had heavier nestlings and were more likely to renest. There was mixed evidence for the effect of feeding on laying date. *Assessment: unknown effectiveness — limited evidence (effectiveness 33%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/534>

● **Provide supplementary food to increase reproductive success (parrots)**

Two studies from New Zealand found evidence that providing supplementary food for kakapos increased the number of breeding attempts made, whilst a third study found that birds provided with specially-formulated pellets appeared to have larger clutches than those fed on nuts. One study found no evidence that providing food increased the number of nesting attempts. *Assessment: unknown effectiveness — limited evidence (effectiveness 33%; certainty 11%; harms 0%).*

<http://www.conservationevidence.com/actions/536>

● **Provide supplementary food to increase reproductive success (petrels)**

A replicated controlled study in Australia found that Gould's petrel chicks provided with supplementary food had similar fledging rates to both control and hand-reared birds, but were significantly heavier than other

birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 19%; certainty 14%; harms 0%).*

<http://www.conservationevidence.com/actions/522>

● **Provide supplementary food to increase reproductive success (pigeons)**

A study in the UK found no differences in reproductive parameters of European turtle doves between years when food was supplied and those when it was not. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 21%; harms 0%).*

<http://www.conservationevidence.com/actions/535>

● **Provide supplementary food to increase reproductive success (rails and coots)**

A small trial in the USA found that fed American coots laid heavier eggs, but not larger clutches, than controls. However, a randomised, replicated and controlled study in Canada found that clutch size, but not egg size, was larger in fed American coot territories. The Canadian study also found that coots laid earlier when fed, whilst a replicated trial from the UK found there was a shorter interval between common moorhens clutches in fed territories, but that fed birds were no more likely to produce second broods. *Assessment: unknown effectiveness — limited evidence (effectiveness 33%; certainty 26%; harms 0%).*

<http://www.conservationevidence.com/actions/528>

● **Provide supplementary food to increase reproductive success (vultures)**

Two studies from the USA and Greece found that there were local increases in two vulture populations following the provision of food in the area. A study from Israel found that a small, regularly supplied feeding station could provide sufficient food for breeding Egyptian vultures. A study from Italy found that a small population of Egyptian vultures declined following the provision of food, and only a single vulture was seen at the feeding station. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 24%; harms 0%).*

<http://www.conservationevidence.com/actions/531>



● **Provide supplementary food to increase reproductive success (waders)**

A small controlled trial from the Netherlands found that Eurasian oystercatchers did not produce larger replacement eggs if provided with supplementary food. Instead their eggs were smaller than the first clutch, whereas control females laid larger replacement eggs. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/529>

● **Provide supplementary food to increase reproductive success (wildfowl)**

A small randomised controlled *ex situ* study from Canada found faster growth and higher weights for fed greater snow goose chicks than unfed ones, but no differences in mortality rates. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/526>

● **Provide supplementary water to increase survival or reproductive success**

A controlled study from Morocco found that northern bald ibises provided with supplementary water had higher reproductive success than those a long way from water sources. *Assessment: unknown effectiveness — limited evidence (effectiveness 43%; certainty 14%; harms 0%).*

<http://www.conservationevidence.com/actions/558>

3.14.5 Translocations

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for translocations?

Beneficial

- Translocate birds to re-establish populations or increase genetic variation (birds in general)
- Translocate birds to re-establish populations or increase genetic variation: raptors

<p>Likely to be beneficial</p>	<ul style="list-style-type: none"> ● Translocate birds to re-establish populations or increase genetic variation: parrots ● Translocate birds to re-establish populations or increase genetic variation: pelicans ● Translocate birds to re-establish populations or increase genetic variation: petrels and shearwaters ● Translocate birds to re-establish populations or increase genetic variation: rails ● Translocate birds to re-establish populations or increase genetic variation: songbirds ● Translocate birds to re-establish populations or increase genetic variation: wildfowl ● Translocate birds to re-establish populations or increase genetic variation: woodpeckers ● Use decoys to attract birds to new sites ● Use techniques to increase the survival of species after capture ● Use vocalisations to attract birds to new sites
<p>Trade-off between benefit and harms</p>	<ul style="list-style-type: none"> ● Translocate birds to re-establish populations or increase genetic variation: gamebirds
<p>Unknown effectiveness (limited evidence)</p>	<ul style="list-style-type: none"> ● Alter habitats to encourage birds to leave ● Ensure translocated birds are familiar with each other before release ● Translocate birds to re-establish populations or increase genetic variation: auks ● Translocate birds to re-establish populations or increase genetic variation: herons, storks and ibises ● Translocate birds to re-establish populations or increase genetic variation: megapodes ● Translocate birds to re-establish populations or increase genetic variation: owls ● Translocate nests to avoid disturbance
<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Ensure genetic variation to increase translocation success



Beneficial

● Translocate birds to re-establish populations or increase genetic variation (birds in general)

A review of 239 bird translocation programmes found 63–67% resulted in establishment of a self-sustaining population. *Assessment: beneficial (effectiveness 64%; certainty 65%; harms 0%).*

<http://www.conservationevidence.com/actions/566>

● Translocate birds to re-establish populations or increase genetic variation (raptors)

Six studies of three translocation programmes in the UK and the USA found that all successfully established populations of white-tailed eagles, red kites and ospreys. A study in Spain found high survival of translocated Montagu's harrier fledglings. *Assessment: beneficial (effectiveness 65%; certainty 66%; harms 0%).*

<http://www.conservationevidence.com/actions/574>

Likely to be beneficial

● Translocate birds to re-establish populations or increase genetic variation (parrots)

Three studies of two translocation programmes from the Pacific and New Zealand found that populations of parrots successfully established on islands after translocation. Survival of translocated birds ranged from 41% to 98% globally. Despite high survival, translocated kakapos in New Zealand had very low reproductive output. *Assessment: likely to be beneficial (effectiveness 50%; certainty 60%; harms 10%).*

<http://www.conservationevidence.com/actions/578>

● Translocate birds to re-establish populations or increase genetic variation (pelicans)

Two reviews of a pelican translocation programme in the USA found high survival of translocated nestlings and rapid target population growth.

Some growth may have been due to additional immigration from the source populations. *Assessment: likely to be beneficial (effectiveness 55%; certainty 49%; harms 0%).*

<http://www.conservationevidence.com/actions/569>

● **Translocate birds to re-establish populations or increase genetic variation (petrels and shearwaters)**

Three studies from Australia and New Zealand found that colonies of burrow-nesting petrels and shearwaters were successfully established following the translocation and hand-rearing of chicks. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/568>

● **Translocate birds to re-establish populations or increase genetic variation (rails)**

Three studies of two translocation programmes in the Seychelles and New Zealand found high survival rates among translocated rail. All three studies round that the birds bred successfully. *Assessment: likely to be beneficial (effectiveness 54%; certainty 44%; harms 14%).*

<http://www.conservationevidence.com/actions/573>

● **Translocate birds to re-establish populations or increase genetic variation (songbirds)**

Nine studies from across the world, including a review of 31 translocation attempts, found that translocations led to the establishment of songbird populations. Eight studies were on islands. Three studies reported on translocations that failed to establish populations. One study found nesting success decreased as the latitudinal difference between source area and release site increased. *Assessment: likely to be beneficial (effectiveness 50%; certainty 68%; harms 0%).*

<http://www.conservationevidence.com/actions/580>

● **Translocate birds to re-establish populations or increase genetic variation (wildfowl)**

Three studies of two duck translocation programmes in New Zealand and Hawaii found high survival, breeding and successful establishment of new



populations. However a study in the USA found that no ducks stayed at the release site and there was high mortality after release. A study in the USA found wing-clipping prevented female ducks from abandoning their ducklings. *Assessment: likely to be beneficial (effectiveness 42%; certainty 50%; harms 19%).*

<http://www.conservationevidence.com/actions/571>

● **Translocate birds to re-establish populations or increase genetic variation (woodpeckers)**

Six studies of four programmes found that >50% translocated birds remained at their new sites, and two studies reported large population increases. Birds from four programmes were reported as forming pairs or breeding and one study round translocated nestlings fledged at similar rates to native chicks. All studies were of red-cockaded woodpeckers. *Assessment: likely to be beneficial (effectiveness 51%; certainty 42%; harms 0%).*

<http://www.conservationevidence.com/actions/577>

● **Use decoys to attract birds to new sites**

Ten studies found that birds nested in areas where decoys were placed or that more birds landed in areas with decoys than control areas. Six studies used multiple interventions at once. One study found that three-dimensional models appeared more effective than two-dimensional ones, and that plastic models were more effective than rag decoys. *Assessment: likely to be beneficial (effectiveness 51%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/586>

● **Use techniques to increase the survival of species after capture**

A study from the USA found that providing dark, quiet environments with readily-available food and water increased the survival of small songbirds after capture and the probability that they would adapt to captivity. A study from the USA found that keeping birds warm during transit increased survival. *Assessment: likely to be beneficial (effectiveness 49%; certainty 41%; harms 0%).*

<http://www.conservationevidence.com/actions/581>

● Use vocalisations to attract birds to new sites

Seven out of ten studies from around the world found that seabirds were more likely to nest or land to areas where vocalisations were played, or moved to new nesting areas after vocalisations were played. Four of these studied multiple interventions at once. Three studies found that birds were no more likely to nest or land in areas where vocalisations were played. *Assessment: likely to be beneficial (effectiveness 45%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/585>

Trade-off between benefit and harms

● Translocate birds to re-establish populations or increase genetic variation (gamebirds)

Three studies from the USA found that translocation of gamebirds led to population establishment or growth or an increase in lekking sites. Four studies from the USA found that translocated birds had high survival, but two found high mortality in translocated birds. Four studies from the USA found breeding rates among translocated birds were high or similar to resident birds. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 47%; harms 35%).*

<http://www.conservationevidence.com/actions/572>

Unknown effectiveness (limited evidence)

● Alter habitats to encourage birds to leave

A study from Canada found that an entire Caspian tern population moved after habitat was altered at the old colony site, alongside several other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/587>

● Ensure translocated birds are familiar with each other before release

Two studies from New Zealand found no evidence that ensuring birds were familiar with each other increased translocation success. *Assessment:*



unknown effectiveness — limited evidence (effectiveness 0%; certainty 33%; harms 0%).

<http://www.conservationevidence.com/actions/582>

● **Translocate birds to re-establish populations or increase genetic variation (auks)**

A study in the USA and Canada found that 20% of translocated Atlantic puffins remained in or near the release site, with up to 7% breeding. *Assessment: unknown effectiveness — limited evidence (effectiveness 36%; certainty 38%; harms 0%).*

<http://www.conservationevidence.com/actions/570>

● **Translocate birds to re-establish populations or increase genetic variation (herons, storks and ibises)**

A study in the USA found that a colony of black-crowned night herons was successfully translocated and bred the year after translocation. *Assessment: unknown effectiveness — limited evidence (effectiveness 44%; certainty 3%; harms 0%).*

<http://www.conservationevidence.com/actions/575>

● **Translocate birds to re-establish populations or increase genetic variation (megapodes)**

A study from Indonesia found that up to 78% maleo eggs hatched after translocation. *Assessment: unknown effectiveness — limited evidence (effectiveness 49%; certainty 29%; harms 0%).*

<http://www.conservationevidence.com/actions/567>

● **Translocate birds to re-establish populations or increase genetic variation (owls)**

A small study from New Zealand found that translocating two male boobooks allowed the establishment of a population when they interbred with a Norfolk Island boobook. A study in the USA found high survival amongst burrowing owls translocated as juveniles, although birds were not seen after release. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 19%; harms 0%).*

<http://www.conservationevidence.com/actions/576>

● **Translocate nests to avoid disturbance**

All five studies captured found some success in relocating nests while they were in use, but one found that fewer than half of the burrowing owls studied were moved successfully; a study found that repeated disturbance caused American kestrels to abandon their nest and a study found that one barn swallow abandoned its nest after it was moved. *Assessment: unknown effectiveness — limited evidence (effectiveness 24%; certainty 39%; harms 30%).*

<http://www.conservationevidence.com/actions/584>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Ensure genetic variation to increase translocation success.

3.15 Captive breeding, rearing and releases (*ex situ* conservation)

3.15.1 Captive breeding

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for captive breeding?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Artificially incubate and hand-rear birds in captivity: raptors ● Artificially incubate and hand-rear birds in captivity: seabirds ● Artificially incubate and hand-rear birds in captivity: songbirds ● Artificially incubate and hand-rear birds in captivity: waders ● Use captive breeding to increase or maintain populations: raptors
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Artificially incubate and hand-rear birds in captivity: bustards ● Artificially incubate and hand-rear birds in captivity: cranes ● Artificially incubate and hand-rear birds in captivity: gamebirds ● Artificially incubate and hand-rear birds in captivity: parrots

	<ul style="list-style-type: none"> ● Artificially incubate and hand-rear birds in captivity: penguins ● Artificially incubate and hand-rear birds in captivity: rails ● Artificially incubate and hand-rear birds in captivity: storks and ibises ● Artificially incubate and hand-rear birds in captivity: vultures ● Artificially incubate and hand-rear birds in captivity: wildfowl ● Freeze semen for artificial insemination ● Use artificial insemination in captive breeding ● Use captive breeding to increase or maintain populations: bustards ● Use captive breeding to increase or maintain populations: cranes ● Use captive breeding to increase or maintain populations: pigeons ● Use captive breeding to increase or maintain populations: rails ● Use captive breeding to increase or maintain populations: seabirds ● Use captive breeding to increase or maintain populations: songbirds ● Use captive breeding to increase or maintain populations: storks and ibises ● Use captive breeding to increase or maintain populations: tinamous ● Use puppets to increase the success of hand-rearing ● Wash contaminated semen and use it for artificial insemination
<p>Evidence not assessed</p>	<ul style="list-style-type: none"> ● Can captive breeding have deleterious effects on individual fitness?



Likely to be beneficial

● Artificially incubate and hand-rear birds in captivity (raptors)

Six studies from across the world found high success rates for artificial incubation and hand-rearing of raptors. A replicated and controlled study from France found that artificially incubated raptor eggs had lower hatching success than parent-incubated eggs but fledging success for hand-reared chicks was similar to wild chicks. A study from Canada found that hand-reared chicks had slower growth and attained a lower weight than parent-reared birds. A replicated study from Mauritius found that hand-rearing of wild eggs had higher success than hand-rearing captive-bred chicks. Three studies that provided methodological comparisons reported that incubation temperature affected hatching success and adding saline to the diet of falcon chicks increased their weight gain. *Assessment: likely to be beneficial (effectiveness 60%; certainty 52%; harms 5%).*

<http://www.conservationevidence.com/actions/614>

● Artificially incubate and hand-rear birds in captivity (seabirds)

Five studies from across the world found evidence for the success of hand-rearing seabirds. One small study in Spain found that one of five hand-reared Audouin's gulls successfully bred in the wild. Four studies found that various petrel species successfully fledged after hand-rearing. One controlled study found that fledging rates of hand-reared birds was similar to parent-reared birds, although a study on a single bird found that the chick fledged at a lower weight and later than parent-reared chicks. *Assessment: likely to be beneficial (effectiveness 67%; certainty 45%; harms 2%).*

<http://www.conservationevidence.com/actions/604>

● Artificially incubate and hand-rear birds in captivity (songbirds)

Four studies from the USA found high rates of success for artificial incubation and hand-rearing of songbirds. One study found that crow chicks fed more food had higher growth rates, but these rates never

matched those of wild birds. *Assessment: likely to be beneficial (effectiveness 51%; certainty 44%; harms 1%).*

<http://www.conservationevidence.com/actions/616>

● **Artificially incubate and hand-rear birds in captivity (waders)**

Three out of four replicated and controlled studies from the USA and New Zealand found that artificially incubated and/or hand-reared waders had higher hatching and fledging success than controls. One study from New Zealand found that hatching success of black stilt was lower for artificially-incubated eggs. *Assessment: likely to be beneficial (effectiveness 64%; certainty 41%; harms 4%).*

<http://www.conservationevidence.com/actions/611>

● **Use captive breeding to increase or maintain populations (raptors)**

Three small studies and a review from around the world found that raptors bred successfully in captivity. Two of these studies found that wild-caught birds bred in captivity after a few years, with one pair of brown goshawks producing 15 young over four years, whilst a study on bald eagle captive breeding found low fertility in captive-bred eggs, but that birds still produced chicks after a year. A review of Mauritius kestrel captive breeding found that 139 independent young were raised over 12 years from 30 eggs and chicks taken from the wild. An update of the same programme found that hand-reared Mauritius kestrels were less successful if they came from captive-bred eggs compared to wild 'harvested' eggs. *Assessment: likely to be beneficial (effectiveness 50%; certainty 41%; harms 10%).*

<http://www.conservationevidence.com/actions/596>

Unknown effectiveness (limited evidence)

● **Artificially incubate and hand-rear birds in captivity (bustards)**

Two reviews of a houbara bustard captive breeding programme in Saudi Arabia found no difference in survival between artificially and parentally incubated eggs, and that removing eggs from clutches as they



were laid increased the number laid by females. *Assessment: unknown effectiveness — limited evidence (effectiveness 31%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/610>

● **Artificially incubate and hand-rear birds in captivity (cranes)**

Two studies from the USA found that hand-reared birds showed normal reproductive behaviour and higher survival than parent-reared birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 76%; certainty 31%; harms 0%).*

<http://www.conservationevidence.com/actions/609>

● **Artificially incubate and hand-rear birds in captivity (gamebirds)**

A study in Finland found that hand-reared grey partridges did not take off to fly as effectively as wild-caught birds, potentially making them more vulnerable to predation. *Assessment: unknown effectiveness — limited evidence (effectiveness 11%; certainty 10%; harms 50%).*

<http://www.conservationevidence.com/actions/607>

● **Artificially incubate and hand-rear birds in captivity (parrots)**

Two studies from South America describe the successful hand-rearing of parrot chicks. A review of the kakapo management programme found that chicks could be successfully raised and released, but that eggs incubated from a young age had low success. A study from the USA found that all hand-reared thick-billed parrots died within a month of release: significantly lower survival than for wild-caught birds translocated to the release site. *Assessment: unknown effectiveness — limited evidence (effectiveness 19%; certainty 30%; harms 11%).*

<http://www.conservationevidence.com/actions/615>

● **Artificially incubate and hand-rear birds in captivity (penguins)**

Two replicated and controlled studies from South Africa found that hand-reared and released African penguins had similar survival and breeding

success as birds which were not hand-reared. *Assessment: unknown effectiveness — limited evidence (effectiveness 41%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/605>

● **Artificially incubate and hand-rear birds in captivity (rails)**

A controlled study from New Zealand found that post-release survival of hand-reared takahe was as high as wild-reared birds and that six of ten released females raised chicks. *Assessment: unknown effectiveness — limited evidence (effectiveness 64%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/608>

● **Artificially incubate and hand-rear birds in captivity (storks and ibises)**

A small study in the USA describes the successful artificial incubation and hand-rearing of two Abdim's stork chicks, whilst a review of northern bald ibis conservation found that only very intensive rearing of a small number of chicks appeared to allow strong bonds, thought to be important for the successful release of birds into the wild, to form between chicks. *Assessment: unknown effectiveness — limited evidence (effectiveness 18%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/612>

● **Artificially incubate and hand-rear birds in captivity (vultures)**

A study in Peru found that hand-reared Andean condors had similar survival to parent-reared birds after release into the wild. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/613>

● **Artificially incubate and hand-rear birds in captivity (wildfowl)**

Two studies in Canada and India found high success rates for hand-rearing buffleheads and bar-headed geese in captivity. Eggs were artificially incubated or incubated under foster parents. A replicated, controlled



study in England found that Hawaiian geese (nene) chicks showed less well-adapted behaviours if they were raised without parental contact. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 10%).*

<http://www.conservationevidence.com/actions/606>

● **Freeze semen for artificial insemination**

Two small trials from the USA found that using thawed frozen semen for artificial insemination resulted in low fertility rates. A small trial from the USA found that a cryoprotectant increased fertility rates achieved using frozen semen. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 10%; harms 45%).*

<http://www.conservationevidence.com/actions/602>

● **Use artificial insemination in captive breeding**

A replicated study from Saudi Arabia found that artificial insemination could increase fertility in houbara bustards. A study of the same programme and a review found that repeated inseminations increased fertility, with the review arguing that artificial insemination had the potential to be a useful technique. Two studies from the USA found that artificially-inseminated raptors had either zero fertility, or approximately 50%. *Assessment: unknown effectiveness – limited evidence (effectiveness 33%; certainty 21%; harms 0%).*

<http://www.conservationevidence.com/actions/601>

● **Use captive breeding to increase or maintain populations (bustards)**

Four studies of a captive breeding programme in Saudi Arabia reported that the houbara bustard chicks were successfully raised in captivity, with 285 chicks hatched in the 7th year of the project after 232 birds were used to start the captive population. Captive birds bred earlier and appeared to lay more eggs than wild birds. Forty-six percent of captive eggs hatched and 43% of chicks survived to ten years old. *Assessment: unknown effectiveness – limited evidence (effectiveness 41%; certainty 16%; harms 5%).*

<http://www.conservationevidence.com/actions/592>

● **Use captive breeding to increase or maintain populations (cranes)**

A study from Canada over 32 years found that whooping cranes successfully bred in captivity eight years after the first eggs were removed from the wild. *Assessment: unknown effectiveness — limited evidence (effectiveness 51%; certainty 17%; harms 6%).*

<http://www.conservationevidence.com/actions/591>

● **Use captive breeding to increase or maintain populations (pigeons)**

A review of a captive-breeding programme on Mauritius and in the UK found that 42 pink pigeons were successfully bred in captivity. *Assessment: unknown effectiveness — limited evidence (effectiveness 69%; certainty 21%; harms 0%).*

<http://www.conservationevidence.com/actions/597>

● **Use captive breeding to increase or maintain populations (rails)**

A study from Australia found that three pairs of Lord Howe Island woodhens successfully bred in captivity, with 66 chicks being produced over four years. *Assessment: unknown effectiveness — limited evidence (effectiveness 26%; certainty 11%; harms 5%).*

<http://www.conservationevidence.com/actions/590>

● **Use captive breeding to increase or maintain populations (seabirds)**

A study from Spain found that a single pair of Audouin's gulls successfully bred in captivity. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 4%; harms 5%).*

<http://www.conservationevidence.com/actions/589>

● **Use captive breeding to increase or maintain populations (songbirds)**

Three studies from Australia and the USA found that three species of songbird bred successfully in captivity. Four out of five pairs of wild-bred,



hand-reared puaiohi formed pairs and laid a total of 39 eggs and a breeding population of helmeted honeyeaters was successfully established through a breeding programme. Only one pair of loggerhead shrikes formed pairs from eight wild birds caught and their first clutch died. *Assessment: unknown effectiveness — limited evidence (effectiveness 77%; certainty 31%; harms 5%).*

<http://www.conservationevidence.com/actions/598>

● Use captive breeding to increase or maintain populations (storks and ibises)

We captured a small study and a review both from the USA describing the captive breeding of storks. The study found that a pair bred; the review found that only seven of 19 species had been successfully bred in captivity. A review of bald ibis conservation found that 1,150 birds had been produced in captivity from 150 founders over 20 years. However, some projects had failed, and a study from Turkey found that captive birds had lower productivity than wild birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 31%; certainty 30%; harms 8%).*

<http://www.conservationevidence.com/actions/595>

● Use captive breeding to increase or maintain populations (tinamous)

A replicated study from Costa Rica found that great tinamous successfully bred in captivity, with similar reproductive success to wild birds. *Assessment: unknown effectiveness — limited evidence (effectiveness 51%; certainty 15%; harms 5%).*

<http://www.conservationevidence.com/actions/588>

● Use puppets to increase the success of hand-rearing

Three studies from the USA and Saudi Arabia found that crows and bustards raised using puppets did not have higher survival, dispersal or growth than chicks hand-reared conventionally. *Assessment: unknown effectiveness — limited evidence (effectiveness 4%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/617>

● **Wash contaminated semen and use it for artificial insemination**

A replicated, controlled study from Spain found that washed, contaminated semen could be used to successfully inseminate raptors. *Assessment: unknown effectiveness – limited evidence (effectiveness 31%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/603>

Evidence not assessed

● **Can captive breeding have deleterious effects?**

We captured no studies investigating the effects of captive-breeding on fitness. Three studies using wild and captive populations or museum specimens found physiological or genetic changes in populations that had been bred in captivity. One found that changes were more likely to be caused by extremely low population levels than by captivity.

<http://www.conservationevidence.com/actions/599>

3.15.2 Release captive-bred individuals

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for captive breeding?	
Likely to be beneficial	<ul style="list-style-type: none">● Provide supplementary food after release● Release captive-bred individuals into the wild to restore or augment wild populations: cranes● Release captive-bred individuals into the wild to restore or augment wild populations: raptors● Release captive-bred individuals into the wild to restore or augment wild populations: songbirds● Release captive-bred individuals into the wild to restore or augment wild populations: vultures
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Clip birds' wings on release● Release birds as adults or sub-adults not juveniles● Release birds in groups● Release captive-bred individuals into the wild to restore or augment wild populations: bustards



	<ul style="list-style-type: none"> ● Release captive-bred individuals into the wild to restore or augment wild populations: gamebirds ● Release captive-bred individuals into the wild to restore or augment wild populations: owls ● Release captive-bred individuals into the wild to restore or augment wild populations: parrots ● Release captive-bred individuals into the wild to restore or augment wild populations: pigeons ● Release captive-bred individuals into the wild to restore or augment wild populations: rails ● Release captive-bred individuals into the wild to restore or augment wild populations: storks and ibises ● Release captive-bred individuals into the wild to restore or augment wild populations: waders ● Release captive-bred individuals into the wild to restore or augment wild populations: wildfowl ● Release chicks and adults in 'coveys' ● Use 'anti-predator training' to improve survival after release ● Use appropriate populations to source released populations ● Use 'flying training' before release ● Use holding pens at release sites ● Use microlites to help birds migrate
--	---

Likely to be beneficial

● Provide supplementary food after release

All three studies captured found that released birds used supplementary food provided. One study from Australia found that malleefowl had higher survival when provided with food and a study from Peru found that supplementary food could be used to increase the foraging ranges of Andean condors after release. *Assessment: likely to be beneficial (effectiveness 45%; certainty 48%; harms 0%).*

<http://www.conservationevidence.com/actions/639>

● **Release captive-bred individuals into the wild to restore or augment wild populations (cranes)**

Four studies of five release programmes from the USA and Russia found that released cranes had high survival or bred in the wild. Two studies from two release programmes in the USA found low survival of captive-bred eggs fostered to wild birds compared with wild eggs, or a failure to increase the wild flock size. A worldwide review found that releases of migratory species were more successful if birds were released into existing flocks, and for non-migratory populations. One study from the USA found that birds released as sub-adults had higher survival than birds cross-fostered to wild birds. *Assessment: likely to be beneficial (effectiveness 55%; certainty 50%; harms 5%).*

<http://www.conservationevidence.com/actions/621>

● **Release captive-bred individuals into the wild to restore or augment wild populations (raptors)**

Five studies of three release programmes from across the world found the establishment or increase of wild populations of falcons. Five studies from the USA found high survival of released raptors although one study from Australia found that a wedge-tailed eagle had to be taken back into captivity after acting aggressively towards humans, and another Australian study found that only one of 15 brown goshawks released was recovered. *Assessment: likely to be beneficial (effectiveness 69%; certainty 56%; harms 10%).*

<http://www.conservationevidence.com/actions/626>

● **Release captive-bred individuals into the wild to restore or augment wild populations (songbirds)**

A study in Mauritius describes the establishment of a population of Mauritius fody following the release of captive-bred individuals. Four studies of three release programmes on Hawaii found high survival of all three species released, with two thrush species successfully breeding. A replicated, controlled study from the USA found that shrike pairs with captive-bred females had lower reproductive success than pairs where both parents were wild-bred. *Assessment: likely to be beneficial (effectiveness 42%; certainty 40%; harms 5%).*

<http://www.conservationevidence.com/actions/630>



● **Release captive-bred individuals into the wild to restore or augment wild populations (vultures)**

Four studies of two release programmes found that release programmes led to large population increases in Andean condors in Colombia and griffon vultures in France. A small study in Peru found high survival of released Andean condors over 18 months, with all fatalities occurring in the first six months after release. *Assessment: likely to be beneficial (effectiveness 73%; certainty 54%; harms 0%).*

<http://www.conservationevidence.com/actions/625>

Unknown effectiveness (limited evidence)

● **Clip birds' wings on release**

Two of four studies found that bustards and geese had lower survival when released into holding pens with clipped wings compared to birds released without clipped wings. One study found no differences in survival for clipped or unclipped northern bald ibis. One study found that adult geese released with clipped wings survived better than geese released before they were able to fly. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 30%; harms 5%).*

<http://www.conservationevidence.com/actions/633>

● **Release birds as adults or sub-adults not juveniles**

Three out of nine studies from across the world found that birds released as sub-adults had higher survival than those released as juveniles. Two studies found lower survival of wing-clipped sub-adult geese and bustards, compared with juveniles and one study found lower survival of all birds released as sub-adults, compared to those released as juveniles. Three studies found no differences in survival for birds released at different ages, although one found higher reproduction in birds released at greater ages. *Assessment: unknown effectiveness — limited evidence (effectiveness 35%; certainty 15%; harms 19%).*

<http://www.conservationevidence.com/actions/636>

● **Release birds in groups**

A study from New Zealand found that released stilts were more likely to move long distances after release if they were released in larger groups. *Assessment: unknown effectiveness — limited evidence (effectiveness 32%; certainty 26%; harms 2%).*

<http://www.conservationevidence.com/actions/634>

● **Release captive-bred individuals into the wild to restore or augment wild populations (bustards)**

Three reviews of a release programme for houbara bustard in Saudi Arabia found low initial survival of released birds, but the establishment of a breeding population and an overall success rate of 41%. The programme tested many different release techniques, the most successful of which was release of sub-adults, which were able to fly, into a large enclosure. *Assessment: unknown effectiveness — limited evidence (effectiveness 34%; certainty 26%; harms 5%).*

<http://www.conservationevidence.com/actions/622>

● **Release captive-bred individuals into the wild to restore or augment wild populations (gamebirds)**

One of five studies from across the world found that releasing gamebirds established a population or bolstered an existing population. A review of a reintroduction programme in Pakistan found some breeding success in released cheer pheasants, but habitat change at the release site then excluded released birds. Three studies from Europe and the USA found that released birds had low survival, low reproductive success and no impact on the wild population. *Assessment: unknown effectiveness — limited evidence (effectiveness 5%; certainty 35%; harms 1%).*

<http://www.conservationevidence.com/actions/619>

● **Release captive-bred individuals into the wild to restore or augment wild populations (owls)**

A study in the USA found that a barn owl population was established following the release of 157 birds in the area over three years. A replicated, controlled study in Canada found that released burrowing owls had similar



reproductive output but higher mortality than wild birds. *Assessment: unknown effectiveness – limited evidence (effectiveness 24%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/627>

● **Release captive-bred individuals into the wild to restore or augment wild populations (parrots)**

A study from Venezuela found that the population of yellow-shouldered amazons increased significantly following the release of captive-bred birds along with other interventions. A study in Costa Rica and Peru found high survival and some breeding of scarlet macaw after release. Three replicated studies in the USA, Dominican Republic and Puerto Rico found low survival in released birds, although the Puerto Rican study also found that released birds bred successfully. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 30%; harms 3%).*

<http://www.conservationevidence.com/actions/629>

● **Release captive-bred individuals into the wild to restore or augment wild populations (pigeons)**

A single review of a captive-release programme in Mauritius found that that released pink pigeons had a first year survival of 36%. *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 5%; harms 1%).*

<http://www.conservationevidence.com/actions/628>

● **Release captive-bred individuals into the wild to restore or augment wild populations (rails)**

One study from Australia found that released Lord Howe Island woodhens successfully bred in the wild, re-establishing a wild population and a study from the UK found high survival of released corncrake in the first summer after release. A replicated study in New Zealand found very low survival of North Island weka following release, mainly due to predation. *Assessment: unknown effectiveness – limited evidence (effectiveness 26%; certainty 16%; harms 0%).*

<http://www.conservationevidence.com/actions/620>

● **Release captive-bred individuals into the wild to restore or augment wild populations (storks and ibises)**

A replicated study and a review of northern bald ibis release programmes in Europe and the Middle East found that only one of four resulted in a wild population being established or supported, with many birds dying or dispersing, rather than forming stable colonies. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 20%; harms 2%).*

<http://www.conservationevidence.com/actions/624>

● **Release captive-bred individuals into the wild to restore or augment wild populations (waders)**

A review of black stilt releases in New Zealand found that birds had low survival (13–20%) and many moved away from their release sites. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 5%; harms 15%).*

<http://www.conservationevidence.com/actions/623>

● **Release captive-bred individuals into the wild to restore or augment wild populations (wildfowl)**

Two studies of reintroduction programmes of ducks in New Zealand found high survival of released birds and population establishment. A study from Alaska found low survival of released cackling geese, but the population recovered from 1,000 to 6,000 birds after releases and the control of mammalian predators. A review of a reintroduction programme from Hawaii found that the release of Hawaiian geese (nene) did not result in the establishment of a self-sustaining population. Two studies from Canada found very low return rates for released ducks with one finding no evidence for survival of released birds over two years, although there was some evidence that breeding success was higher for released birds than wild ones. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 24%; harms 0%).*

<http://www.conservationevidence.com/actions/618>

● **Release chicks and adults in ‘coveys’**

Two out of three studies found that geese and partridges released in coveys had higher survival than young birds released on their own or adults



released in pairs. A study from Saudi Arabia found that bustard chicks had low survival when released in coveys with flightless females. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 36%; harms 6%).*

<http://www.conservationevidence.com/actions/635>

● **Use ‘anti-predator training’ to improve survival after release**

Both studies captured found higher survival for birds given predator training before release, compared with un-trained birds. One found that using a live fox, but not a model, for training increased survival in bustards, but that several birds were injured during training. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 9%).*

<http://www.conservationevidence.com/actions/637>

● **Use appropriate populations to source released populations**

Two studies from Europe found that birds from populations near release sites adapted better and in one case had higher reproductive productivity than those from more distant populations. *Assessment: unknown effectiveness – limited evidence (effectiveness 53%; certainty 31%; harms 0%).*

<http://www.conservationevidence.com/actions/631>

● **Use ‘flying training’ before release**

A study from the Dominican Republic found that parrots had higher first-year survival if they were given pre-release flying training. *Assessment: unknown effectiveness – limited evidence (effectiveness 30%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/638>

● **Use holding pens at release sites**

Three of four studies from North America and Saudi Arabia found that birds released into holding pens were more likely to form pairs or had higher survival than birds released into the open. One study found that parrots released into pens had lower survival than those released without preparation. A review of northern bald ibis releases found that holding

pens could be used to prevent birds from migrating from the release site and so increase survival. *Assessment: unknown effectiveness — limited evidence (effectiveness 51%; certainty 36%; harms 2%).*

<http://www.conservationevidence.com/actions/632>

● **Use microlites to help birds migrate**

A study from Europe found that northern bald ibises followed a microlite south in the winter but failed to make the return journey the next year. *Assessment: unknown effectiveness — limited evidence (effectiveness 3%; certainty 5%; harms 5%).*

<http://www.conservationevidence.com/actions/640>

4. FARMLAND CONSERVATION

Lynn V. Dicks, Joscelyne E. Ashpole, Juliana Dänhardt, Katy James, Annelie Jönsson, Nicola Randall, David A. Showler, Rebecca K. Smith, Susan Turpie, David R. Williams & William J. Sutherland

Expert assessors

Lynn V. Dicks, University of Cambridge, UK

Ian Hodge, University of Cambridge, UK

Clunie Keenleyside, Institute for European Environmental Policy, UK

Will Peach, Royal Society for the Protection of Birds, UK

Nicola Randall, Harper Adams University, UK

Jörn Scharlemann, United Nations Environment Programme – World Conservation Monitoring Centre, UK

Gavin Siriwardena, British Trust for Ornithology, UK

Henrik Smith, Lund University, Sweden

Rebecca K. Smith, University of Cambridge, UK

William J. Sutherland, University of Cambridge, UK

Scope of assessment: for native farmland wildlife in northern and western Europe (European countries west of Russia, but not south of France, Switzerland, Austria, Hungary and Romania).

Assessed: 2014.

Effectiveness measure is the % of experts that answered yes to the question: based on the evidence presented does this intervention benefit wildlife? (Yes, no or don't know).

Certainty measure is the median % score for the question: how much do we understand the extent to which this intervention benefits wildlife on farmland? (0 = no evidence, 100% = certainty).

Harm measure was not scored for this synopsis.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

4.1 All farming systems

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for all farming systems?	
Beneficial	<ul style="list-style-type: none"> ● Create uncultivated margins around intensive arable or pasture fields ● Plant grass buffer strips/margins around arable or pasture fields ● Plant nectar flower mixture/wildflower strips ● Plant wild bird seed or cover mixture ● Provide or retain set-aside areas in farmland
Likely to be beneficial	<ul style="list-style-type: none"> ● Manage ditches to benefit wildlife ● Manage hedgerows to benefit wildlife (includes no spray, gap-filling and laying) ● Pay farmers to cover the costs of conservation measures ● Provide supplementary food for birds or mammals
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Connect areas of natural or semi-natural habitat ● Increase the proportion of natural or semi-natural habitat in the farmed landscape ● Make direct payments per clutch for farmland birds ● Manage the agricultural landscape to enhance floral resources ● Mark bird nests during harvest or mowing ● Plant new hedges ● Provide nest boxes for bees (solitary bees or bumblebees) ● Provide nest boxes for birds ● Provide other resources for birds (water, sand for bathing) ● Provide refuges during harvest or mowing

<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Apply ‘cross compliance’ environmental standards linked to all subsidy payments ● Implement food labelling schemes relating to biodiversity-friendly farming (organic, LEAF marque) ● Introduce nest boxes stocked with solitary bees ● Maintain in-field elements such as field islands and rockpiles ● Manage stone-faced hedge banks to benefit wildlife ● Manage woodland edges to benefit wildlife ● Plant in-field trees (not farm woodland) ● Protect in-field trees (includes management such as pollarding and surgery) ● Provide badger gates ● Provide foraging perches (e.g. for shrikes) ● Provide otter holts ● Provide red squirrel feeders ● Reduce field size (or maintain small fields) ● Restore or maintain dry stone walls ● Support or maintain low-intensity agricultural systems
---	--

Beneficial

● **Create uncultivated margins around intensive arable or pasture fields**

Twenty studies (including one randomized, replicated, controlled trial) from seven countries found uncultivated margins support more invertebrates, small mammal species or higher plant diversity than other habitats. Four studies (including two replicated studies from the UK) found positive associations between birds and uncultivated margins. Fifteen studies (including one randomized, replicated, controlled trial) from four countries found naturally regenerated margins had lower invertebrate or plant abundance or diversity than conventional fields or sown margins. Six studies (one randomized, replicated, controlled) from three countries found uncultivated margins did not have higher plant or invertebrate

abundance or diversity than cropped or sown margins. *Assessment: beneficial (effectiveness 100%; certainty 63%).*

<http://www.conservationevidence.com/actions/63>

● **Plant grass buffer strips/margins around arable or pasture fields**

Twenty studies (including two randomized, replicated, controlled studies) from four countries found grass margins benefited invertebrates, including increases in abundance or diversity. Nine studies (including two replicated, controlled trials) from the UK found grass buffer strips benefit birds, with increased numbers, diversity or use. Seven replicated studies (four controlled, two randomized) from two countries found grass buffer strips increased plant cover and species richness, a review found benefits to plants. Five studies (two replicated, controlled) from two countries found benefits to small mammals. Six (including three replicated, controlled trials) from two countries found no clear effect on invertebrate or bird numbers. *Assessment: beneficial (effectiveness 90%; certainty 65%).*

<http://www.conservationevidence.com/actions/246>

● **Plant nectar flower mixture/wildflower strips**

Forty-one studies (including one randomized, replicated, controlled trial) from eight countries found flower strips increased invertebrate numbers or diversity. Ten studies (two replicated, controlled) found invertebrates visited flower strips. Fifteen studies (two randomized, replicated, controlled) found mixed or negative effects on invertebrates. Seventeen studies (one randomized, replicated, controlled) from seven countries found more plants or plant species on flower strips, four did not. Five studies (two randomized, replicated, controlled) from two countries found bird numbers, diversity or use increased in flower strips, two studies did not. Five studies (four replicated) found increases in small mammal abundance or diversity in flower strips. *Assessment: beneficial (effectiveness 100%; certainty 75%).*

<http://www.conservationevidence.com/actions/442>

● **Plant wild bird seed or cover mixture**

Fifteen studies (including a systematic review) from the UK found fields sown with wild bird cover mix had more birds or bird species than other

farmland habitats. Six studies (including two replicated trials) from the UK found birds used wild bird cover more than other habitats. Nine replicated studies from France and the UK found mixed or negative effects on birds. Eight studies (including two randomized, replicated, controlled studies) from the UK found wild bird cover had more invertebrates, four (including two replicated trials) found mixed or negative effects on invertebrate numbers. Six studies (including two replicated, controlled trials) from the UK found wild bird cover mix benefited plants, two replicated studies did not. *Assessment: beneficial (effectiveness 100%; certainty 65%).*

<http://www.conservationevidence.com/actions/594>

● Provide or retain set-aside areas in farmland

Thirty-seven studies (one systematic review, no randomized, replicated, controlled trials) compared use of set-aside areas with control farmed fields. Twenty-one (including the systematic review) showed benefits to, or higher use by, all wildlife groups considered. Thirteen studies found some species or groups used set-aside more than crops; others did not. Two found higher Eurasian skylark reproductive success and one study found lower success on set-aside than control fields. Four studies found set-aside had no effect on wildlife, one found an adverse effect. Two studies found neither insects nor small mammals preferred set-aside. *Assessment: beneficial (effectiveness 90%; certainty 70%).*

<http://www.conservationevidence.com/actions/156>

Likely to be beneficial

● Manage ditches to benefit wildlife

Five studies (including one replicated, controlled study) from the UK and the Netherlands found ditch management had positive effects on numbers, diversity or biomass of some or all invertebrates, amphibians, birds or plants studied. Three studies from the Netherlands and the UK (including two replicated site comparisons) found negative or no clear effects on plants or some birds. *Assessment: likely to be beneficial (effectiveness 40%; certainty 45%).*

<http://www.conservationevidence.com/actions/135>

● **Manage hedgerows to benefit wildlife (includes no spray, gap-filling and laying)**

Ten studies from the UK and Switzerland (including one randomized, replicated, controlled trial) found managing hedges for wildlife increased berry yields, diversity or abundance of plants, invertebrates or birds. Five UK studies (including one randomized, replicated, controlled trial) found plants, bees and farmland birds were unaffected by hedge management. Two replicated studies found hedge management had mixed effects on invertebrates or reduced hawthorn berry yield. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%).*

<http://www.conservationevidence.com/actions/116>

● **Pay farmers to cover the cost of conservation measures (as in agri-environment schemes)**

For birds, twenty-four studies (including one systematic review) found increases or more favourable trends in bird populations, while eleven studies (including one systematic review) found negative or no effects of agri-environment schemes. For plants, three studies found more plant species, two found fewer plant species and seven found little or no effect of agri-environment schemes. For invertebrates, five studies found increases in abundance or species richness, while six studies found little or no effect of agri-environment schemes. For mammals, one replicated study found positive effects of agri-environment schemes and three studies found mixed effects in different regions or for different species. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%).*

<http://www.conservationevidence.com/actions/700>

● **Provide supplementary food for birds or mammals**

Nine studies (two randomized, replicated, controlled) from France, Sweden and the UK found providing supplementary food increased abundance, overwinter survival or productivity of some birds. Two of the studies did not separate the effects of several interventions. Four studies (one replicated, controlled and one randomized, replicated) from Finland and the UK found some birds or mammals used supplementary food. Six replicated studies (three controlled) from Sweden and the UK found no clear effect on some birds or plants. *Assessment: likely to be beneficial (effectiveness 90%; certainty 50%).*

<http://www.conservationevidence.com/actions/648>

Unknown effectiveness (limited evidence)

● Connect areas of natural or semi-natural habitat

All four studies (including two replicated trials) from the Czech Republic, Germany and the Netherlands investigating the effects of linking patches of natural or semi-natural habitat found some colonization by invertebrates or mammals. Colonization by invertebrates was slow or its extent varied between taxa. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 15%).*

<http://www.conservationevidence.com/actions/579>

● Increase the proportion of semi-natural habitat in the farmed landscape

Of five studies monitoring the effects of the Swiss Ecological Compensation Areas scheme at a landscape scale (including three replicated site comparisons), one found an increase in numbers of birds of some species, two found no effect on birds and three found some species or groups increasing and others decreasing. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 20%).*

<http://www.conservationevidence.com/actions/145>

● Make direct payments per clutch for farmland birds

Two replicated, controlled studies from the Netherlands found per clutch payments did not increase overall bird numbers. A replicated site comparison from the Netherlands found more birds bred on 12.5 ha plots under management including per-clutch payments but there were no differences at the field-scale. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 20%).*

<http://www.conservationevidence.com/actions/146>

● Manage the agricultural landscape to enhance floral resources

A large replicated, controlled study from the UK found the number of long-tongued bumblebees on field margins was positively correlated with the number of 'pollen and nectar' agri-environment agreements in a 10 km

square. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%).*

<http://www.conservationevidence.com/actions/362>

● **Mark bird nests during harvest or mowing**

A replicated study from the Netherlands found that marked northern lapwing nests were less likely to fail as a result of farming operations than unmarked nests. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 15%).*

<http://www.conservationevidence.com/actions/148>

● **Plant new hedges**

Two studies (including one replicated trial) from France and the UK found new hedges had more invertebrates or plant species than fields or field margins. A review found new hedges had more ground beetles than older hedges. However, an unreplicated site comparison from Germany found only two out of 85 ground beetle species dispersed along new hedges. A review found lower pest outbreaks in areas with new hedges. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 25%).*

<http://www.conservationevidence.com/actions/538>

● **Provide nest boxes for bees (solitary bees or bumblebees)**

Ten studies (nine replicated) from Germany, Poland and the UK found solitary bee nest boxes were used by bees. Two replicated trials from the UK found bumblebee nest boxes had very low uptake. Two replicated studies found the local population size or number of emerging red mason bees increased when nest boxes were provided. A replicated trial in Germany found the number of occupied solitary bee nests almost doubled over three years with repeated nest box provision. *Assessment: unknown effectiveness — limited evidence (effectiveness 90%; certainty 38%).*

<http://www.conservationevidence.com/actions/80>

● **Provide nest boxes for birds**

Two studies (including one before-and-after trial) from the Netherlands and the UK found providing nest boxes increased the number of clutches or breeding adults of two bird species. A replicated study from Switzerland

found nest boxes had mixed effects on the number of broods produced by two species. Eight studies (six replicated) from five countries found nest boxes were used by birds. A controlled study from the UK found one species did not use artificial nest sites. Three replicated studies (one paired) from the UK and Sweden found box location influenced use or nesting success. *Assessment: unknown effectiveness – limited evidence (effectiveness 30%; certainty 23%).*

<http://www.conservationevidence.com/actions/155>

● **Provide other resources for birds (water, sand for bathing)**

A small study in France found grey partridge density was higher in areas where water, shelter, sand and food were provided. *Assessment: unknown effectiveness – limited evidence (effectiveness 0%; certainty 1%).*

<http://www.conservationevidence.com/actions/117>

● **Provide refuges during harvest or mowing**

A replicated study from France found mowing refuges reduced contact between mowing machinery and unfledged quails and corncrakes. A replicated controlled study and a review from the UK found Eurasian skylark did not use nesting refuges more than other areas. *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 11%).*

<http://www.conservationevidence.com/actions/147>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Apply 'cross compliance' environmental standards linked to all subsidy payments
- Implement food labelling schemes relating to biodiversity-friendly farming (organic, LEAF marque)
- Introduce nest boxes stocked with solitary bees
- Maintain in-field elements such as field islands and rockpiles
- Manage stone-faced hedge banks to benefit wildlife
- Manage woodland edges to benefit wildlife
- Plant in-field trees (not farm woodland)

- Protect in-field trees (includes management such as pollarding and surgery)
- Provide badger gates
- Provide foraging perches (e.g. for shrikes)
- Provide otter holts
- Provide red squirrel feeders
- Reduce field size (or maintain small fields)
- Restore or maintain dry stone walls
- Support or maintain low intensity agricultural systems

4.2 Arable farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for arable farming systems?	
Beneficial	<ul style="list-style-type: none"> • Create skylark plots • Leave cultivated, uncropped margins or plots (includes 'lapwing plots')
Likely to be beneficial	<ul style="list-style-type: none"> • Create beetle banks • Leave overwinter stubbles • Reduce tillage • Undersow spring cereals, with clover for example
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Convert or revert arable land to permanent grassland • Create rotational grass or clover leys • Increase crop diversity • Plant cereals in wide-spaced rows • Plant crops in spring rather than autumn • Plant nettle strips • Sow rare or declining arable weeds
No evidence found (no assessment)	<ul style="list-style-type: none"> • Add 1% barley into wheat crop for corn buntings • Create corn bunting plots • Leave unharvested cereal headlands within arable fields • Use new crop types to benefit wildlife (such as perennial cereal crops)
Evidence not assessed	<ul style="list-style-type: none"> • Implement 'mosaic management', a Dutch agri-environment option • Plant more than one crop per field (intercropping) • Take field corners out of management

Beneficial

● Create skylark plots

All four studies (two replicated, controlled trials) from Switzerland and the UK investigating the effect of skylark plots on Eurasian skylarks found positive effects, including increases in population size. A replicated study from Denmark found skylarks used undrilled patches in cereal fields. Three studies (one replicated, controlled) from the UK found benefits to plants and invertebrates. Two replicated studies (one controlled) from the UK found no significant differences in numbers of invertebrates or seed-eating songbirds. *Assessment: beneficial (effectiveness 100%; certainty 80%).*

<http://www.conservationevidence.com/actions/540>

● Leave cultivated, uncropped margins or plots (includes 'lapwing plots')

Seventeen of nineteen individual studies looking at uncropped, cultivated margins or plots (including one replicated, randomized, controlled trial) primarily from the UK found benefits to some or all target farmland bird species, plants, invertebrates or mammals. Two studies (one replicated) from the UK found no effect on ground beetles or most farmland birds. Two replicated site comparisons from the UK found cultivated, uncropped margins were associated with lower numbers of some bird species or age groups in some areas. *Assessment: beneficial (effectiveness 100%; certainty 65%).*

<http://www.conservationevidence.com/actions/562>

Likely to be beneficial

● Create beetle banks

Five reports from two replicated studies (one controlled) and a review from Denmark and the UK found beetle banks had positive effects on invertebrate numbers, diversity or distributions. Five replicated studies (two controlled) found lower or no difference in invertebrate numbers. Three studies (including a replicated, controlled trial) from the UK found beetle banks, alongside other management, had positive effects on bird numbers or usage. Three studies (one replicated site comparison) from the

UK found mixed or no effects on birds, two found negative on no clear effects on plants. Two studies (one controlled) from the UK found harvest mice nested on beetle banks. *Assessment: likely to be beneficial (effectiveness 80%; certainty 60%).*

<http://www.conservationevidence.com/actions/651>

● **Leave overwinter stubbles**

Eighteen studies investigated the effects of overwinter stubbles. Thirteen studies (including two replicated site comparisons and a systematic review) from Finland, Switzerland and the UK found leaving overwinter stubbles benefits some plants, invertebrates, mammals or birds. Three UK studies (one randomized, replicated, controlled) found only certain birds were positively associated with overwinter stubbles. *Assessment: likely to be beneficial (effectiveness 90%; certainty 50%).*

<http://www.conservationevidence.com/actions/695>

● **Reduce tillage**

Thirty-four studies (including seven randomized, replicated, controlled trials) from nine countries found reducing tillage had some positive effects on invertebrates, weeds or birds. Twenty-seven studies (including three randomized, replicated, controlled trials) from nine countries found reducing tillage had negative or no clear effects on some invertebrates, plants, mammals or birds. Three of the studies did not distinguish between the effects of reducing tillage and reducing chemical inputs. *Assessment: likely to be beneficial (effectiveness 60%; certainty 60%).*

<http://www.conservationevidence.com/actions/126>

● **Undersow spring cereals, with clover for example**

Eleven studies (including three randomized, replicated, controlled trials) from Denmark, Finland, Switzerland and the UK found undersowing spring cereals benefited some birds, plants or invertebrates, including increases in numbers or species richness. Five studies (including one replicated, randomized, controlled trial) from Austria, Finland and the UK found no benefits to invertebrates, plants or some birds. *Assessment: likely to be beneficial (effectiveness 60%; certainty 43%).*

<http://www.conservationevidence.com/actions/136>

Unknown effectiveness (limited evidence)

● Convert or revert arable land to permanent grassland

All seven individual studies (including two replicated, controlled trials) from the Czech Republic, Denmark and the UK looking at the effects of reverting arable land to grassland found no clear benefits to birds, mammals or plants. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 20%).*

<http://www.conservationevidence.com/actions/561>

● Create rotational grass or clover leys

A controlled study from Finland found more spiders and fewer pest insects in clover leys than the crop. A replicated study from the UK found grass leys had fewer plant species than other conservation habitats. A UK study found newer leys had lower earthworm abundance and species richness than older leys. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 10%).*

<http://www.conservationevidence.com/actions/643>

● Increase crop diversity

Four studies (including one replicated, controlled trial) from Belgium, Germany and Hungary found more ground beetle or plant species or individuals in fields with crop rotations or on farms with more crops in rotation than monoculture fields. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 9%).*

<http://www.conservationevidence.com/actions/560>

● Plant cereals in wide-spaced rows

Two studies (one randomized, replicated, controlled) from the UK found planting cereals in wide-spaced rows had inconsistent, negative or no effects on plant and invertebrate abundance or species richness. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 18%).*

<http://www.conservationevidence.com/actions/564>

● **Plant crops in spring rather than autumn**

Seven studies (including two replicated, controlled trials) from Denmark, Sweden and the UK found sowing crops in spring had positive effects on farmland bird numbers or nesting rates, invertebrate numbers or weed diversity or density. Three of the studies found the effects were seasonal. A review of European studies found fewer invertebrates in spring wheat than winter wheat. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 35%).*

<http://www.conservationevidence.com/actions/137>

● **Plant nettle strips**

A small study from Belgium found nettle strips in field margins had more predatory invertebrate species than the crop, but fewer individuals than the crop or natural nettle stands. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%).*

<http://www.conservationevidence.com/actions/118>

● **Sow rare or declining arable weeds**

Two randomized, replicated, controlled studies from the UK identified factors important in establishing rare or declining arable weeds, including type of cover crop, cultivation and herbicide treatment. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 15%).*

<http://www.conservationevidence.com/actions/642>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Add 1% barley into wheat crop for corn buntings
- Create corn bunting plots
- Leave unharvested cereal headlands in arable fields
- Use new crop types to benefit wildlife (such as perennial cereal crops)

Evidence not assessed

● **Implement ‘mosaic management’, a Dutch agri-environment option**

A replicated, controlled before-and-after study from the Netherlands found mosaic management had mixed effects on population trends of wading bird species. A replicated, paired sites study from the Netherlands found one bird species had higher productivity under mosaic management. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/130>

● **Plant more than one crop per field (intercropping)**

All five studies (including three randomized, replicated, controlled trials) from the Netherlands, Poland, Switzerland and the UK looking at the effects of planting more than one crop per field found increases in the number of earthworms or ground beetles. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/124>

● **Take field corners out of management**

A replicated site comparison from the UK found a positive correlation between grey partridge overwinter survival and taking field corners out of management. Brood size, ratio of young to old birds and density changes were unaffected. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/128>

4.3 Perennial (non-timber) crops

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for perennial (non-timber) crops?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Maintain traditional orchards
No evidence found (no assessment)	<ul style="list-style-type: none">• Manage short-rotation coppice to benefit wildlife (includes 8m rides)• Restore or create traditional orchards

Unknown effectiveness (limited evidence)

● Maintain traditional orchards

A replicated, controlled site comparison from Germany found more plant species in mown orchards than grazed or abandoned ones, but found no effects on wasps or bees. Two replicated site comparisons from Germany and Switzerland found traditional orchards managed under agri-environment schemes either did not have more plant species than controls or offered no clear benefits to birds. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 15%).*

<http://www.conservationevidence.com/actions/703>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Manage short-rotation coppice to benefit wildlife (includes 8 m rides)
- Restore or create traditional orchards

4.4 Livestock farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for livestock farming?	
Beneficial	<ul style="list-style-type: none"> • Restore or create species-rich semi-natural grassland • Use mowing techniques to reduce mortality
Likely to be beneficial	<ul style="list-style-type: none"> • Delay mowing or first grazing date on grasslands • Leave uncut strips of rye grass on silage fields • Maintain species-rich, semi-natural grassland • Maintain traditional water meadows (includes management for breeding and/or wintering waders/waterfowl) • Maintain upland heath/moorland • Reduce management intensity on permanent grasslands (several interventions at once) • Restore or create traditional water meadows
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Add yellow rattle seed <i>Rhinanthus minor</i> to hay meadows • Employ areas of semi-natural habitat for rough grazing (includes salt marsh, lowland heath, bog, fen) • Exclude livestock from semi-natural habitat (including woodland) • Maintain wood pasture and parkland • Plant cereals for whole crop silage • Raise mowing height on grasslands • Restore or create upland heath/moorland • Restore or create wood pasture • Use traditional breeds of livestock

Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Reduce grazing intensity on grassland (including seasonal removal of livestock)
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Maintain rush pastures ● Mark fencing to avoid bird mortality ● Plant Brassica fodder crops (grazed <i>in situ</i>)
Evidence not assessed	<ul style="list-style-type: none"> ● Create open patches or strips in permanent grassland ● Provide short grass for birds ● Use mixed stocking

Beneficial

● Restore or create species-rich, semi-natural grassland

Twenty studies (including three randomized, replicated, controlled trials) from six countries found restored species-rich, semi-natural grasslands had similar invertebrate, plant or bird diversity or abundance to other grasslands. Seven studies (two randomized, replicated, controlled trials) from five countries found no clear effect on plant or invertebrate numbers, three replicated studies (of which two site comparisons) from two countries found negative effects. Forty studies (including six randomized, replicated, controlled trials) from nine countries identified effective techniques for restoring species-rich grassland. *Assessment: beneficial (effectiveness 100%; certainty 73%).*

<http://www.conservationevidence.com/actions/133>

● Use mowing techniques to reduce mortality

Seven studies (including two replicated trials, one controlled and one randomized) from Germany, Ireland, Switzerland and the UK found mowing techniques that reduced mortality or injury in amphibians, birds, invertebrates or mammals. A review found the UK corncrake population increased around the same time that Corncrake Friendly Mowing was introduced and a replicated trial found mowing from the field centre outwards reduced corncrake chick mortality. *Assessment: beneficial (effectiveness 100%; certainty 78%).*

<http://www.conservationevidence.com/actions/698>

Likely to be beneficial

● Delay mowing or first grazing date on grasslands

Eight studies (including a European systematic review) from the Netherlands, Sweden and the UK found delaying mowing or grazing benefited some or all plants, invertebrates or birds, including increases in numbers or productivity. Three reviews found the UK corncrake population increased following management that included delayed mowing. Six studies (including a European systematic review) from five countries found no clear effect on some plants, invertebrates or birds. *Assessment: likely to be beneficial (effectiveness 60%; certainty 45%).*

<http://www.conservationevidence.com/actions/131>

● Leave uncut strips of rye grass on silage fields

Four studies (including two replicated, controlled trials) from the UK found uncut strips of rye grass benefited some birds, with increased numbers. A randomized, replicated, controlled study from the UK found higher ground beetle diversity on uncut silage plots, but only in the third study year. *Assessment: likely to be beneficial (effectiveness 80%; certainty 49%).*

<http://www.conservationevidence.com/actions/132>

● Maintain species-rich, semi-natural grassland

Nine studies (including two randomized, replicated before-and-after trials) from Switzerland and the UK looked at the effectiveness of agri-environment schemes in maintaining species-rich grassland and all except one found mixed results. All twelve studies (including a systematic review) from six countries looking at grassland management options found techniques that improved or maintained vegetation quality. A site comparison from Finland and Russia found butterfly communities were more affected by grassland age and origin than present management. *Assessment: likely to be beneficial (effectiveness 80%; certainty 60%).*

<http://www.conservationevidence.com/actions/702>

● **Maintain traditional water meadows (includes management for breeding and/or wintering waders/waterfowl)**

Four studies (including a replicated site comparison) from Belgium, Germany, the Netherlands and the UK found maintaining traditional water meadows increased numbers of some birds or plant diversity. One bird species declined. Two studies (including a replicated site comparison from the Netherlands) found mixed or inconclusive effects on birds, plants or wildlife generally. A replicated study from the UK found productivity of one wading bird was too low to sustain populations in some areas of wet grassland managed for wildlife. *Assessment: likely to be beneficial (effectiveness 56%; certainty 50%).*

<http://www.conservationevidence.com/actions/696>

● **Maintain upland heath/moorland**

Eight studies (including one randomized, replicated, controlled trial) from the UK found management, including reducing grazing, can help to maintain the conservation value of upland heath or moorland. Benefits included increased numbers of plants or invertebrates. Three studies (including a before-and-after trial) from the UK found management to maintain upland heath or moorland had mixed effects on some wildlife groups. Four studies (including a controlled site comparison) from the UK found reducing grazing had negative impacts on soil organisms, but a randomized, replicated before-and-after study found heather cover declined where grazing intensity had increased. *Assessment: likely to be beneficial (effectiveness 90%; certainty 50%).*

<http://www.conservationevidence.com/actions/647>

● **Reduce management intensity on permanent grasslands (several interventions at once)**

Eleven studies (including four replicated site comparisons) from three countries found reducing management intensity benefited plants. Sixteen studies (including four paired site comparisons) from four countries found benefits to some or all invertebrates. Five studies (including one paired, replicated site comparison) from four countries found positive effects on some or all birds. Twenty-one studies (including two randomized, replicated, controlled trials) from six countries found no clear effects of reducing management intensity on some or all plants, invertebrates or birds.

Five studies (including two paired site comparisons) from four countries found negative effects on plants, invertebrates or birds. *Assessment: likely to be beneficial (effectiveness 100%; certainty 60%).*

<http://www.conservationevidence.com/actions/69>

● **Restore or create traditional water meadows**

Three studies (two before-and-after trials) from Sweden and the UK looked at bird numbers following water meadow restoration, one found increases, one found increases and decreases, one found no increases. Seventeen studies (two randomized, replicated, controlled) from six countries found successful techniques for restoring wet meadow plant communities. Three studies (one replicated, controlled) from four countries found restoration of wet meadow plant communities had reduced or limited success. *Assessment: likely to be beneficial (effectiveness 100%; certainty 50%).*

<http://www.conservationevidence.com/actions/119>

Unknown effectiveness (limited evidence)

● **Add yellow rattle seed *Rhinanthus minor* to hay meadows**

A review from the UK reported that hay meadows had more plant species when yellow rattle was present. A randomized, replicated controlled trial in the UK found yellow rattle could be established by 'slot seeding'. *Assessment: unknown effectiveness — limited evidence (effectiveness 70%; certainty 20%).*

<http://www.conservationevidence.com/actions/129>

● **Employ areas of semi-natural habitat for rough grazing (includes salt marsh, lowland heath, bog, fen)**

Three studies (two replicated) from the UK and unspecified European countries found grazing had positive effects on birds, butterflies or biodiversity generally. A series of site comparisons from the UK found one bird species used heathland managed for grazing as feeding but not nesting sites. Two studies (one replicated site comparison) from the UK found grazing had negative effects on two bird species. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 10%).*

<http://www.conservationevidence.com/actions/697>

● **Exclude livestock from semi-natural habitat (including woodland)**

Three studies (including one randomized, replicated, controlled trial) from Ireland and the UK found excluding livestock from semi-natural habitats benefited plants and invertebrates. Three studies (one replicated, controlled and one replicated paired sites comparison) from Ireland and the UK did not find benefits to plants or birds. Two studies (one replicated, controlled and a review) from Poland and the UK found limited or mixed effects. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 15%).*

<http://www.conservationevidence.com/actions/150>

● **Maintain wood pasture and parkland**

A randomized, replicated, controlled trial in Sweden found annual mowing on wood pasture maintained the highest number of plant species. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%).*

<http://www.conservationevidence.com/actions/649>

● **Plant cereals for whole crop silage**

A replicated study from the UK found cereal-based whole crop silage had higher numbers of some birds than other crops. A review from the UK reported that seed-eating birds avoided cereal-based whole crop silage in winter, but used it as much as spring barley in summer. *Assessment: unknown effectiveness — limited evidence (effectiveness 80%; certainty 28%).*

<http://www.conservationevidence.com/actions/149>

● **Raise mowing height on grasslands**

Three studies (including one replicated, controlled trial) from the UK or unspecified European countries found raised mowing heights caused less damage to amphibians and invertebrates or increased Eurasian skylark productivity. Two studies (one randomized, replicated, controlled) from the UK found no effect on bird or invertebrate numbers and a replicated study from the UK found young birds had greater foraging success in shorter grass. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 35%).*

<http://www.conservationevidence.com/actions/138>

● Restore or create upland heath/moorland

A small trial in northern England found moorland restoration increased the number of breeding northern lapwing. A UK review concluded that vegetation changes were slow during the restoration of heather moorland from upland grassland. *Assessment: unknown effectiveness – limited evidence (effectiveness 78%; certainty 20%).*

<http://www.conservationevidence.com/actions/650>

● Restore or create wood pasture

A replicated, controlled trial in Belgium found survival and growth of tree seedlings planted in pasture was enhanced when they were protected from grazing. A replicated study in Switzerland found cattle browsing had negative effects on tree saplings. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 5%).*

<http://www.conservationevidence.com/actions/644>

● Use traditional breeds of livestock

Three studies (one replicated) from the UK found the breed of livestock affected vegetation structure, invertebrate communities and the amount of plants grazed. A replicated trial from France, Germany and the UK found no difference in the number of plant species or the abundance of birds, invertebrates or mammals between areas grazed by traditional or commercial livestock. *Assessment: unknown effectiveness – limited evidence (effectiveness 0%; certainty 20%).*

<http://www.conservationevidence.com/actions/539>

Likely to be ineffective or harmful

● Reduce grazing intensity on grassland (including seasonal removal of livestock)

Fifteen studies (including three randomized, replicated, controlled trials) from four countries found reducing grazing intensity benefited birds, invertebrates or plants. Three studies (including one randomized, replicated, controlled trial) from the Netherlands and the UK found no benefit to plants or invertebrates. Nine studies (including a systematic review) from France, Germany and the UK found mixed effects for some

or all wildlife groups. The systematic review concluded that intermediate grazing levels are usually optimal but different wildlife groups are likely to have different grazing requirements. *Assessment: likely to be ineffective (effectiveness 30%; certainty 70%).*

<http://www.conservationevidence.com/actions/704>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain rush pastures
- Mark fencing to avoid bird mortality
- Plant brassica fodder crops (grazed *in situ*)

Evidence not assessed

● Create open patches or strips in permanent grassland

A randomized, replicated, controlled study from the UK found more Eurasian skylarks used fields containing open strips, but numbers varied. A randomized, replicated, controlled study from the UK found insect numbers on grassy headlands initially dropped when strips were cleared. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/563>

● Provide short grass for birds

A replicated UK study found two bird species spent more time foraging on short grass than longer grass. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/115>

● Use mixed stocking

A replicated, controlled study in the UK found more spiders, harvestmen and pseudoscorpions in grassland grazed by sheep-only than grassland grazed by sheep and cattle. Differences were only found when suction sampling not pitfall-trapping. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/93>

4.5 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Provide owl nest boxes (tawny owl, barn owl)
No evidence found (no assessment)	<ul style="list-style-type: none">• Maintain traditional farm buildings• Provide bat boxes, bat grilles, improvements to roosts

Unknown effectiveness (limited evidence)

● Provide owl nest boxes (tawny owl, barn owl)

Two studies (one before-and-after study) from the Netherlands and the UK found providing nest boxes increased barn owl populations. A replicated study from the UK found a decrease in the proportion of breeding barn owls was not associated with the number of nest boxes. *Assessment: unknown effectiveness – limited evidence (effectiveness 100%; certainty 33%).*

<http://www.conservationevidence.com/actions/154>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain traditional farm buildings
- Provide bat boxes, bat grilles, improvements to roosts

4.6 Threat: Agri-chemicals

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for agri-chemicals?	
Beneficial	<ul style="list-style-type: none"> • Leave headlands in fields unsprayed (conservation headlands) • Reduce fertilizer, pesticide or herbicide use generally • Use organic rather than mineral fertilisers
Likely to be beneficial	<ul style="list-style-type: none"> • Reduce chemical inputs in grassland management
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Provide buffer strips alongside water courses (rivers and streams) • Restrict certain pesticides
No evidence found (no assessment)	<ul style="list-style-type: none"> • Buffer in-field ponds
Evidence not assessed	<ul style="list-style-type: none"> • Make selective use of spring herbicides

Beneficial

● Leave headlands in fields unsprayed (conservation headlands)

Twenty-two studies from 14 experiments (including two randomized, replicated, controlled) from five countries found conservation headlands had higher invertebrate or plant diversity than other habitats, twelve studies from ten experiments (three randomized, replicated, controlled) did not. Twenty-seven studies from 15 experiments (of which 13 replicated, controlled) from five countries found positive effects on abundance or behaviour of some wildlife groups. Nineteen studies from 13 experiments

(12 replicated, controlled) from four countries found similar, or lower, numbers of birds, invertebrates or plants on conservation headlands than other habitats. *Assessment: beneficial (effectiveness 90%; certainty 75%).*

<http://www.conservationevidence.com/actions/652>

● Reduce fertilizer, pesticide or herbicide use generally

Thirty-four studies (including a systematic review) from 10 countries found reducing fertilizer, pesticide or herbicide inputs benefited some invertebrates, plants or birds. Twenty-five studies (including seven randomized, replicated, controlled trials) from eight countries found negative or no clear effects on some invertebrates, plants or birds. *Assessment: beneficial (effectiveness 100%; certainty 70%).*

<http://www.conservationevidence.com/actions/139>

● Use organic rather than mineral fertilizers

Fourteen studies (including four randomized, replicated, controlled trials) from six countries found areas treated with organic rather than mineral fertilizers had more plants or invertebrates or higher diversity. A randomized, replicated, controlled trial from the UK found no effect on weed numbers. Two studies (including a small trial from Belgium) found organic fertilizers benefited invertebrates, a UK review found that in large quantities they did not. *Assessment: beneficial (effectiveness 100%; certainty 70%).*

<http://www.conservationevidence.com/actions/134>

Likely to be beneficial

● Reduce chemical inputs in grassland management

Six studies (including a randomized, replicated, controlled before-and-after trial) from three countries found stopping fertilizer inputs on grassland improved plant or invertebrate species richness or abundance. Two reviews from the Netherlands and the UK found no or low fertilizer input grasslands favour some birds and invertebrates. Five studies (two replicated trials of which one randomized and one replicated) from three countries found no clear effects on invertebrates or plants. *Assessment: likely to be beneficial (effectiveness 90%; certainty 60%).*

<http://www.conservationevidence.com/actions/694>

Unknown effectiveness (limited evidence)

● Provide buffer strips alongside water courses (rivers and streams)

Three studies (including one replicated site comparison) from the Netherlands and the UK found riparian buffer strips increased diversity or abundance of plants, invertebrates or birds and supported vegetation associated with water vole habitats. Two replicated site comparisons from France and Ireland found farms with buffer strips did not have more plant species than farms without strips. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 15%).*

<http://www.conservationevidence.com/actions/120>

● Restrict certain pesticides

A small UK study found two fungicides that reduced insect abundance less than an alternative. A replicated, controlled trial in Switzerland found applying slug pellets in a band at the field edge was as effective as spreading the pellets across the field. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 5%).*

<http://www.conservationevidence.com/actions/565>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Buffer in-field ponds

Evidence not assessed

● Make selective use of spring herbicides

A randomized, replicated, controlled study from the UK found spring herbicides had some benefits for beneficial weeds and arthropods. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/98>

4.7 Threat: Transport and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for transport and service corridors?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Manage land under power lines to benefit wildlife

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Manage land under power lines to benefit wildlife

4.8 Threat: Hunting and trapping (for pest control, food or sport)

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for hunting and trapping (for pest control, food or sport)?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Enforce legislation to protect birds against persecution • Provide 'sacrificial' grasslands to reduce the impact of wild geese on crops
No evidence found (no assessment)	<ul style="list-style-type: none"> • Avoid use of lead shot • Use alerts to reduce grey partridge by-catch during shoots
Evidence not assessed	<ul style="list-style-type: none"> • Use scaring devices (e.g. gas guns) and other deterrents to reduce persecution of native species

Unknown effectiveness (limited evidence)

● Enforce legislation to protect birds against persecution

Two before-and-after studies from Denmark and the UK found increased numbers or survival of raptors under legislative protection. *Assessment: unknown effectiveness — limited evidence (effectiveness 90%; certainty 18%).*

<http://www.conservationevidence.com/actions/101>

● Provide 'sacrificial' grasslands to reduce the impact of wild geese on crops

All six studies from the UK (including four replicated, controlled trials) found that managing grasslands for geese increased the number of geese using these areas. Four of these studies found geese were moving within the study sites. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 5%).*

<http://www.conservationevidence.com/actions/641>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Avoid use of lead shot
- Use alerts to reduce grey partridge by-catch during shoots

Evidence not assessed

● Use scaring devices (e.g. gas guns) and other deterrents to reduce persecution of native species

A replicated, controlled trial in Germany found phosphorescent tape was more effective than normal yellow tape at deterring one of three mammal species. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/645>

4.9 Threat: Natural system modification

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for natural system modification?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Raise water levels in ditches or grassland
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Create scrapes and pools ● Manage heather by swiping to simulate burning ● Mangle heather, gorse or grass by burning ● Remove flood defence banks to allow inundation
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Re-wet moorland

Likely to be beneficial

● Raise water levels in ditches or grassland

Eight studies (including two replicated, controlled trials) from Denmark, the Netherlands and the UK found raising water levels increased numbers of birds, invertebrates or plants or allowed wet grassland plant species to establish more rapidly. Three studies (two replicated) from the Netherlands and the UK found raising water levels had negative, limited or no effects on plants or birds. A replicated study from the UK found unflooded pastures had a greater weight of soil invertebrates than flooded pastures. *Assessment: likely to be beneficial (effectiveness 100%; certainty 55%).*

<http://www.conservationevidence.com/actions/121>

Unknown effectiveness (limited evidence)

● Create scrapes and pools

Five studies (including a replicated, controlled, paired trial) from Sweden and the UK found creating scrapes and pools provided habitat for birds, invertebrates or plants or increased invertebrate diversity. Two replicated studies (one controlled, paired) from Ireland and the UK found mixed or no differences in invertebrate numbers between created ponds and controls or natural ponds. A study in Sweden found fewer fish species in constructed than natural wetlands. *Assessment: unknown effectiveness — limited evidence (effectiveness 100%; certainty 28%).*

<http://www.conservationevidence.com/actions/153>

● Manage heather by swiping to simulate burning

A replicated, controlled trial from the UK found heather moorland subject to flailing had fewer plant species than burned plots but more species than unflailed plots. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 9%).*

<http://www.conservationevidence.com/actions/151>

● Manage heather, gorse or grass by burning

A long-term replicated, controlled trial in Switzerland found burning of chalk grassland did not increase the number of plant species. A replicated, controlled trial in the UK found more plant species on burned than unburned heather moorland. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 5%).*

<http://www.conservationevidence.com/actions/152>

● Remove flood defence banks to allow inundation

A controlled before-and-after study from the UK found a stretch of river that was allowed to flood had more bird species and territories than a channelized section. A study from Belgium found flooding and mowing increased plant species richness in meadow plots. *Assessment: unknown effectiveness — limited evidence (effectiveness 80%; certainty 10%).*

<http://www.conservationevidence.com/actions/122>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Re-wet moorland

4.10 Threat: Invasive and other problematic species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for invasive and other problematic species?	
Likely to be beneficial	<ul style="list-style-type: none"> • Control predatory mammals and birds (foxes, crows, stoats and weasels)
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Control scrub • Control weeds without damaging other plants in conservation areas • Protect individual nests of ground-nesting birds
No evidence found (no assessment)	<ul style="list-style-type: none"> • Control grey squirrels • Erect predator-proof fencing around important breeding sites for waders • Manage wild deer numbers • Remove coarse fish
Evidence not assessed	<ul style="list-style-type: none"> • Control bracken • Control invasive non-native plants on farmland (such as Himalayan balsam, Japanese knotweed) • Control mink • Provide medicated grit for grouse

Likely to be beneficial

- **Control predatory mammals and birds (foxes, crows, stoats and weasels)**

Eight studies (including a systematic review) from France and the UK found predator control (sometimes alongside other interventions) increased the

abundance, population size or productivity of some birds. A randomized, replicated, controlled study from the UK did not. *Assessment: likely to be beneficial (effectiveness 90%; certainty 60%).*

<http://www.conservationevidence.com/actions/699>

Unknown effectiveness (limited evidence)

● Control scrub

A replicated site comparison from the UK found the number of young grey partridge per adult was negatively associated with management that included scrub control. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 2%).*

<http://www.conservationevidence.com/actions/127>

● Control weeds without damaging other plants in conservation areas

Two studies (one randomized, replicated, controlled) from the UK found that after specific plants were controlled, new plants established or diversity increased. A replicated, controlled laboratory and grassland study found a specific herbicide had negative impacts on one beetle species. Eleven studies investigated different methods of controlling plants. *Assessment: unknown effectiveness — limited evidence (effectiveness 90%; certainty 28%).*

<http://www.conservationevidence.com/actions/123>

● Protect individual nests of ground-nesting birds

Two randomized, replicated, controlled studies from Sweden found nest enclosures increased measures of ground-nesting bird productivity, however both found bird numbers or adult predation rates were unaffected or negatively affected by enclosures. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 13%).*

<http://www.conservationevidence.com/actions/108>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Control grey squirrels

- Erect predator-proof fencing around important breeding sites for waders
- Manage wild deer numbers
- Remove coarse fish

Evidence not assessed

● Control bracken

A systematic review found repeated herbicide applications reduced bracken abundance but cutting may be equally effective. A laboratory trial found the same herbicide could inhibit the growth of mosses under certain conditions. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/105>

● Control invasive non-native plants on farmland (such as Himalayan balsam, Japanese knotweed)

Two randomized, replicated, controlled trials in the Czech Republic found removing all giant hogweed flower heads at peak flowering time reduced seed production. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/104>

● Control mink

A systematic review found trapping may be an effective method of reducing American mink populations. A study in the UK found mink were successfully eradicated from a large area by systematic trapping. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/107>

● Provide medicated grit for grouse

A controlled study from the UK found higher red grouse productivity where medicated grit was provided. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/112>

4.11 Threat: Education and awareness

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for education and awareness?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Provide specialist advice, assistance preparing conservation plans
Evidence not assessed	<ul style="list-style-type: none">• Provide training for land managers, farmers and farm advisers

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Provide specialist advice, assistance preparing conservation plans

Evidence not assessed

- **Provide training for land managers, farmers and farm advisers**

A study from the UK found farmers who were trained in how to implement agri-environment schemes created better quality wildlife habitat over five years. *Assessment: this intervention has not been assessed.*

<http://www.conservationevidence.com/actions/113>

5. FOREST CONSERVATION

Har'el Agra, Simon Schowanek, Yohay Carmel, Rebecca K. Smith
& Gidi Ne'eman

Expert assessors

Rhett Harrison, Consultative Group on International Agricultural Research, Zambia

Keith Kirby, University of Oxford, UK

Gillian Petrokofsky, Biodiversity Institute Oxford, UK

Rebecca K. Smith, University of Cambridge, UK

William J. Sutherland, University of Cambridge, UK

Tom Swinfield, Royal Society for the Protection of Birds, UK

Scope of assessment: for the conservation of forest habitat (not specific species within forests), including tropical forests, temperate forests, woodland, scrubland, shrubland and dry forests.

Assessed: 2016.

Effectiveness measure is the median % score.

Certainty measure is the median % certainty of evidence, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects on the forest habitat of concern.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target habitat for each intervention. The assessment may therefore refer to different habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target habitats or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

5.1 Threat: Residential and commercial development

5.1.1 Housing and urban areas

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development in housing and urban areas?

No evidence found (no assessment)

- Compensate for woodland removal with compensatory planting
- Incorporate existing trees or woods into the landscape of new developments
- Provide legal protection of forests from development

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Compensate for woodland removal with compensatory planting
- Incorporate existing trees or woods into the landscape of new developments
- Provide legal protection of forests from development

5.1.2 Tourism and recreation areas

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development in tourism and recreation areas?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Adopt ecotourism• Create managed paths/signs to contain disturbance• Re-route paths, control access or close paths• Use warning signs to prevent fire

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Adopt ecotourism
- Create managed paths/signs to contain disturbance
- Re-route paths, control access or close paths
- Use warning signs to prevent fire.

5.2 Threat: Agriculture

5.2.1 Livestock farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for livestock farming?	
Likely to be beneficial	<ul style="list-style-type: none">• Use wire fences within grazing areas to exclude livestock from specific forest sections
Trade-offs between benefit and harms	<ul style="list-style-type: none">• Prevent livestock grazing in forests
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Reduce the intensity of livestock grazing in forests• Shorten livestock grazing period or control grazing season in forests
No evidence found (no assessment)	<ul style="list-style-type: none">• Provide financial incentives not to graze

Likely to be beneficial

- **Use wire fences within grazing areas to exclude livestock from specific forest sections**

Three of four studies, including one replicated, randomized, controlled study in Kenya, Israel, Mexico and Panama found that excluding livestock using wire fences increased the size, density or number of regenerating trees. One study found no effect on tree size and decreased tree density. Four of eight studies, including two replicated, randomized, controlled studies across the world found that excluding livestock using increased

biomass, species richness, density or cover of understory plants. Four studies found mixed or no effects on understory plants. *Assessment: likely to be beneficial (effectiveness 58%; certainty 63%; harms 18%).*

<http://www.conservationevidence.com/actions/1205>

Trade-off between benefit and harms

● Prevent livestock grazing in forests

One site comparison study in Israel found that preventing cattle grazing increased the density of seedlings and saplings. Two of three studies, including one replicated, controlled study, in Brazil, Costa Rica and the UK found that preventing livestock grazing increased survival, species richness or diversity of understory plants. One study found mixed effects. *Assessment: trade-offs between benefits and harms (effectiveness 69%; certainty 45%; harms 20%).*

<http://www.conservationevidence.com/actions/1206>

Unknown effectiveness (limited evidence)

● Reduce the intensity of livestock grazing in forests

Two studies, including one replicated, randomized, controlled study, in the UK and Greece found that reducing grazing intensity increased the number of tree saplings or understory total weight. *Assessment: unknown effectiveness (effectiveness 78%; certainty 34%; harms 0%).*

<http://www.conservationevidence.com/actions/1207>

● Shorten livestock grazing period or control grazing season in forests

One of two studies, including one replicated, controlled study, in Spain and Australia found that shortening the grazing period increased the abundance and size of regenerating trees. One found no effect native plant species richness. One replicated study in the UK found that numbers of tree seedlings were higher following summer compared to winter grazing. *Assessment: unknown effectiveness (effectiveness 58%; certainty 33%; harms 0%).*

<http://www.conservationevidence.com/actions/1208>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide financial incentives not to graze.

5.3 Threat: Transport and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for transport and service corridors?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Maintain/create habitat corridors

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain/create habitat corridors.

5.4 Threat: Biological resource use

5.4.1 Thinning and wood harvesting

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for thinning and wood harvesting?	
Beneficial	<ul style="list-style-type: none"> • Log/remove trees within forests: effect on understory plants
Likely to be beneficial	<ul style="list-style-type: none"> • Thin trees within forests: effects on understory plants • Thin trees within forests: effects on young trees • Use shelterwood harvest instead of clearcutting
Trade-offs between benefit and harms	<ul style="list-style-type: none"> • Thin trees within forests: effects on mature trees
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Log/remove trees within forests: effects on young trees • Use partial retention harvesting instead of clearcutting • Use summer instead of winter harvesting
Unlikely to be beneficial	<ul style="list-style-type: none"> • Remove woody debris after timber harvest
Likely to be ineffective or harmful	<ul style="list-style-type: none"> • Log/remove trees within forests: effect on mature trees • Log/remove trees within forests: effect on non-vascular plants • Thin trees within forests: effect on non-vascular plants
No evidence found (no assessment)	<ul style="list-style-type: none"> • Adopt continuous cover forestry • Use brush mats during harvesting to avoid soil compaction

Beneficial

● Log/remove trees within forests: effects on understory plants

Eight of 12 studies, including four replicated, randomized, controlled studies, in India, Australia, Bolivia, Canada and the USA found that logging increased the density and cover or species richness and diversity of understory plants. Two studies found mixed and three found no effect. *Assessment: beneficial (effectiveness 65%; certainty 65%; harms 10%).*

<http://www.conservationevidence.com/actions/1273>

Likely to be beneficial

● Thin trees within forests: effects on understory plants

Twenty five of 38 studies, including 12 replicated, randomized, controlled studies, across the world found that thinning trees increased the density and cover or species richness and diversity of understory plants. Nine studies found mixed and two no effects, and one found a decrease the abundance of herbaceous species. *Assessment: Likely to be beneficial (effectiveness 58%; certainty 73%; harms 13%).*

<http://www.conservationevidence.com/actions/1211>

● Thin trees within forests: effects on young trees

Six of 12 studies, including two replicated, randomized, controlled studies, in Japan and the USA found that thinning increased the density of young trees and a study in Peru found it increased the growth rate of young trees. One study found thinning decreased the density and five found mixed or no effect on young trees. One replicated, controlled study in the USA found no effect on the density of oak acorns. *Assessment: Likely to be beneficial (effectiveness 60%; certainty 65%; harms 15%).*

<http://www.conservationevidence.com/actions/1210>

● Use shelterwood harvest instead of clearcutting

Three replicated, controlled studies in Sweden and the USA found that shelterwood harvesting increased density of trees or plant diversity, or decreased grass cover compared with clearcutting. *Assessment: Likely to be beneficial (effectiveness 75%; certainty 55%; harms 15%).*

<http://www.conservationevidence.com/actions/1214>

Trade-off between benefit and harms

● Thin trees within forests: effects on mature trees

Eleven of 12 studies, including two replicated, randomized, controlled studies, in Brazil, Canada, and the USA found that thinning trees decreased the density and cover of mature trees and in one case tree species diversity. Five of six studies, including one replicated, controlled, before-and-after study, in Australia, Sweden and the USA found that thinning increased mature tree size, the other found mixed effects. One of three studies, including two replicated controlled studies, in the USA found that thinning reduced the number of trees killed by beetles. *Assessment: trade-offs between benefits and harms (effectiveness 47%; certainty 55%; harms 35%).*

<http://www.conservationevidence.com/actions/1209>

Unknown effectiveness (limited evidence)

● Log/remove trees within forests: effects on young trees

One of two replicated controlled studies in Canada and Costa Rica found that logging increased the density of young trees, the other found mixed effects. *Assessment: unknown effectiveness (effectiveness 50%; certainty 18%; harms 10%).*

<http://www.conservationevidence.com/actions/1272>

● Use partial retention harvesting instead of clearcutting

Three studies, including one replicated, randomized, controlled study, in Canada found that using partial retention harvesting instead of clearcutting decreased the density of young trees. *Assessment: unknown effectiveness (effectiveness 5%; certainty 35%; harms 45%).*

<http://www.conservationevidence.com/actions/1215>

● Use summer instead of winter harvesting

One replicated study in the USA found no effect of logging season on plant species richness and diversity. *Assessment: unknown effectiveness (effectiveness 0%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/1216>

Unlikely to be beneficial

● Remove woody debris after timber harvest

Two studies, including one replicated, randomized, controlled study, in France and the USA found no effect of woody debris removal on cover or species diversity of trees. One of six studies, including two replicated, randomized, controlled studies, in Ethiopia, Spain, Canada and the USA found that woody debris removal increased young tree density. One found that it decreased young tree density and three found mixed or no effect on density or survival. One of six studies, including two replicated, randomized, controlled studies, in the USA and France found that woody debris removal increased understory vegetation cover. Five studies found mixed or no effects on understory vegetation cover or species richness and diversity. *Assessment: unlikely to be beneficial (effectiveness 23%; certainty 50%; harms 10%).*

<http://www.conservationevidence.com/actions/1213>

Likely to be ineffective or harmful

● Log/remove trees within forests: effect on mature trees

Three of seven studies, including two replicated, controlled studies, across the world found that logging trees decreased the density and cover of mature trees. Two found it increased tree density and two found no effect. Four of nine studies, including one replicated, randomized, controlled study, across the world found that logging increased mature tree size or diversity. Four found it decreased tree size or species richness and diversity, and two found no effect on mature tree size or diversity. One replicated, controlled study in Canada found that logging increased mature tree mortality rate. *Assessment: likely to be ineffective or harmful (effectiveness 35%; certainty 50%; harms 30%).*

<http://www.conservationevidence.com/actions/1271>

● **Log/remove trees within forests: effect on effects on non-vascular plants**

Two of three studies, including one replicated, paired sites study, in Australia, Norway and Sweden found that logging decreased epiphytic plant abundance and fern fertility. One found mixed effects depending on species. *Assessment: likely to be ineffective or harmful (effectiveness 18%; certainty 40%; harms 50%).*

<http://www.conservationevidence.com/actions/1270>

● **Thin trees within forests: effects on non-vascular plants**

Three of four studies, including one replicated, randomized, controlled study, in Canada, Finland and Sweden found that thinning decreased epiphytic plant abundance and species richness. Three found mixed effects depending on thinning method and species. *Assessment: likely to be ineffective or harmful (effectiveness 20%; certainty 48%; harms 50%).*

<http://www.conservationevidence.com/actions/1212>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Adopt continuous cover forestry
- Use brush mats during harvesting to avoid soil compaction

5.4.2 Harvest forest products

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for harvesting forest products?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Adopt certification
No evidence found (no assessment)	<ul style="list-style-type: none"> • Sustainable management of non-timber products

Unknown effectiveness (limited evidence)

● Adopt certification

One replicated, site comparison study in Ethiopia found that deforestation risk was lower in certified than uncertified forests. One controlled, before-and-after trial in Gabon found that, when corrected for logging intensity, although tree damage did not differ, changes in above-ground biomass were smaller in certified than in uncertified forests. *Assessment: unknown effectiveness (effectiveness 50%; certainty 20%; harms 3%).*

<http://www.conservationevidence.com/actions/1150>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Sustainable management of non-timber products

5.4.3 Firewood

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for firewood?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Provide fuel efficient stoves• Provide paraffin stoves

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide fuel efficient stoves
- Provide paraffin stoves.

5.5 Habitat protection

5.5.1 Changing fire frequency

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for changing fire frequency?	
Trade-offs between benefit and harms	<ul style="list-style-type: none">● Use prescribed fire: effect on understory plants● Use prescribed fire: effect on young trees
Likely to be ineffective or harmful	<ul style="list-style-type: none">● Use prescribed fire: effect on mature trees
No evidence found (no assessment)	<ul style="list-style-type: none">● Mechanically remove understory vegetation to reduce wildfires● Use herbicides to remove understory vegetation to reduce wildfires

Trade-off between benefit and harms

● Use prescribed fire: effect on understory plants

Eight of 22 studies, including seven replicated, randomized, controlled studies, in Australia, Canada and the USA found that prescribed fire increased the cover, density or biomass of understory plants. Six found it decreased plant cover and eight found mixed or no effect on cover or density. Fourteen of 24 studies, including 10 replicated, randomized, controlled studies, in Australia, France, West Africa and the USA found that fire increased species richness and diversity of understory plants.

One found it decreased species richness and nine found mixed or no effect on understory plants. *Assessment: trade-offs between benefits and harms (effectiveness 55%; certainty 70%; harms 25%).*

<http://www.conservationevidence.com/actions/1221>

● Use prescribed fire: effect on young trees

Five of 15 studies, including four replicated, randomized, controlled studies, in France, Canada and the USA found that prescribed fire increased the density and biomass of young trees. Two found that fire decreased young tree density. Eight found mixed or no effect on density and two found mixed effects on species diversity of young trees. Two replicated, controlled studies in the USA found mixed effects of prescribed fire on young tree survival. *Assessment: trade-offs between benefits and harms (effectiveness 45%; certainty 55%; harms 23%).*

<http://www.conservationevidence.com/actions/1220>

Likely to be ineffective or harmful

● Use prescribed fire: effect on mature trees

Four of nine studies, including two replicated, randomized, controlled studies, in the USA found that prescribed fire decreased mature tree cover, density or diversity. Two studies found it increased tree cover or size, and four found mixed or no effect. Seven studies, including one replicated, randomized, controlled study, in the USA found that fire increased mature tree mortality. *Assessment: likely to be ineffective or harmful (effectiveness 25%; certainty 50%; harms 50%).*

<http://www.conservationevidence.com/actions/1217>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Mechanically remove understory vegetation to reduce wildfires
- Use herbicides to remove understory vegetation to reduce wildfires

5.5.2 Water management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for water management?	
No evidence found (no assessment)	<ul style="list-style-type: none"> • Construct water detention areas to slow water flow and restore riparian forests • Introduce beavers to impede water flow in forest watercourses • Recharge groundwater to restore wetland forest

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Construct water detention areas to slow water flow and restore riparian forests
- Introduce beavers to impede water flow in forest watercourses
- Recharge groundwater to restore wetland forest

5.5.3 Changing disturbance regime

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for changing the disturbance regime?	
Trade-offs between benefit and harms	<ul style="list-style-type: none"> • Use clearcutting to increase understory diversity • Use group-selection harvesting • Use shelterwood harvesting
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Thin trees by girdling (cutting rings around tree trunks) • Use herbicides to thin trees
Unlikely to be beneficial	<ul style="list-style-type: none"> • Use thinning followed by prescribed fire
No evidence found (no assessment)	<ul style="list-style-type: none"> • Adopt conservation grazing of woodland • Coppice trees • Halo ancient trees • Imitate natural disturbances by pushing over trees

- | |
|---|
| <ul style="list-style-type: none">● Pollard trees (top cutting or top pruning)● Reintroduce large herbivores● Retain fallen trees |
|---|

Trade-off between benefit and harms

● Use clearcutting to increase understory diversity

Three of nine studies, including four replicated, randomized, controlled studies, in Australia, Japan, Brazil, Canada and the USA found that clearcutting decreased density, species richness or diversity of mature trees. One study found it increased trees species richness and six found mixed or no effect or mixed effect on density, size, species richness or diversity. One replicated, randomized, controlled study in Finland found that clearcutting decreased total forest biomass, particularly of evergreen shrubs. Three of six studies, including five replicated, randomized, controlled studies, in Brazil, Canada and Spain found that clearcutting increased the density and species richness of young trees. One found it decreased young tree density and two found mixed or no effect. Eight of 12 studies, including three replicated, randomized, controlled studies, across the world found that clearcutting increased the cover or species richness of understory plants. Two found it decreased density or species richness, and two found mixed or no effect. *Assessment: trade-offs between benefits and harms (effectiveness 63%; certainty 65%; harms 30%).*

<http://www.conservationevidence.com/actions/1222>

● Use group-selection harvesting

Four of eight studies, including one replicated, controlled study, in Australia, Canada, Costa Rica and the USA found that group-selection harvesting increased cover or diversity of understory plants, or the density of young trees. Two studies found it decreased understory species richness or biomass. Three studies found no effect on understory species richness or diversity or tree density or growth-rate. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 58%; harms 30%).*

<http://www.conservationevidence.com/actions/1224>

● Use shelterwood harvesting

Six of seven studies, including five replicated, controlled studies, in Australia, Iran, Nepal and the USA found that shelterwood harvesting increased abundance, species richness or diversity or understory plants, as well as the growth and survival rate of young trees. One study found shelterwood harvesting decreased plant species richness and abundance and one found no effect on abundance. One replicated, controlled study in Canada found no effect on oak acorn production. *Assessment: trade-offs between benefits and harms (effectiveness 78%; certainty 70%; harms 28%).*

<http://www.conservationevidence.com/actions/1223>

Unknown effectiveness (limited evidence)

● Thin trees by girdling (cutting rings around tree trunks)

One before-and-after study in Canada found that thinning trees by girdling increased understory plant species richness, diversity and cover. *Assessment: unknown effectiveness — limited evidence (effectiveness 58%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/1226>

● Use herbicides to thin trees

One replicated, controlled study in Canada found no effect of using herbicide to thin trees on total plant species richness. *Assessment: unknown effectiveness — limited evidence (effectiveness 5%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/1225>

Unlikely to be beneficial

● Use thinning followed by prescribed fire

Three of six studies, including one replicated, randomized, controlled study, in the USA found that thinning followed by prescribed fire increased cover or abundance of understory plants, and density of deciduous trees. One study found it decreased tree density and species richness. Three studies found mixed or no effect or mixed effect on tree growth rate or density

of young trees. One replicated, controlled study Australia found no effect of thinning then burning on the genetic diversity of black ash. *Assessment: unlikely to be beneficial (effectiveness 35%; certainty 40%; harms 15%).*

<http://www.conservationevidence.com/actions/1227>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Adopt conservation grazing of woodland
- Coppice trees
- Halo ancient trees
- Imitate natural disturbances by pushing over trees
- Pollard trees (top cutting or top pruning)
- Reintroduce large herbivores
- Retain fallen trees.

5.6 Threat: Invasive and other problematic species

5.6.1 Invasive plants

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for invasive plants?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Manually/mechanically remove invasive plants• Use herbicides to remove invasive plant species
No evidence found (no assessment)	<ul style="list-style-type: none">• Use grazing to remove invasive plant species• Use prescribed fire to remove invasive plant species

Unknown effectiveness (limited evidence)

● Manually/mechanically remove invasive plants

Two replicated, controlled studies in Hawaii and Ghana found that removing invasive grass or weed species increased understory plant biomass or tree seedling height. Two replicated, controlled studies in the USA and Hawaii found no effect of removing invasive shrubs or plants on understory plant diversity or growth rate of native species. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 33%; harms 15%).*

<http://www.conservationevidence.com/actions/1228>

● **Use herbicides to remove invasive plant species**

One replicated, randomized, controlled study in the USA found no effect of controlling invasive plants using herbicide on native plant species richness. *Assessment: unknown effectiveness — limited evidence (effectiveness 5%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/1229>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use grazing to remove invasive plant species
- Use prescribed fire to remove invasive plant species

5.6.2 Native plants

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for native plants?	
No evidence found (no assessment)	• Manually/mechanically remove native plants

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Manually/mechanically remove native plants

5.6.3 Herbivores

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for herbivores?	
Likely to be beneficial	• Use wire fences to exclude large native herbivores
Unknown effectiveness (limited evidence)	• Use electric fencing to exclude large native herbivores

No evidence found (no assessment)	<ul style="list-style-type: none"> ● Control large herbivore populations ● Control medium-sized herbivores ● Use fencing to enclose large herbivores (e.g. deer)
--	---

Likely to be beneficial

● Use wire fences to exclude large native herbivores

Two replicated, controlled studies in the USA found that excluding large herbivores increased tree density. One of three studies, including two replicated, paired-sites, before-and-after studies, in Canada, Bhutan and Ireland found that excluding large herbivores increased the biomass of young trees. One found it decreased the density of young trees and one found mixed effects on species. Five of 10 studies, including two replicated, randomized, controlled studies, across the world found that excluding large herbivores increased the cover or and size of understory plants. Six found no effect on the cover, seed density, species richness or diversity of understory plants. *Assessment: Likely to be beneficial (effectiveness 50%; certainty 65%; harms 10%).*

<http://www.conservationevidence.com/actions/1230>

Unknown effectiveness (limited evidence)

● Use electric fencing to exclude large native herbivores

One controlled study in South Africa found that using electric fencing to exclude elephants and nyalas increased tree density. *Assessment: Unknown effectiveness (effectiveness 65%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/1231>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Control large herbivore populations
- Control medium-sized herbivores
- Use fencing to enclose large herbivores (e.g. deer)

5.6.4 Rodents

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for rodents?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Control rodents

Unknown effectiveness (limited evidence)

● Control rodents

One controlled study in New Zealand found that rodent control decreased native plant species richness and had no effect on total plant species richness. *Assessment: unknown effectiveness — limited evidence (effectiveness 10%; certainty 10%; harms 50%).*

<http://www.conservationevidence.com/actions/1232>

5.6.5 Birds

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for birds?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Control birds

Unknown effectiveness (limited evidence)

● Control birds

One controlled study in Australia found that removing birds did not improve the health of the trees in a narrow-leaved peppermint forest. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 15%; harms 0%).*

<http://www.conservationevidence.com/actions/1151>

5.7 Threat: Pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for pollution?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Maintain/create buffer zones
No evidence found (no assessment)	<ul style="list-style-type: none">• Remove nitrogen and phosphorus using harvested products

Unknown effectiveness (limited evidence)

● Maintain/create buffer zones

One site comparison study in Australia found that a forest edge protected by a planted buffer strip had higher canopy cover and lower stem density, but similar understory species richness to an unbuffered forest edge. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%; harms 0%).*

<http://www.conservationevidence.com/actions/1168>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Remove nitrogen and phosphorus using harvested products.

5.8 Threat: Climate change and severe weather

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for climate change and severe weather?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Prevent damage from strong winds

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Prevent damage from strong winds.

5.9 Habitat protection

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat protection?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Adopt community-based management to protect forests• Legal protection of forests
No evidence found (no assessment)	<ul style="list-style-type: none">• Adopt Protected Species legislation (impact on forest management)

Unknown effectiveness (limited evidence)

● Adopt community-based management to protect forests

Two studies, including one replicated, before-and-after, site comparison, in Ethiopia and Nepal found that forest cover increased more in community-managed forests than in forests not managed by local communities. However, one replicated, site comparison study in Colombia found that deforestation rates in community-managed forests did not differ from deforestation rates in unmanaged forests. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 35%; harms 0%).*

<http://www.conservationevidence.com/actions/1152>

● Legal protection of forests

Two site comparison studies in Nigeria and Iran found that legal protection of forest increased tree species richness and diversity or the density of young trees. One replicated, paired site study in Mexico found no effect of forest

protection on seed density and diversity of trees and shrubs. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/1233>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Adopt Protected Species legislation (impact on forest management).

5.10 Habitat restoration and creation

5.10.1 Restoration after wildfire

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for restoration after wildfire?	
Trade-offs between benefit and harms	● Thin trees after wildfire
Unknown effectiveness (limited evidence)	● Remove burned trees
Likely to be ineffective or harmful	● Sow tree seeds after wildfire
No evidence found (no assessment)	● Plant trees after wildfire

Trade-off between benefit and harms

● Thin trees after wildfire

Four of five replicated, controlled studies in Spain, Israel, Canada and the USA found that thinning trees in burnt forest areas increased plant species richness, cover or survival of saplings. One study found thinning decreased plant biomass. One paired-site study in Canada found that logging after wildfire decreased species richness and diversity of mosses. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 50%; harms 38%).*

<http://www.conservationevidence.com/actions/1234>

Unknown effectiveness (limited evidence)

● Remove burned trees

Two replicated, controlled studies in Israel and Spain found that removing burned trees increased total plant species richness or the cover and species richness of some plant species. *Assessment: unknown effectiveness (effectiveness 60%; certainty 20%; harms 25%).*

<http://www.conservationevidence.com/actions/1237>

Likely to be ineffective or harmful

● Sow tree seeds after wildfire

Three studies, including one replicated, randomized, controlled study, in the USA found that sowing herbaceous plant seeds in burnt forest areas decreased the density of tree seedlings or the number and cover of native species. All three found no effect of seeding on total plant cover or species richness. *Assessment: likely to be ineffective or harmful (effectiveness 0%; certainty 43%; harms 40%).*

<http://www.conservationevidence.com/actions/1236>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Plant trees after wildfire

5.10.2 Restoration after agriculture

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for restoration after agriculture?	
Unknown effectiveness (limited evidence)	● Restore wood pasture (e.g. introduce grazing)

Unknown effectiveness (limited evidence)

● **Restore wood pasture (e.g. introduce grazing)**

One replicated paired study in Sweden found that partial harvesting in abandoned wood pastures increased tree seedling density, survival and growth. *Assessment: unknown effectiveness (effectiveness 65%; certainty 25%; harms 0%).*

<http://www.conservationevidence.com/actions/1164>

5.10.3 Manipulate habitat to increase planted tree survival during restoration

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for manipulating habitat to increase planted tree survival during restoration?

Unknown effectiveness (limited evidence)

- Apply herbicides after restoration planting
- Cover the ground using techniques other than plastic mats after restoration planting
- Cover the ground with plastic mats after restoration planting
- Use selective thinning after restoration planting

Unknown effectiveness (limited evidence)

● **Apply herbicides after restoration planting**

One replicated, randomized, controlled study in the USA found that controlling vegetation using herbicides after restoration planting decreased plant species richness and diversity. *Assessment: unknown effectiveness (effectiveness 45%; certainty 25%; harms 40%).*

<http://www.conservationevidence.com/actions/1241>

● **Cover the ground using techniques other than plastic mats after restoration planting**

One replicated, randomized, controlled study in the USA found that covering the ground with mulch after planting increased total plant cover. *Assessment: unknown effectiveness (effectiveness 30%; certainty 15%; harms 10%).*

<http://www.conservationevidence.com/actions/1240>

● **Cover the ground with plastic mats after restoration planting**

One replicated study in Canada found that covering the ground with plastic mats after restoration planting decreased the cover of herbaceous plants and grasses. *Assessment: unknown effectiveness (effectiveness 40%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/1239>

● **Use selective thinning after restoration planting**

One replicated, paired sites study in Canada found that selective thinning after restoration planting conifers increased the abundance of herbaceous species. *Assessment: unknown effectiveness (effectiveness 43%; certainty 18%; harms 0%).*

<http://www.conservationevidence.com/actions/1238>

5.10.4 Restore forest community

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for restoring a forest community?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Build bird-perches to enhance natural seed dispersal ● Plant a mixture of tree species to enhance diversity ● Sow tree seeds ● Water plants to preserve dry tropical forest species
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Restore woodland herbaceous plants using transplants and nursery plugs ● Use rotational grazing to restore oak savannas

Unknown effectiveness (limited evidence)

● Build bird-perches to enhance natural seed dispersal

One replicated, randomized, controlled, before-and-after study in Brazil found that sowing tree seeds increased the density and species richness of new trees. *Assessment: unknown effectiveness (effectiveness 50%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/1245>

● Plant a mixture of tree species to enhance diversity

One replicated, randomized, controlled study in Brazil found that planting various tree species increased species richness, but had no effect on the density of new trees. One replicated, controlled study in Greece found that planting native tree species increased total plant species richness, diversity and cover. *Assessment: unknown effectiveness (effectiveness 50%; certainty 28%; harms 0%).*

<http://www.conservationevidence.com/actions/1243>

● Sow tree seeds

One replicated, randomized, controlled, before-and-after study in Brazil found that sowing tree seeds increased the density and species richness of new trees. *Assessment: unknown effectiveness (effectiveness 60%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/1244>

● Water plants to preserve dry tropical forest species

One replicated, controlled study in Hawaii found that watering plants increased the abundance and biomass of forest plants. *Assessment: unknown effectiveness (effectiveness 65%; certainty 18%; harms 0%).*

<http://www.conservationevidence.com/actions/1242>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restore woodland herbaceous plants using transplants and nursery plugs
- Use rotational grazing to restore oak savannas

5.10.5 Prevent/encourage leaf litter accumulation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for preventing/encouraging leaf litter accumulation?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> Remove or disturb leaf litter to enhance germination
No evidence found (no assessment)	<ul style="list-style-type: none"> Encourage leaf litter development in new planting

Unknown effectiveness (limited evidence)

● Remove or disturb leaf litter to enhance germination

One of two replicated, controlled studies in Poland and Costa Rica found that removing leaf litter increased understory plant species richness. The two studies found that removal decreased understory plant cover or the density of new tree seedlings. *Assessment: unknown effectiveness (effectiveness 40%; certainty 25%; harms 23%).*

<http://www.conservationevidence.com/actions/1246>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Encourage leaf litter development in new planting

5.10.6 Increase soil fertility

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for increasing soil fertility?	
Likely to be beneficial	<ul style="list-style-type: none"> Use vegetation removal together with mechanical disturbance to the soil
Trade-offs between benefit and harms	<ul style="list-style-type: none"> Add organic matter Use fertilizer Use soil scarification or ploughing to enhance germination

Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Add lime to the soil to increase fertility ● Use soil disturbance to enhance germination (excluding scarification or ploughing)
Likely to be ineffective or harmful	<ul style="list-style-type: none"> ● Enhance soil compaction

Likely to be beneficial

● Use vegetation removal together with mechanical disturbance to the soil

Three studies, including one replicated, randomized, controlled study, in Portugal and France found that vegetation removal together with mechanical disturbance of the soil increased the cover or diversity of understory plants, or density of young trees. One of the studies found it decreased understory shrub cover. *Assessment: Likely to be beneficial (effectiveness 61%; certainty 40%; harms 15%).*

<http://www.conservationevidence.com/actions/1274>

Trade-off between benefit and harms

● Add organic matter

One of two studies, including one replicated, randomized, controlled study, in Brazil and Costa Rica found that adding leaf litter increased species richness of young trees. One found it decreased young tree density in artificial forest gaps and both found no effect on the density of tree regenerations under intact forest canopy. One of two replicated, controlled study in Portugal and the USA found that adding plant material increased total plant cover. One found mixed effects on cover depending on plant group. *Assessment: trade-offs between benefits and harms (effectiveness 45%; certainty 43%; harms 28%).*

<http://www.conservationevidence.com/actions/1250>

● Use fertilizer

Six of eight studies, including five replicated, randomized, controlled, in Europe, Brazil, Australia and the USA found that applying fertilizer

increased total plant cover, understory plant biomass, size of young trees, biomass of grasses or cover of artificially seeded plant species. Five of the studies found no effect on plant biomass, cover, seedling abundance, tree growth or tree seedling diversity. *Assessment: trade-offs between benefits and harms (effectiveness 55%; certainty 65%; harms 25%).*

<http://www.conservationevidence.com/actions/1248>

● **Use soil scarification or ploughing to enhance germination**

Two studies, including one replicated, randomized, controlled study, in Portugal and the USA found that ploughing increased the cover or diversity of understory plants. Two of five studies, including two replicated, randomized, controlled, in Canada, Brazil, Ethiopia and Sweden found that ploughing increased the density of young trees. One found a decrease in density and two found mixed effects depending on tree species. One replicated, before-and-after trial in Finland found that ploughing decreased the cover of plants living on wood surface. One replicated, controlled study in the USA found that ploughing did not decrease the spreading distance and density of invasive grass seedlings. *Assessment: unknown effectiveness (effectiveness 60%; certainty 50%; harms 25%).*

<http://www.conservationevidence.com/actions/1251>

Unknown effectiveness (limited evidence)

● **Add lime to the soil to increase fertility**

One replicated, randomized controlled study in the USA found that adding lime increased vegetation cover. *Assessment: unknown effectiveness (effectiveness 80%; certainty 18%; harms 0%).*

<http://www.conservationevidence.com/actions/1249>

● **Use soil disturbance to enhance germination (excluding scarification or ploughing)**

Two replicated, controlled studies in Canada and Finland found that disturbance of the forest floor decreased understory vegetation cover. *Assessment: unknown effectiveness (effectiveness 30%; certainty 35%; harms 40%).*

<http://www.conservationevidence.com/actions/1252>

Likely to be ineffective or harmful

● Enhance soil compaction

Two of three studies, including two replicated, randomized, controlled studies in Canada and the USA found that soil compaction increased understory plant cover and density. Two found it decreased tree regeneration height or density and understory plant species richness. *Assessment: likely to be ineffective or harmful (effectiveness 28%; certainty 40%; harms 45%).*

<http://www.conservationevidence.com/actions/1253>

5.11 Actions to improve survival and growth rate of planted trees

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to improve the survival and growth rate of planted trees?	
Beneficial	<ul style="list-style-type: none"> • Prepare the ground before tree planting • Use mechanical thinning before or after planting
Likely to be beneficial	<ul style="list-style-type: none"> • Fence to prevent grazing after tree planting • Use herbicide after tree planting
Trade-offs between benefit and harms	<ul style="list-style-type: none"> • Use prescribed fire after tree planting
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Apply insecticide to protect seedlings from invertebrates • Add lime to the soil after tree planting • Add organic matter after tree planting • Cover the ground with straw after tree planting • Improve soil quality after tree planting (excluding applying fertilizer) • Manage woody debris before tree planting • Use shading for planted trees • Use tree guards or shelters to protect planted trees • Use weed mats to protect planted trees • Water seedlings
Unlikely to be beneficial	<ul style="list-style-type: none"> • Mechanically remove understory vegetation after tree planting • Use different planting or seeding methods • Use fertilizer after tree planting



<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Apply fungicide to protect seedlings from fungal diseases ● Infect tree seedlings with mycorrhizae ● Introduce leaf litter to forest stands ● Plant a mixture of tree species to enhance the survival and growth of planted trees ● Reduce erosion to increase seedling survival ● Transplant trees ● Use pioneer plants or crops as nurse-plants
---	---

Beneficial

● Prepare the ground before tree planting

Six of seven studies, including five replicated, randomized, controlled studies, in Canada and Sweden found that ground preparation increased the survival or growth rate of planted trees. One study found no effect of creating mounds on frost damage to seedlings. *Assessment: beneficial (effectiveness 78%; certainty 73%; harms 0%).*

<http://www.conservationevidence.com/actions/1263>

● Use mechanical thinning before or after planting

Five of six studies, including two replicated, randomized, controlled studies, in Brazil, Canada, Finland, France and the USA found that thinning trees after planting increased survival or size of planted trees. One study found mixed effects on survival and size and one found it decreased their density. One replicated study in the USA found that seedling survival rate increased with the size of the thinned area. *Assessment: beneficial (effectiveness 75%; certainty 63%; harms 10%).*

<http://www.conservationevidence.com/actions/1261>

Likely to be beneficial

● Fence to prevent grazing after tree planting

Four of five studies, including two replicated, randomized, controlled studies, in Finland, Australia, Canada and the USA found that using fences

to exclude grazing increased the survival, size or cover of planted trees. Two studies found no effect on survival rate and one found mixed effects on planted tree size. *Assessment: Likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/1254>

● Use herbicide after tree planting

Two of three studies, including two replicated, randomized, controlled studies, in Sweden and the USA found that using herbicide increased the size of planted trees. One study found no effect. One replicated, randomized, controlled study in Sweden found no effect of using herbicide on frost damage to seedlings. *Assessment: unlikely to be beneficial (effectiveness 58%; certainty 45%; harms 0%).*

<http://www.conservationevidence.com/actions/1262>

Trade-off between benefit and harms

● Use prescribed fire after tree planting

Two of four studies, including one replicated, randomized, controlled study, in Finland, France and the USA found that using prescribed fire after planting increased the survival and sprouting rate of planted trees. One study found fire decreased planted tree size and one found no effect on the size and survival rate. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 43%; harms 20%).*

<http://www.conservationevidence.com/actions/1255>

Unknown effectiveness (limited evidence)

● Apply insecticide to protect seedlings from invertebrates

One randomized, replicated, controlled study in the USA found that applying insecticide increased tree seedling emergence and survival. *Assessment: unknown effectiveness (effectiveness 70%; certainty 13%; harms 0%).*

<http://www.conservationevidence.com/actions/1149>

● **Add lime to the soil after tree planting**

One of two replicated, randomized, controlled studies in the USA found that adding lime before restoration planting decreased the survival of pine seedlings. One found no effect on seedling growth. *Assessment: unknown effectiveness (effectiveness 0%; certainty 30%; harms 50%).*

<http://www.conservationevidence.com/actions/1259>

● **Add organic matter after tree planting**

Two replicated, randomized, controlled studies in the USA found that adding organic matter before restoration planting increased seedling biomass, but decreased seedling emergence or survival. *Assessment: unknown effectiveness (effectiveness 20%; certainty 25%; harms 50%).*

<http://www.conservationevidence.com/actions/1258>

● **Cover the ground with straw after tree planting**

One replicated, randomized, controlled study in the Czech Republic found that covering the ground with straw, but not bark or fleece, increased the growth rate of planted trees and shrubs. *Assessment: unknown effectiveness (effectiveness 75%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/1266>

● **Improve soil quality after tree planting (excluding applying fertilizer)**

Two randomized, replicated, controlled studies in Australia found that different soil enhancers had mixed or no effects on tree seedling survival and height, and no effect on diameter or health. *Assessment: unknown effectiveness (effectiveness 25%; certainty 23%; harms 13%).*

<http://www.conservationevidence.com/actions/1153>

● **Manage woody debris before tree planting**

One replicated, randomized, controlled study in Canada found that removing woody debris increased the survival rate of planted trees. One replicated, controlled study in the USA found mixed effects on the size of planted trees. *Assessment: unknown effectiveness (effectiveness 40%; certainty 25%; harms 13%).*

<http://www.conservationevidence.com/actions/1257>

● Use shading for planted trees

One replicated, controlled study in Panama found that shading increased the survival rate of planted native tree seedlings. *Assessment: unknown effectiveness (effectiveness 85%; certainty 23%; harms 0%).*

<http://www.conservationevidence.com/actions/1269>

● Use tree guards or shelters to protect planted trees

One replicated, randomized, controlled study in the USA found that using light but not dark coloured plastic tree shelters increased the survival rate of planted tree seedlings. One replicated, controlled study in Hong Kong found that tree guards increased tree height after 37 but not 44 months. *Assessment: unknown effectiveness (effectiveness 60%; certainty 28%; harms 20%).*

<http://www.conservationevidence.com/actions/1268>

● Use weed mats to protect planted trees

One replicated, controlled study in Hong Kong found no effect of using weed mats on seedling height. *Assessment: unknown effectiveness (effectiveness 0%; certainty 18%; harms 0%).*

<http://www.conservationevidence.com/actions/1267>

● Water seedlings

One replicated, randomized, controlled study in Spain found that watering seedlings increased or had no effect on seedling emergence and survival, depending on habitat and water availability. *Assessment: unknown effectiveness (effectiveness 45%; certainty 20%; harms 0%).*

<http://www.conservationevidence.com/actions/1154>

Unlikely to be beneficial

● Mechanically remove understory vegetation after tree planting

Four of five studies, including three replicated, randomized, controlled studies in France, Sweden, Panama, Canada and the USA found no effect of controlling understory vegetation on the emergence, survival, growth rate or frost damage of planted seedlings. One found that removing shrubs

increased the growth rate and height of planted seedlings, and another that removing competing herbs increased seedling biomass. *Assessment: unlikely to be beneficial (effectiveness 20%; certainty 50%; harms 0%).*

<http://www.conservationevidence.com/actions/1256>

● Use different planting or seeding methods

Four studies, including one replicated, randomized study, in Australia, Brazil, Costa Rica and Mexico found no effect of planting or seeding methods on the size and survival rate of seedlings. One replicated, controlled study in Brazil found that planting early succession pioneer tree species decreased the height of other planted species. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 43%; harms 13%).*

<http://www.conservationevidence.com/actions/1264>

● Use fertilizer after tree planting

Two of five studies, including two randomized, replicated, controlled studies, in Canada, Australia, France and Portugal found that applying fertilizer after planting increased the size of the planted trees. Three studies found no effect on the size, survival rate or health of planted trees. One randomized, replicated, controlled study in Australia found that soil enhancers including fertilizer had mixed effects on seedling survival and height. *Assessment: unlikely to be beneficial (effectiveness 38%; certainty 45%; harms 3%).*

<http://www.conservationevidence.com/actions/1260>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Apply fungicide to protect seedlings from fungal diseases
- Infect tree seedlings with mycorrhizae
- Introduce leaf litter to forest stands
- Plant a mixture of tree species to enhance the survival and growth of planted trees
- Reduce erosion to increase seedling survival
- Transplant trees
- Use pioneer plants or crops as nurse-plants.

5.12 Education and awareness raising

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to improve education and awareness raising?

No evidence found (no assessment)

- Provide education programmes about forests
- Raise awareness amongst the general public through campaigns and public information

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide education programmes about forests
- Raise awareness amongst the general public through campaigns and public information.

6. PEATLAND CONSERVATION

Global evidence for the effects of interventions to conserve peatland vegetation

Nigel G. Taylor, Patrick Grillas & William J. Sutherland

Expert assessors

Stephanie Boudreau, Canadian Sphagnum Peat Moss Association, Canada

Emma Goodyer, IUCN UK Peatlands Programme, UK

Laura Graham, Borneo Orangutan Survival Foundation, Indonesia

Richard Lindsay, University of East London, UK

Edgar Karofeld, University of Tartu, Estonia

David Locky, MacEwan University, Canada

Nancy Ockendon, University of Cambridge, UK

Anabel Rial, Independent Consultant & IUCN Species Survival Commission, Colombia

Sarah Ross, Penny Anderson Associates, UK

Nigel Taylor, Tour du Valat, France

Tim Thom, Yorkshire Peat Partnership, UK

Jennie Whinam, University of Tasmania, Australia

Scope of assessment: for the conservation of vegetation in wet peatlands, including bogs, fens, fen meadows and tropical peat swamps. The focus is on overall communities and habitat-defining species, rather than rare species.

Assessed: 2018.

Effectiveness measure is the median % score. How effective is the intervention at conserving peatland vegetation in the collated evidence?

Certainty measure is the median % certainty for the effectiveness score across all peatlands that are appropriate targets of the intervention, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score. Are there any negative side effects of the intervention, on peatland vegetation, in the collated evidence?

Each **effectiveness category** assumes that the aims of the intervention match your management goals. For example, planting trees/shrubs is likely to be beneficial assuming that you want to create forested/shrubby peatland. This might not be a desirable outcome on all peatland types or in all locations.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target habitat for each intervention. The assessment may therefore refer to different habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target habitats or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

6.1 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential/commercial development?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Remove residential or commercial development from peatlands• Retain/create habitat corridors in developed areas

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Remove residential or commercial development from peatlands
- Retain/create habitat corridors in developed areas.

6.2 Threat: Agriculture and aquaculture

6.2.1 Multiple farming systems

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for multiple farming systems?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> Retain/create habitat corridors in farmed areas
No evidence found (no assessment)	<ul style="list-style-type: none"> Implement 'mosaic management' of agriculture

Unknown effectiveness (limited evidence)

● Retain/create habitat corridors in farmed areas

- *Vegetation structure*: One study in Indonesia found that a peat swamp forest corridor contained 5,819 trees/ha: 331 large trees, 1,360 saplings and 4,128 seedlings.
- *Overall plant richness/diversity*: The same study recorded 18–29 tree species (depending on size class) in the peat swamp forest corridor.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 45%; certainty 15%; harms 4%)*. Based on evidence from: tropical peat swamps (one study).

<https://www.conservationevidence.com/actions/1730>



No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Implement 'mosaic management' of agriculture.

6.2.2 Wood and pulp plantations

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for wood and pulp plantations?

Likely to be beneficial	<ul style="list-style-type: none"> • Cut/remove/thin forest plantations • Cut/remove/thin forest plantations and rewet peat
-------------------------	---

Likely to be beneficial

● Cut/remove/thin forest plantations

- *Herb cover*: Three replicated studies (two also paired and controlled) in bogs in the UK and fens in Sweden reported that tree removal increased cover of some herbs, including cottongrasses *Eriophorum* spp. and sedges overall. One of the studies reported no effect on other herb species, including purple moor grass *Molinia caerulea*.
- *Moss cover*: Two replicated studies, in bogs in the UK and a drained rich fen in Sweden, reported that tree removal reduced moss cover after 3–5 years (specifically fen-characteristic mosses or *Sphagnum* moss). However, one replicated, paired, controlled study in partly rewetted rich fens in Sweden reported that tree removal increased *Sphagnum* moss cover after eight years.
- *Overall plant richness/diversity*: Two replicated, paired, controlled studies in rich fens in Sweden reported that tree removal increased total plant species richness, especially in rewetted plots.
- *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 10%). Based on evidence from: fens (three studies); bogs (one study).*

<https://www.conservationevidence.com/actions/1731>

● **Cut/remove/thin forest plantations and rewet peat**

- *Plant community composition*: Of three replicated studies in fens in Finland and Sweden, two found that removing trees/rewetting did not affect the overall plant community composition. One reported only a small effect. Two site comparison studies, in bogs and fens in Finland, found that removing trees/rewetting changed the community composition: it became less like forested/drained sites.
- *Characteristic plants*: Two before-and-after studies (one site comparison, one controlled) in bogs and fens in Finland and Sweden reported that removing trees/rewetting increased the abundance of wetland-characteristic plants.
- *Moss cover*: Five studies (four replicated, three site comparisons) in Sweden and Finland examined the effect of removing trees/rewetting on *Sphagnum* moss cover. Of these, two studies in bogs and fens found that removing trees/rewetting increased *Sphagnum* cover. One study in forested fens found no effect. Two studies in a bog and a fen found mixed effects amongst sites or species. Four studies (three replicated, two paired) in the UK and Finland examined the effect of removing trees/rewetting on other moss cover. Of these, three found that removing trees/rewetting reduced moss cover, but one study in forested fens found no effect.
- *Herb cover*: Seven studies (two replicated, paired, controlled) in bogs and fens in the UK, Finland and Sweden reported that removing trees/rewetting increased cover of at least one group of herbs. This included cottongrasses *Eriophorum* spp. in four of five studies and other/total sedges in three of three studies. One study reported that tree removal/rewetting reduced cover of cottongrass (where it was rare before intervention) and purple moor grass *Molinia caerulea*.
- *Vegetation structure*: One replicated study in a bog in the UK found that removing trees/rewetting increased ground vegetation height, but another in a fen in Sweden reported no effect on canopy height after eight years. Two replicated, paired, site comparison studies in bogs and fens in Finland reported that thinning trees/rewetting reduced the number of tall trees present for 1–3 years after intervention (but not to the level of natural peatlands).

- *Overall plant richness/diversity:* Of four replicated studies in fens in Sweden and Finland, two (also paired and controlled) reported that removing trees/rewetting increased plant species richness. The other two studies found that removing trees/rewetting had no effect on plant species richness or diversity.
- *Assessment: likely to be beneficial (effectiveness 60%; certainty 60%; harms 10%). Based on evidence from: fens (six studies); bogs (two studies); mixed peatlands (three studies).*

<https://www.conservationevidence.com/actions/1732>

6.2.3 Livestock farming and ranching

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for livestock farming and ranching?	
Likely to be beneficial	<ul style="list-style-type: none"> • Exclude or remove livestock from degraded peatlands
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Reduce intensity of livestock grazing
No evidence found (no assessment)	<ul style="list-style-type: none"> • Use barriers to keep livestock off ungrazed peatlands • Change type of livestock • Change season/timing of livestock grazing

Likely to be beneficial

- **Exclude or remove livestock from degraded peatlands**
 - *Plant community composition:* Of two replicated, paired, controlled studies in bogs in the UK, one found that excluding sheep had no effect on the plant community. The other found that excluding sheep only affected the community in drier areas of the bog, favouring plants typically found on dry moorlands.

- *Herb cover*: Seven studies (six replicated, paired, controlled) in bogs and fens in the UK, Australia and the USA found that excluding/removing livestock did not affect cover of key herb groups: cottongrasses *Eriophorum* spp. in five of five studies and true sedges *Carex* spp. in two of two studies. However, one before-and-after study in a poor fen in Spain reported that rush cover increased after cattle were excluded (along with rewetting). One site comparison study in Chile found that excluding livestock, along with other interventions, increased overall herb cover but one replicated, paired, controlled study in bogs in Australia found that excluding livestock had no effect on herb cover.
- *Moss cover*: Five replicated, paired, controlled studies in bogs in the UK and Australia found that excluding livestock typically had no effect on *Sphagnum* moss cover. Three of the studies in the UK also found no effect on cover of other mosses. One before-and-after study in a poor fen in Spain reported that *Sphagnum* moss appeared after excluding cattle (along with rewetting).
- *Tree/shrub cover*: Five replicated, paired, controlled studies in bogs in the UK and Australia found that excluding livestock typically had no effect on shrub cover (specifically heather *Calluna vulgaris* or heathland plants). However, one of these studies found that heather cover increased in drier areas. Three studies (two site comparisons) in bogs in the UK, fens in the USA and a peatland in Chile found that excluding/removing livestock increased shrub cover.
- *Vegetation structure*: One replicated, paired, controlled study in a bog in the UK found that excluding sheep increased total vegetation, shrub and bryophyte biomass, but had no effect on grass-like plants.
- *Assessment: likely to be beneficial (effectiveness 40%; certainty 50%; harms 12%). Based on evidence from: bogs (seven studies); fens (two studies); unspecified peatlands (one study).*

<https://www.conservationevidence.com/actions/1734>



Unknown effectiveness (limited evidence)

● Reduce intensity of livestock grazing

- *Vegetation cover:* One replicated, paired, controlled study in bogs in the UK found greater cover of total vegetation, shrubs and sheathed cottongrass *Eriophorum vaginatum* under lower grazing intensities.
- *Vegetation structure:* The same study found that vascular plant biomass was higher under lower grazing intensities.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 25%; harms 1%). Based on evidence from: bogs (one study).*

<https://www.conservationevidence.com/actions/1735>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use barriers to keep livestock off ungrazed peatlands
- Change type of livestock
- Change season/timing of livestock grazing.

6.3 Threat: Energy production and mining

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for energy production and mining?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Replace blocks of vegetation after mining or peat extraction
No evidence found (no assessment)	<ul style="list-style-type: none"> • Retain/create habitat corridors in areas of energy production or mining

Unknown effectiveness (limited evidence)

● Replace blocks of vegetation after mining or peat extraction

- *Plant community composition*: Two studies, in a bog in the UK and a fen in Canada, reported that transplanted blocks of peatland vegetation retained their overall community composition: over time in the UK, or relative to an undisturbed fen in Canada.
- *Vegetation cover*: One before-and-after study in the UK reported that bare peat next to translocated bog vegetation developed vegetation cover (mainly grasses/rushes). *Sphagnum* moss cover declined in the translocated blocks. One site comparison study in a fen in Canada reported that replaced vegetation blocks retained similar *Sphagnum* and shrub cover to an undisturbed fen.



- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 35%; harms 10%). Based on evidence from: bogs (one study); fens (one study).*

<https://www.conservationevidence.com/actions/1738>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Retain/create habitat corridors in areas of energy production or mining.

6.4 Threat: Transportation and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for transportation and service corridors?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Maintain/restore water flow across service corridors
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Backfill trenches dug for pipelines ● Retain/create habitat corridors across service corridors

Unknown effectiveness (limited evidence)

● Maintain/restore water flow across service corridors

- *Characteristic plants:* One before-and-after study in a fen in the USA found that after restoring water inflow across a road, along with general rewetting, cover of wet peatland sedges increased whilst cover of grasses preferring drier conditions decreased.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 20%; harms 1%). Based on evidence from: fens (one study).*

<https://www.conservationevidence.com/actions/1741>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Backfill trenches dug for pipelines
- Retain/create habitat corridors across service corridors.

6.5 Threat: Biological resource use

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for biological resource use?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Reduce intensity of harvest
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Reduce frequency of harvest ● Use low impact harvesting techniques ● Use low impact vehicles for harvesting ● Implement 'mosaic management' when harvesting wild biological resources ● Provide new technologies to reduce pressure on wild biological resources

Unknown effectiveness (limited evidence)

● Reduce intensity of harvest

- *Moss cover*: One replicated, controlled study in a bog in New Zealand reported that *Sphagnum* moss cover was higher, three years after harvesting, when some *Sphagnum* was left in plots than when it was completely harvested.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 70%; certainty 25%; harms 0%)*. Based on evidence from: bogs (one study).

<https://www.conservationevidence.com/actions/1744>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce frequency of harvest
- Use low impact harvesting techniques
- Use low impact vehicles for harvesting
- Implement 'mosaic management' when harvesting wild biological resources
- Provide new technologies to reduce pressure on wild biological resources.

6.6 Threat: Human intrusions and disturbance

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for human intrusions and disturbance?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Physically exclude vehicles from peatlands
No evidence found (no assessment)	<ul style="list-style-type: none"> • Restrict vehicle use on peatlands • Restrict pedestrian access to peatlands • Physically exclude pedestrians from peatlands • Install boardwalks/paths to prevent trampling • Wear snowshoes to prevent trampling • Adopt ecotourism principles/create an ecotourism site

Unknown effectiveness (limited evidence)

● Physically exclude vehicles from peatlands

- *Vegetation structure:* One replicated, paired, controlled, site comparison study in a floating fen in the USA reported that fencing off airboat trails allowed total and non-woody vegetation biomass to increase, up to levels recorded in undisturbed fen. Woody plant biomass did not recover.
- *Overall plant richness/diversity:* The same study reported that fencing off airboat trails allowed overall plant diversity to increase, recovering to levels recorded in undisturbed fen.

- *Assessment: unknown effectiveness – limited evidence (effectiveness 70%; certainty 35%; harms 0%). Based on evidence from: fens (one study).*

<https://www.conservationevidence.com/actions/1750>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restrict vehicle use on peatlands
- Restrict pedestrian access to peatlands
- Physically exclude pedestrians from peatlands
- Install boardwalks/paths to prevent trampling
- Wear snowshoes to prevent trampling
- Adopt ecotourism principles/create an ecotourism site.

6.7 Threat: Natural system modifications

6.7.1 Modified water management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for modified water management?	
Beneficial	● Rewet peatland (raise water table)
Unknown effectiveness (limited evidence)	● Irrigate peatland
No evidence found (no assessment)	● Reduce water level of flooded peatlands ● Restore natural water level fluctuations

Beneficial

● Rewet peatland (raise water table)

- *Plant community composition:* Ten of thirteen studies reported that rewetting affected the overall plant community composition. Six before-and-after studies (four also replicated) in peatlands in Finland, Hungary, Sweden, Poland and Germany reported development of wetland- or peatland-characteristic communities following rewetting. One replicated, paired, controlled study in the Czech Republic found differences between rewetted and drained parts of a bog. Three site comparison studies in Finland and Canada reported differences between rewetted and natural peatlands. In contrast,

three replicated studies in peatlands in the UK and fens in Germany reported that rewetting typically had no effect, or insignificant effects, on the plant community.

- *Characteristic plants*: Five studies (including one replicated site comparison) in peatlands in Canada, the UK, China and Poland reported that rewetting, sometimes along with other interventions, increased the abundance of wetland- or peatland-characteristic plants. Two replicated site comparison studies, in fens and fen meadows in Europe, found that rewetting reduced the number of fen-characteristic plant species. Two studies (one replicated, paired, controlled, before-and-after) in fens in Sweden reported that rewetting had no effect on cover of fen-characteristic plants.
- *Moss cover*: Twelve studies (two replicated, paired, controlled) in peatlands in Europe and Canada reported that rewetting, sometimes along with other interventions, increased *Sphagnum* moss cover or abundance. However two replicated studies, in bogs in Latvia and forested fens in Finland, reported that rewetting did not affect *Sphagnum* cover. Five studies (one paired, controlled, before-and-after) in bogs and fens in Finland, Sweden and Canada reported that rewetting did not affect cover of non-*Sphagnum* mosses/lichens. However two controlled studies, in bogs in Ireland and the UK, reported that rewetting reduced cover of non-*Sphagnum* bryophytes. One study in Finland reported similar moss cover in rewetted and natural peatlands, but one study in Canada reported that a rewetted bog had lower moss cover than target peatlands.
- *Herb cover*: Twenty-one studies (four replicated, paired, controlled) reported that rewetting, sometimes along with other interventions, increased cover of at least one group of herbs: reeds/rushes in five of seven studies, cottongrasses *Eriophorum* spp. in eight of nine studies, and other/total sedges in 13 of 15 studies. The studies were in bogs, fens or other peatlands in Europe, North America and China. Of four before-and-after studies in peatlands in the UK and Sweden, three reported that rewetting reduced cover of purple moor grass *Molinia caerulea* but one reported no effect. One replicated site comparison study, in forested fens in Finland, reported that rewetting had no effect on total herb cover. Two site comparison studies in Europe



reported that rewetted peatlands had greater herb cover (total or sedges/rushes) than natural peatlands.

- *Tree/shrub cover*: Ten studies (two paired and controlled) in peatlands in Finland, the UK, Germany, Latvia and Canada reported that rewetting typically reduced or had no effect on tree and/or shrub cover. Two before-and-after studies in fens in Sweden and Germany reported that tree/shrub cover increased following rewetting. One before-and-after study in a bog in the UK reported mixed effects of rewetting on different tree/shrub species.
- *Overall vegetation cover*: Of four before-and-after studies (including three controlled), two in bogs in Ireland and Sweden reported that rewetting increased overall vegetation cover. One study in a fen in New Zealand reported that rewetting reduced vegetation cover. One study in a peatland in Finland reported no effect.
- *Overall plant richness/diversity*: Six studies (including one replicated, paired, controlled, before-and-after) in Sweden, Germany and the UK reported that rewetting increased total plant species richness or diversity in peatlands. However, five studies found no effect: in bogs in the Czech Republic and Latvia, fens in Sweden and Germany, and forested fens in Finland. One study in fen meadows in the Netherlands found scale-dependent effects. One paired, controlled, before-and-after study in a peatland in Finland reported that rewetting reduced plant diversity. Of four studies that compared rewetted and natural peatlands, two in Finland and Germany reported lower species richness in rewetted peatlands, one in Sweden found higher species richness in rewetted fens, and one in Europe found similar richness in rewetted and natural fens.
- *Growth*: One replicated site comparison study, in forested fens in Finland, found that rewetting increased *Sphagnum* moss growth to natural levels.
- *Assessment: beneficial (effectiveness 80%; certainty 80%; harms 10%). Based on evidence from: bogs (fifteen studies); fens (fourteen studies); fen meadows (one study); mixed or unspecified peatlands (six studies).*

<https://www.conservationevidence.com/actions/1756>

Unknown effectiveness (limited evidence)

● **Irrigate peatland**

- *Vegetation cover:* One replicated, paired, controlled, before-and-after study in a bog in Canada found that irrigation increased the number of *Sphagnum* moss shoots present after one growing season, but had no effect after two. One before-and-after study in Germany reported that an irrigated fen was colonized by wetland- and fen-characteristic herbs, whilst cover of dryland grasses decreased.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 55%; certainty 30%; harms 1%). Based on evidence from: bogs (one study); fens (one study).*

<https://www.conservationevidence.com/actions/1859>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce water level of flooded peatlands
- Restore natural water level fluctuations.

6.7.2 Modified vegetation management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for modified vegetation management?	
Likely to be beneficial	<ul style="list-style-type: none"> • Cut/mow herbaceous plants to maintain or restore disturbance • Cut large trees/shrubs to maintain or restore disturbance
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Use grazing to maintain or restore disturbance
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Remove plant litter to maintain or restore disturbance • Use prescribed fire to maintain or restore disturbance



Likely to be beneficial

● Cut/mow herbaceous plants to maintain or restore disturbance

- *Plant community composition*: Six replicated studies in fens and fen meadows in the UK, Belgium, Germany and the Czech Republic reported that mowing altered the overall plant community composition (vs no mowing, before mowing or grazing). One site comparison study in Poland reported that mowing a degraded fen, along with other interventions, made the plant community more similar to target fen meadow vegetation.
- *Characteristic plants*: Four studies (including one replicated, paired, controlled, before-and-after) in fens and fen meadows in Switzerland, Germany, the Czech Republic and Poland found that cutting/mowing increased cover of fen meadow- or wet meadow-characteristic plants. One replicated before-and-after study, in fens in the UK, found that a single mow typically did not affect cover of fen-characteristic plants. In Poland and the UK, the effect of mowing was not separated from the effects of other interventions.
- *Moss cover*: Four replicated, paired studies (three also controlled) in fens and fen meadows in Belgium, Switzerland and the Czech Republic found that mowing increased total moss or bryophyte cover. Two replicated studies (one also controlled) in fens in Poland and the UK found that a single mow typically had no effect on bryophyte cover (total or hollow-adapted mosses).
- *Herb cover*: Six replicated studies (three also randomized and controlled) in fens and fen meadows in Belgium, Germany, Poland and the UK found that mowing reduced cover or abundance of at least one group of herbs (including bindweed *Calystegia sepium*, purple moor grass *Molinia caerulea*, reeds, sedges, and grass-like plants overall). One before-and-after study in a fen in Poland found that mowing, along with other interventions, increased sedge cover. One replicated, randomized, paired, controlled study in fen meadows in Switzerland found that mowing had no effect on overall herb cover.

- *Tree/shrub cover*: Of three replicated studies in fens, two in the UK found that a single mow, sometimes along with other interventions, reduced overall shrub cover. The other study, in Poland, found that a single mow had no effect on overall shrub cover.
- *Vegetation structure*: In the following studies, vegetation structure was measured 6–12 months after the most recent cut/mow. Three replicated studies in fens in Poland and the UK reported that a single mow, sometimes along with other interventions, had no (or no consistent) effect on vegetation height. One replicated, paired, site comparison study in fen meadows in Switzerland found that mowing reduced vegetation height. Three studies in fen meadows in Switzerland, Poland and Italy found mixed effects of mowing on vegetation biomass (total, moss, sedge/rush, or common reed *Phragmites australis*). One replicated, paired, site comparison study in Germany reported that vegetation structure was similar in mown and grazed fen meadows.
- *Overall plant richness/diversity*: Eight studies in fens and fen meadows in the UK, Belgium, Switzerland, Germany, the Czech Republic and Poland found that mowing/cutting increased plant species richness (vs no mowing, before mowing or grazing). Three studies (two replicated, randomized, paired, controlled) in fens in Poland and the UK found that a single mow, sometimes along with other interventions, typically did not affect plant richness/diversity.
- *Assessment: likely to be beneficial (effectiveness 70%; certainty 60%; harms 10%). Based on evidence from: fens (seven studies); fen meadows (seven studies).*

<https://www.conservationevidence.com/actions/1759>

● **Cut large trees/shrubs to maintain or restore disturbance**

- *Plant community composition*: One study in a fen in Poland found that where shrubs were removed, along with other interventions, the plant community became more like a target fen meadow over time.
- *Characteristic plants*: One study in a fen in Poland found that where shrubs were removed, along with other interventions, the abundance of fen meadow plant species increased over time.



- *Vegetation cover*: One replicated, paired, controlled study in a forested fen in the USA found that cutting and removing trees increased herb cover, but did not affect shrub cover.
- *Vegetation structure*: One replicated, paired, controlled study in a forested fen in the USA found that cutting and removing trees increased herb biomass and height.
- *Assessment*: likely to be beneficial (effectiveness 60%; certainty 45%; harms 5%). Based on evidence from: fens (two studies).

<https://www.conservationevidence.com/actions/1761>

Trade-off between benefit and harms

● Use grazing to maintain or restore disturbance

- *Plant community composition*: One replicated, paired, site comparison study in Germany found that the overall plant community composition differed between grazed and mown fen meadows.
- *Characteristic plants*: One replicated, paired, controlled study in Germany reported that the abundance of bog/fen-characteristic plants was similar in grazed and ungrazed fen meadows. One replicated before-and-after study, in a fen in the UK, reported that cover of fen-characteristic mosses did not change after grazers were introduced. One replicated, paired, site comparison study in Germany found that grazed fen meadows contained fewer fen-characteristic plant species than mown meadows.
- *Herb cover*: Two before-and-after studies in fens in the UK reported that grazing increased cover of some herb species/groups (common cottongrass *Eriophorum angustifolium*, carnation sedge *Carex panicea* or grass-like plants overall). One of the studies found that grazing reduced cover of purple moor grass *Molinia caerulea*, but the other found that grazing typically had no effect on this species.
- *Moss cover*: One replicated before-and-after study, in a fen in the UK, reported that cover of fen-characteristic mosses did not change after grazers were introduced. One controlled, before-and-after study in a fen in the UK found that grazing reduced *Sphagnum* moss cover.

- *Tree/shrub cover*: Of two before-and-after studies in fens in the UK, one found that grazing reduced overall shrub cover but the other found that grazing typically had no effect on overall shrub cover.
- *Overall plant richness/diversity*: Of two before-and-after studies in fens in the UK, one (also controlled) reported that grazing increased plant species richness but the other (also replicated) found that grazing had no effect. One replicated, paired, site comparison study in Germany found that grazed fen meadows contained fewer plant species than mown meadows.
- *Assessment: trade-off between benefit and harms (effectiveness 40%; certainty 40%; harms 25%)*. Based on evidence from: fens (two studies); fen meadows (two studies).

<https://www.conservationevidence.com/actions/1762>

Unknown effectiveness (limited evidence)

● Remove plant litter to maintain or restore disturbance

- *Plant community composition*: Two studies (including one replicated, paired, controlled, before-and-after) in a fen meadow in Germany and a fen in Czech Republic found that removing plant litter did not affect plant community composition.
- *Vegetation cover*: One replicated, paired, controlled, before-and-after study in a fen in the Czech Republic found that removing plant litter did not affect cover of bryophytes or tall moor grass *Molinia arundinacea*.
- *Overall plant richness/diversity*: Of two replicated, controlled studies, one (also randomized) in a fen meadow in Germany reported that removing plant litter increased plant species richness and diversity. The other study (also paired and before-and-after) in a fen in the Czech Republic found that removing litter did not affect vascular plant diversity.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 35%; certainty 38%; harms 7%)*. Based on evidence from: fens (one study); fen meadows (one study).

<https://www.conservationevidence.com/actions/1760>



● Use prescribed fire to maintain or restore disturbance

- *Characteristic plants*: One replicated before-and-after study in a fen in the UK reported that burning, along with other interventions, did not affect cover of fen-characteristic mosses or herbs.
- *Herb cover*: One replicated, controlled study in a fen in the USA reported that burning reduced forb cover and increased sedge/rush cover, but had no effect on grass cover. One replicated before-and-after study in a fen in the UK reported that burning, along with other interventions, reduced grass/sedge/rush cover.
- *Tree/shrub cover*: Two replicated studies in fens in the USA and the UK reported that burning, sometimes along with other interventions, reduced overall tree/shrub cover.
- *Overall plant richness/diversity*: Two replicated, controlled studies in a fen in the USA and a bog in New Zealand found that burning increased plant species richness or diversity. However, one replicated before-and-after study in a fen in the UK reported that burning, along with other interventions, typically had no effect on plant species richness and diversity.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 35%; harms 20%)*. Based on evidence from: fens (two studies); bogs (one study).

<https://www.conservationevidence.com/actions/1763>

6.7.3 Modified wild fire regime

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for modified wild fire regime?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Thin vegetation to prevent wild fires• Rewet peat to prevent wild fires• Build fire breaks• Adopt zero burning policies near peatlands

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Thin vegetation to prevent wild fires
- Rewet peat to prevent wild fires
- Build fire breaks
- Adopt zero burning policies near peatlands.

6.8 Threat: Invasive and other problematic species

This section includes evidence for the effects of interventions on peatland vegetation overall. Studies that only report effects on the target problematic species are, or will be, summarized in separate chapters (like Chapter 10).

6.8.1 All problematic species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for all problematic species?	
No evidence found (no assessment)	• Implement biosecurity measures to prevent introductions of problematic species

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Implement biosecurity measures to prevent introductions of problematic species.

6.8.2 Problematic plants

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for problematic plants?	
Trade-off between benefit and harms	• Use prescribed fire to control problematic plants

<p>Unknown effectiveness (limited evidence)</p>	<ul style="list-style-type: none"> ● Physically remove problematic plants ● Use cutting/mowing to control problematic herbaceous plants ● Change season/timing of cutting/mowing ● Use cutting to control problematic large trees/shrubs ● Use herbicide to control problematic plants ● Introduce an organism to control problematic plants
<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Physically damage problematic plants ● Use grazing to control problematic plants ● Use covers/barriers to control problematic plants

Trade-off between benefit and harms

● Use prescribed fire to control problematic plants

- *Plant community composition*: One replicated, paired, site comparison study in Germany found that the overall plant community composition differed between grazed and mown fen meadows.
- *Moss cover*: One replicated, paired, controlled study in bogs in Germany found that burning increased moss/lichen/bare ground cover in the short term (2–7 months after burning). Three replicated, paired studies in one bog in the UK found that moss cover (including *Sphagnum*) was higher in plots burned more often.
- *Herb cover*: Four replicated, paired studies (two also controlled) in bogs in Germany and the UK examined the effect of prescribed fire on cottongrass *Eriophorum* spp. cover. One found that burning had no effect on cottongrass cover after 2–7 months. One found that burning increased cottongrass cover after 8–18 years. Two reported that cottongrass cover was similar in plots burned every 10 or 20 years. The study in Germany also found that burning reduced cover of purple moor grass *Molinia caerulea* after 2–7 months but had mixed effects, amongst sites, on cover of other grass-like plants and forbs.
- *Tree/shrub cover*: Four replicated, paired studies (two also controlled) in bogs in Germany and the UK found that burning, or burning more often, reduced heather *Calluna vulgaris* cover. Two replicated,

controlled studies in the bogs in Germany and fens in the USA found that burning, sometimes along with other interventions, had no effect on cover of other woody plants.

- *Vegetation structure*: One replicated, paired, controlled study in a bog in the UK found that plots burned more frequently contained more biomass of grass-like plants than plots burned less often, but contained less total vegetation, shrub and bryophyte biomass.
- *Overall plant richness/diversity*: Two replicated, controlled studies in fens in the USA and a bog in the UK found that burning reduced or limited plant species richness. In the USA, burning was carried out along with other interventions.
- *Assessment: trade-off between benefit and harms (effectiveness 45%; certainty 40%; harms 20%)*. Based on evidence from: bogs (five studies); fens (one study).

<https://www.conservationevidence.com/actions/1774>

Unknown effectiveness (limited evidence)

● Physically remove problematic plants

- *Characteristic plants*: One replicated, randomized, controlled study in a fen in Ireland reported that cover of fen-characteristic plants increased after mossy vegetation was removed.
- *Herb cover*: Three replicated, controlled studies in fens in the Netherlands and Ireland reported mixed effects of moss removal on herb cover after 2–5 years. Results varied between species or between sites, and sometimes depended on other treatments applied to plots.
- *Moss cover*: One replicated, randomized, controlled study in a fen in Ireland reported that removing the moss carpet reduced total bryophyte and *Sphagnum* moss cover for three years. Two replicated, controlled, before-and-after studies in fens in the Netherlands reported that removing the moss carpet had no effect on moss cover 2–5 years later in wet plots, but reduced total moss and *Sphagnum* cover in drained plots.
- *Overall plant richness/diversity*: One replicated, controlled, before-and-after study in a fen in the Netherlands reported that removing

moss from a drained area increased plant species richness, but that there was no effect in a wetter area.

- *Assessment: unknown effectiveness – limited evidence (effectiveness 48%; certainty 35%; harms 12%). Based on evidence from: fens (three studies).*

<https://www.conservationevidence.com/actions/1768>

● Use cutting/mowing to control problematic herbaceous plants

- *Plant community composition:* Two replicated, randomized, paired, controlled, before-and-after studies in rich fens in Sweden found that mowing typically did not affect plant community composition. One controlled study in a fen meadow in the UK reported that mown plots developed different communities to unmown plots.
- *Characteristic plants:* One replicated, randomized, paired, controlled, before-and-after study in a fen in Sweden found that mown plots contained more fen-characteristic plant species than unmown plots, although their overall cover did not differ significantly between treatments.
- *Vegetation cover:* Of two replicated, randomized, paired, controlled, before-and-after studies in rich fens in Sweden, one found that mowing had no effect on vascular plant or bryophyte cover over five years. The other study reported that mowing typically increased cover of *Sphagnum* moss and reduced cover of purple moor grass *Molinia caerulea*, but had mixed effects on cover of other plant species.
- *Growth:* One replicated, controlled, before-and-after study in a bog in Estonia found that clipping competing vegetation did not affect *Sphagnum* moss growth.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 35%; harms 10%). Based on evidence from: fens (two studies); fen meadows (one study); bogs (one study).*

<https://www.conservationevidence.com/actions/1770>

● Change season/timing of cutting/mowing

- *Plant community composition:* One replicated, randomized, paired, before-and after study in a fen meadow in the UK reported that changes in plant community composition over time were similar in

spring-, summer- and autumn-mown plots. One study in a peatland in the Netherlands reported that summer- and winter-mown areas developed different plant community types.

- *Overall plant richness/diversity*: One replicated, randomized, paired, before-and after study in a fen meadow in the UK found that plant species richness increased more, over two years, in summer-mown plots than spring- or autumn-mown plots.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 25%; harms 10%)*. Based on evidence from: fen meadows (one study); mixed peatlands (one study).

<https://www.conservationevidence.com/actions/1771>

● Use cutting to control problematic large trees/shrubs

- *Plant community composition*: Two studies (one replicated, controlled, before-and-after) in fens in the USA and Sweden reported that the plant community composition changed after removing trees/shrubs to less like unmanaged fens or more like undegraded, open fen.
- *Characteristic plants*: One study in a fen in Sweden found that species richness and cover of fen-characteristic plants increased after trees/shrubs were removed.
- *Vegetation cover*: One study in a fen in Sweden found that bryophyte and vascular plant cover increased after trees/shrubs were removed. One replicated, controlled, before-and-after study in fens in the USA found that removing shrubs, along with other interventions, could not prevent increases in total woody plant cover over time.
- *Overall plant richness/diversity*: One study in a fen in Sweden found that moss and vascular plant species richness increased after trees/shrubs were removed. However, one replicated, controlled, before-and-after study in fens in the USA found that removing shrubs, along with other interventions, prevented increases in total plant species richness.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 30%; harms 15%)*. Based on evidence from: fens (two studies).

<https://www.conservationevidence.com/actions/1772>

● Use herbicide to control problematic plants

- *Plant community composition*: One replicated, controlled, before-and-after study in fens in the USA found that applying herbicide to shrubs, along with other interventions, changed the overall plant community composition.
- *Tree/shrub cover*: The same study found that applying herbicide to shrubs, along with other interventions, could not prevent increases in total woody plant cover over time.
- *Overall plant richness/diversity*: The same study found that applying herbicide to shrubs, along with other interventions, prevented increases in plant species richness.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 20%; harms 30%). Based on evidence from: fens (one study).*

<https://www.conservationevidence.com/actions/1776>

● Introduce an organism to control problematic plants

- *Plant community composition*: One controlled, before-and-after study in a fen meadow in Belgium found that introducing a parasitic plant altered the plant community composition.
- *Vegetation cover*: The same study found that introducing a parasitic plant reduced cover of the dominant sedge *Carex acuta* but increased moss cover.
- *Overall plant richness/diversity*: The same study found that introducing a parasitic plant increased overall plant species richness.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 20%; harms 15%). Based on evidence from: fen meadows (one study).*

<https://www.conservationevidence.com/actions/1777>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Physically damage problematic plants
- Use grazing to control problematic plants
- Use covers/barriers to control problematic plants.



6.8.3 Problematic animals

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for problematic animals?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> Exclude wild herbivores using physical barriers
No evidence found (no assessment)	<ul style="list-style-type: none"> Control populations of wild herbivores

Unknown effectiveness (limited evidence)

● Exclude wild herbivores using physical barriers

- *Vegetation cover*: One replicated, paired, controlled study in a fen meadow in Poland reported that the effect of boar- and deer exclusion on vascular plant and moss cover depended on other treatments applied to plots.
- *Vegetation structure*: The same study reported that the effect of boar- and deer exclusion on total vegetation biomass depended on other treatments applied to plots.
- *Overall plant richness/diversity*: The same study reported that the effect of boar- and deer exclusion on plant species richness depended on other treatments applied to plots.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 30%; certainty 25%; harms 10%). Based on evidence from: fen meadows (one study).*

<https://www.conservationevidence.com/actions/1860>

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Control populations of wild herbivores.

6.9 Threat: Pollution

6.9.1 Multiple sources of pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for multiple sources of pollution?	
Likely to be beneficial	<ul style="list-style-type: none"> • Divert/replace polluted water source(s)
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Clean waste water before it enters the environment • Slow down input water to allow more time for pollutants to be removed
No evidence found (no assessment)	<ul style="list-style-type: none"> • Retain or create buffer zones between pollution sources and peatlands • Use artificial barriers to prevent pollution entering peatlands • Reduce fertilizer or herbicide use near peatlands • Manage fertilizer or herbicide application near peatlands

Likely to be beneficial

- **Divert/replace polluted water source(s)**
 - *Characteristic plants:* One study in a fen in the Netherlands found that after a nutrient-enriched water source was replaced, along with other interventions to reduce pollution, cover of mosses characteristic of low nutrient levels increased.



- *Vegetation cover:* Two studies in bogs in the UK and Japan reported that after polluting water sources were diverted, sometimes along with other interventions, *Sphagnum* moss cover increased. Both studies reported mixed effects on different species of herbs.
- *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 10%). Based on evidence from: bogs (two studies); fens (one study).*

<https://www.conservationevidence.com/actions/1779>

Unknown effectiveness (limited evidence)

● Clean waste water before it enters the environment

- *Characteristic plants:* One study in the Netherlands found that cleaning water entering a floating fen, along with other interventions to reduce pollution, allowed cover of mosses characteristic of low nutrient levels to increase.
- *Vegetation structure:* The same study found that after the input water began to be cleaned, along with other interventions to reduce pollution, vascular plant biomass decreased.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 25%; harms 0%). Based on evidence from: fens (one study).*

<https://www.conservationevidence.com/actions/1778>

● Slow down input water to allow more time for pollutants to be removed

- *Characteristic plants:* One before-and-after study in a floating fen in the Netherlands found that after input water was rerouted on a longer path, along with other interventions to reduce pollution, cover of mosses characteristic of low nutrient levels increased.
- *Vegetation structure:* The same study found that after the input water was rerouted on a longer path, along with other interventions to reduce pollution, vascular plant biomass decreased.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 5%). Based on evidence from: fens (one study).*

<https://www.conservationevidence.com/actions/1780>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Retain or create buffer zones between pollution sources and peatlands
- Use artificial barriers to prevent pollution entering peatlands
- Reduce fertilizer or herbicide use near peatlands
- Manage fertilizer or herbicide application near peatlands.

6.9.2 Agricultural and aquacultural effluents

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for agricultural/aquacultural effluents?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Convert to organic agriculture or aquaculture near peatlands• Limit the density of livestock on farmland near peatlands• Use biodegradable oil in farming machinery

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Convert to organic agriculture or aquaculture near peatlands
- Limit the density of livestock on farmland near peatlands
- Use biodegradable oil in farming machinery.

6.9.3 Industrial and military effluents

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for industrial and military effluents?	
No evidence found (no assessment)	<ul style="list-style-type: none"> • Remove oil from contaminated peatlands

No evidence found (no assessment)

We have captured no evidence for the following intervention:

- Remove oil from contaminated peatlands.

6.9.4 Airborne pollutants

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for airborne pollutants?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Remove pollutants from waste gases before they enter the environment • Add lime to reduce acidity and/or increase fertility • Drain/replace acidic water

Unknown effectiveness (limited evidence)

● **Remove pollutants from waste gases before they enter the environment**

- *Plant richness/diversity:* One study in bogs in Estonia reported that after dust filters were installed in industrial plants, along with a general reduction in emissions, the number of *Sphagnum* moss species increased but the total number of plant species decreased.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 0%). Based on evidence from: bogs (one study).*

<https://www.conservationevidence.com/actions/1789>

● Add lime to reduce acidity and/or increase fertility

- *Vegetation structure:* One replicated, controlled study in a fen meadow in the Netherlands found that liming increased overall vegetation biomass (mostly velvety bentgrass *Agrostis canina*).
- *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 15%; harms 20%). Based on evidence from: fen meadows (one study).*

<https://www.conservationevidence.com/actions/1790>

● Drain/replace acidic water

- *Vegetation cover:* Two controlled studies in fens in the Netherlands reported that draining acidic water had mixed effects on cover of *Sphagnum* moss and herbs after 4–5 years, depending on the species and whether moss was also removed.
- *Overall plant richness/diversity:* One controlled, before-and-after study in a fen in the Netherlands reported that draining and replacing acidic water increased plant species richness.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 35%; harms 10%). Based on evidence from: fens (two studies).*

<https://www.conservationevidence.com/actions/1791>

6.10 Threat: Climate change and severe weather

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for climate change and severe weather?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Add water to peatlands to compensate for drought• Plant shelter belts to protect peatlands from wind• Build barriers to protect peatlands from the sea• Restore/create peatlands in areas that will be climatically suitable in the future

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Add water to peatlands to compensate for drought
- Plant shelter belts to protect peatlands from wind
- Build barriers to protect peatlands from the sea
- Restore/create peatlands in areas that will be climatically suitable in the future.

6.11 Habitat creation and restoration

Remember, the effectiveness category for each intervention assumes that the aims of the intervention match your management goals. You should consider whether each intervention is necessary and appropriate in your focal peatland.

6.11.1 General habitat creation and restoration

Based on the collated evidence, what is the current assessment of the effectiveness of general habitat creation and restoration interventions?	
Likely to be beneficial	<ul style="list-style-type: none">• Restore/create peatland vegetation (multiple interventions)• Restore/create peatland vegetation using the moss layer transfer technique

Likely to be beneficial

- **Restore/create peatland vegetation (multiple interventions)**
 - *Plant community composition:* One replicated, controlled, before-and-after study in the UK reported that the overall plant community composition differed between restored and unrestored bogs. One replicated, controlled, site comparison study in Estonia found that restored and natural bogs contained more similar plant communities than unrestored and natural bogs. However, one site comparison study in Canada reported that after five years, bogs being restored as fens contained a different plant community to natural fens.



- *Characteristic plants*: One controlled study, in a fen in France, reported that restoration interventions increased cover of fen-characteristic plants.
- *Moss cover*: Five studies (one replicated, paired, controlled, before-and-after) in bogs or other peatlands in the UK, Estonia and Canada found that restoration interventions increased total moss or bryophyte cover. Two studies (one replicated and controlled) in bogs in the Czech Republic and Estonia reported that restoration interventions increased *Sphagnum* moss cover, but one replicated before-and-after study in bogs in the UK reported no change in *Sphagnum* cover following intervention. Two site comparison studies in Canada reported that after 1–15 years, restored areas had lower moss cover than natural fens.
- *Herb cover*: Five studies (one replicated, paired, controlled, before-and-after) in peatlands in the Czech Republic, the UK, Estonia and Canada reported that restoration interventions increased cover of herbs, including cottongrasses *Eriophorum* spp. and other grass-like plants.
- *Overall vegetation cover*: Three studies (one replicated, controlled, before-and-after) in bogs in the UK and France reported that restoration interventions increased overall vegetation cover.
- *Assessment: likely to be beneficial (effectiveness 75%; certainty 60%; harms 5%). Based on evidence from: bogs (six studies); fens (one study); mixed or unspecified peatlands (two studies).*

<https://www.conservationevidence.com/actions/1803>

● Restore/create peatland vegetation using the moss layer transfer technique

- *Plant community composition*: One replicated study in bogs in Canada reported that the majority of restored areas developed a community of bog-characteristic plant species within eleven years. One controlled, before-and-after study in a bog in Canada reported that a restored area (included in the previous study) developed a more peatland-characteristic plant community over time, and relative to an unrestored area.

- *Vegetation cover*: Two controlled studies in one bog in Canada reported that after 4–8 years, a restored area had greater cover than an unrestored area of mosses and bryophytes (including *Sphagnum* spp.) and herbs (including cottongrasses *Eriophorum* spp.), but less cover of shrubs. One of the studies reported that vegetation in the restored area became more similar to local natural bogs.
- *Overall plant richness/diversity*: One controlled, before-and-after study in a bog in Canada reported that after eight years, a restored area contained more plant species than an unrestored area.
- *Assessment: likely to be beneficial (effectiveness 70%; certainty 60%; harms 1%). Based on evidence from: bogs (four studies).*

<https://www.conservationevidence.com/actions/1804>

6.11.2 Modify physical habitat only

Based on the collated evidence, what is the current assessment of the effectiveness of interventions that modify the physical habitat only?	
Likely to be beneficial	<ul style="list-style-type: none"> • Fill/block ditches to create conditions suitable for peatland plants • Remove upper layer of peat/soil
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Excavate pools • Reprofile/relandscape peatland • Disturb peatland surface to encourage growth of desirable plants • Add inorganic fertilizer • Cover peatland with organic mulch • Cover peatland with something other than mulch • Stabilize peatland surface to help plants colonize • Build artificial bird perches to encourage seed dispersal
No evidence found (no assessment)	<ul style="list-style-type: none"> • Roughen peat surface to create microclimates • Bury upper layer of peat/soil • Introduce nurse plants



Likely to be beneficial

● Fill/block ditches to create conditions suitable for peatland plants

- *Vegetation cover:* Two studies, in a bog in the UK and a fen in the USA, reported that blocked or filled ditches were colonized by peatland vegetation within 2–3 years. In the USA, vegetation cover was restored to natural, undisturbed levels. One replicated study in bogs in the UK reported that plants had not colonized blocked gullies after six months.
- *Overall plant richness/diversity:* One site comparison study in a fen in the USA found that after two years, a filled ditch contained more plant species than adjacent undisturbed fen.
- *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 0%). Based on evidence from: bogs (two studies); fens (one study).*

<https://www.conservationevidence.com/actions/1805>

● Remove upper layer of peat/soil

- *Plant community composition:* Five studies (one replicated, randomized, paired, controlled) in a peatland in the USA and fens or fen meadows in the Netherlands and Poland reported that plots stripped of topsoil developed different plant communities to unstripped peatlands. In one study, the effect of stripping was not separated from the effect of rewetting. Two studies in fen meadows in Germany and Poland reported that the depth of soil stripping affected plant community development.
- *Characteristic plants:* Four studies (one replicated, randomized, paired, controlled) in fen meadows in Germany and the Netherlands, and a peatland in the USA, reported that stripping soil increased cover of wetland- or peatland-characteristic plants after 4–13 years. In the Netherlands, the effect of stripping was not separated from the effect of rewetting. One replicated site comparison study in fens in Belgium and the Netherlands found that stripping soil increased fen-characteristic plant richness.

- *Herb cover*: Three studies (one replicated, paired, controlled) in fens or fen meadows in Germany, the UK and Poland found that stripping soil increased rush, reed or sedge cover after 2–6 years. One controlled study in a fen meadow in the Netherlands reported that stripping soil had no effect on cover of true sedges *Carex* spp. or velvety bentgrass *Agrostis canina* after five years. Two controlled studies, in fens or fen meadows in the Netherlands and the UK, found that stripping soil reduced cover of purple moor grass *Molinia caerulea* for 2–5 years.
- *Vegetation structure*: Two studies, in fens or fen meadows in the Netherlands and Belgium, found that stripping soil reduced vegetation biomass (total or herbs) for up to 18 years. One replicated, randomized, paired, controlled study in a peatland in the USA found that stripping soil did not affect vegetation biomass after four years.
- *Overall plant richness/diversity*: Three studies (one replicated, paired, controlled) in fens or fen meadows in the UK, Belgium and the Netherlands reported that stripping soil increased total plant species richness over 2–18 years. In one study, the effect of stripping was not separated from the effect of rewetting. One replicated, controlled study in a fen in Poland found that stripping soil had no effect on plant species richness after three years. One replicated, randomized, paired, controlled study in a peatland in the USA found that stripping soil increased plant species richness and diversity, after four years, in one field but decreased it in another. One replicated study in a fen meadow in Poland reported that plant species richness increased after soil was stripped.
- *Assessment: likely to be beneficial (effectiveness 55%; certainty 50%; harms 10%). Based on evidence from: fen meadows (six studies); fens (three studies); unspecified peatlands (one study).*

<https://www.conservationevidence.com/actions/1809>

Unknown effectiveness (limited evidence)

● Excavate pools

- *Plant community composition*: One replicated, before-and-after, site comparison study in bogs in Canada reported that excavated pools were colonized by some peatland vegetation over 4–6 years, but



contained different plant communities to natural pools. In particular, cattail *Typha latifolia* was more common in created pools.

- *Vegetation cover*: One replicated, before-and-after, site comparison study in bogs in Canada reported that after four years, created pools had less cover than natural pools of *Sphagnum* moss, herbs and shrubs.
- *Overall plant richness/diversity*: One replicated, before-and-after, site comparison study in bogs in Canada reported that after six years, created pools contained a similar number of plant species to natural pools.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 45%; certainty 38%; harms 5%)*. Based on evidence from: bogs (two studies).

<https://www.conservationevidence.com/actions/1806>

● Reprofile/relandscape peatland

- *Plant community composition*: One site comparison study in Canada reported that after five years, reprofiled and rewetted bogs (being restored as fens) contained a different plant community to nearby natural fens.
- *Vegetation cover*: The same study reported that after five years, reprofiled and rewetted bogs (being restored as fens) had lower vegetation cover than nearby natural fens (specifically *Sphagnum* moss, other moss and vascular plants).
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 20%; harms 10%)*. Based on evidence from: bogs (one study).

<https://www.conservationevidence.com/actions/1807>

● Disturb peatland surface to encourage growth of desirable plants

- *Plant community composition*: Two replicated, paired, controlled, before-and-after studies (one also randomized) in fens in Germany and Sweden reported that soil disturbance affected development of the plant community over 2–3 years. In Germany, disturbed plots developed greater cover of weedy species from the seed bank than undisturbed plots. In Sweden, the community in disturbed and undisturbed plots became less similar over time.

- *Characteristic plants:* The same two studies reported that wetland- or fen-characteristic plants colonized plots that had been disturbed (along with other interventions). The study in Germany noted that no peat-forming species colonized the fen.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 45%; certainty 30%; harms 20%). Based on evidence from: fens (two studies).*

<https://www.conservationevidence.com/actions/1811>

● Add inorganic fertilizer

- *Vegetation cover:* One replicated, randomized, paired, controlled, before-and-after study in a bog in New Zealand reported that fertilizing typically increased total vegetation cover.
- *Vegetation structure:* One replicated, paired, controlled study in a fen meadow in the Netherlands found that fertilizing with phosphorous typically increased total above-ground vegetation biomass, but other chemicals typically had no effect.
- *Overall plant richness/diversity:* One replicated, randomized, paired, controlled, before-and-after study in a bog in New Zealand reported that fertilizing typically increased plant species richness.
- *Growth:* One replicated, controlled, before-and-after study in a bog in Germany found that fertilizing with phosphorous typically increased herb and shrub growth rate, but other chemicals had no effect.
- *Other:* Three replicated, controlled studies in a fen meadow in Germany and bogs in Germany and New Zealand reported that effects of fertilizer on peatland vegetation were more common when phosphorous was added, than when nitrogen or potassium were added.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 30%; harms 15%). Based on evidence from: bogs (two studies); fen meadows (one study).*

<https://www.conservationevidence.com/actions/1812>

● Cover peatland with organic mulch

- *Vegetation cover:* One replicated, randomized, paired, controlled, before-and-after study in a bog (being restored as a fen) in Canada found that mulching bare peat did not affect cover of fen-characteristic



plants. One replicated, controlled, before-and-after study in a bog in Australia reported that plots mulched with straw had similar *Sphagnum* moss cover to unmulched plots.

- *Characteristic plants*: One replicated, randomized, paired, controlled, before-and-after study in a bog (being restored as a fen) in Canada found that covering bare peat with straw mulch increased the number of fen characteristic plants, but not their overall cover.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 30%; harms 5%)*. Based on evidence from: bogs (two studies).

<https://www.conservationevidence.com/actions/1813>

● Cover peatland with something other than mulch

- *Vegetation cover*: One replicated, controlled, before-and-after study in a bog in Germany reported that covering bare peat with fleece or fibre mats did not affect the number of seedlings of five herb/shrub species. One replicated, controlled, before-and-after study in bogs in Australia reported that recently-burned plots shaded with plastic mesh developed greater cover of native plants, forbs and *Sphagnum* moss than unshaded plots.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 30%; harms 5%)*. Based on evidence from: bogs (two studies).

<https://www.conservationevidence.com/actions/1814>

● Stabilize peatland surface to help plants colonize

- *Vegetation cover*: One controlled, before-and-after study in a bog in the UK found that pegging coconut fibre rolls onto almost-bare peat did not affect the development of vegetation cover (total, mosses, shrubs or common cottongrass *Eriophorum angustifolium*).
- *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 20%; harms 5%)*. Based on evidence from: bogs (one study).

<https://www.conservationevidence.com/actions/1815>

● Build artificial bird perches to encourage seed dispersal

- *Vegetation cover*: One replicated, paired, controlled study in a peat swamp forest in Indonesia found that artificial bird perches had no significant effect on tree seedling abundance.

- *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 20%; harms 1%). Based on evidence from: tropical peat swamps (one study).*

<https://www.conservationevidence.com/actions/1817>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Roughen peat surface to create microclimates
- Bury upper layer of peat/soil
- Introduce nurse plants.

6.11.3 Introduce peatland vegetation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions that introduce peatland vegetation?	
Beneficial	<ul style="list-style-type: none"> • Add mosses to peatland surface • Add mixed vegetation to peatland surface
Likely to be beneficial	<ul style="list-style-type: none"> • Directly plant peatland mosses • Directly plant peatland herbs • Directly plant peatland trees/shrubs • Introduce seeds of peatland herbs • Introduce seeds of peatland trees/shrubs

Beneficial

● Add mosses to peatland surface

- *Sphagnum moss cover*: Eleven studies in bogs in the UK, Canada, Finland and Germany and fens in the USA reported that *Sphagnum* moss was present, after 1–4 growing seasons, in at least some plots sown with *Sphagnum*. Cover ranged from negligible to >90%. Six of these studies were controlled and found that there was more *Sphagnum* in sown than unsown plots. One additional study in Canada found that adding *Sphagnum* to bog pools did not affect *Sphagnum* cover.



- *Other moss cover*: Four studies (including one replicated, randomized, paired, controlled, before-and-after) in bogs in Canada and fens in Sweden and the USA reported that mosses other than *Sphagnum* were present, after 2–3 growing seasons, in at least some plots sown with moss fragments. Cover ranged from negligible to 76%. In the fens in Sweden and the USA, moss cover was low (<1%) unless the plots were mulched, shaded or limed.
- *Assessment: beneficial* (effectiveness 78%; certainty 70%; harms 1%).
Based on evidence from: bogs (eleven studies); fens (two studies).

<https://www.conservationevidence.com/actions/1821>

● Add mixed vegetation to peatland surface

- *Characteristic plants*: One replicated, randomized, paired, controlled, before-and-after study in a degraded bog (being restored as a fen) in Canada found that adding fen vegetation increased the number and cover of fen-characteristic plant species.
- *Sphagnum moss cover*: Seventeen replicated studies (five also randomized, paired, controlled, before-and-after) in bogs in Canada, the USA and Estonia reported that *Sphagnum* moss was present, after 1–6 growing seasons, in at least some plots sown with vegetation containing *Sphagnum*. Cover ranged from <1 to 73%. Six of the studies were controlled and found that *Sphagnum* cover was higher in sown than unsown plots. Five of the studies reported that *Sphagnum* cover was very low (<1%) unless plots were mulched after spreading fragments.
- *Other moss cover*: Eight replicated studies (seven before-and-after, one controlled) in bogs in Canada, the USA and Estonia reported that mosses or bryophytes other than *Sphagnum* were present, after 1–6 growing seasons, in at least some plots sown with mixed peatland vegetation. Cover ranged from <1 to 65%.
- *Vascular plant cover*: Ten replicated studies in Canada, the USA and Estonia reported that vascular plants appeared following addition of mixed vegetation fragments to bogs. Two of the studies were controlled: one found that vascular plant cover was significantly higher in sown than unsown plots, but one found that sowing peatland vegetation did not affect herb cover.

- *Assessment: beneficial (effectiveness 78%; certainty 68%; harms 1%). Based on evidence from: bogs (eighteen studies).*

<https://www.conservationevidence.com/actions/1822>

Likely to be beneficial

● Directly plant peatland mosses

- *Survival:* One study in Lithuania reported that 47 of 50 *Sphagnum*-dominated sods planted into a rewetted bog survived for one year.
- *Growth:* Two before-and-after studies, in a fen in the Netherlands and bog pools in the UK, reported that mosses grew after planting.
- *Moss cover:* Five before-and-after studies in a fen in the Netherlands and bogs in Germany, Ireland, Estonia and Australia reported that after planting mosses, the area covered by moss increased in at least some cases. The study in the Netherlands reported spread of planted moss beyond the introduction site. The study in Australia was controlled and reported that planted plots developed greater *Sphagnum* moss cover than unplanted plots.
- *Assessment: likely to be beneficial (effectiveness 75%; certainty 60%; harms 0%). Based on evidence from: bogs (six studies); fens (one study).*

<https://www.conservationevidence.com/actions/1818>

● Directly plant peatland herbs

- *Survival:* Three replicated studies, in a fen meadow in the Netherlands and fens in the USA, reported that planted herbs survived over 2–3 years. However, for six of nine species only a minority of individuals survived.
- *Growth:* Two replicated before-and-after studies, in a bog in Germany and fens in the USA, reported that planted herbs grew.
- *Vegetation cover:* One replicated, controlled, before-and-after study in Canada found that planting herbs had no effect on moss, herb or shrub cover in created bog pools relative to natural colonization.
- *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%). Based on evidence from: bogs (two studies); fens (two studies); fen meadows (one study).*

<https://www.conservationevidence.com/actions/1819>



● Directly plant peatland trees/shrubs

- *Survival*: Eight studies (seven replicated) in peat swamp forests in Thailand, Malaysia and Indonesia and bogs in Canada reported that the majority of planted trees/shrubs survived over periods between 10 weeks and 13 years. One study in a peat swamp forest in Indonesia reported <5% survival of planted trees after five months, following unusually deep flooding. One replicated study in a fen in the USA reported that most planted willow *Salix* spp. cuttings died within two years.
- *Growth*: Four studies (including two replicated, before-and-after) in peat swamp forests in Thailand, Indonesia and Malaysia reported that planted trees grew. One replicated before-and-after study in bogs in Canada reported that planted shrubs grew.
- *Assessment*: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%). Based on evidence from: tropical peat swamps (seven studies); bogs (three studies); fens (one study).

<https://www.conservationevidence.com/actions/1820>

● Introduce seeds of peatland herbs

- *Germination*: Two replicated studies (one also controlled, before-and-after) reported that some planted herb seeds germinated. In a bog in Germany three of four species germinated, but in a fen in the USA only one of seven species germinated.
- *Characteristic plants*: Three studies (two controlled) in fen meadows in Germany and a peatland in China reported that wetland-characteristic or peatland-characteristic plants colonized plots where herb seeds were sown (sometimes along with other interventions).
- *Herb cover*: Three before-and-after studies (one also replicated, randomized, paired, controlled) in a bog in New Zealand, fen meadows in Switzerland and a peatland in China reported that plots sown with herb seeds developed cover of the sown herbs (and, in New Zealand, greater cover than unsown plots). In China, the effect of sowing was not separated from the effects of other interventions. One replicated, randomized, paired, controlled study in a fen in the USA found that plots sown with herb (and shrub) seeds developed similar herb cover to plots that were not sown.

- *Overall vegetation cover:* Of three replicated, controlled studies, one in a fen in the USA found that sowing herb (and shrub) seeds increased total vegetation cover. One study in a bog in New Zealand found that sowing herb seeds had no effect on total vegetation cover. One study in a fen meadow in Poland found that the effect of adding seed-rich hay depended on other treatments applied to plots.
- *Overall plant richness/diversity:* Two replicated, controlled studies in fens in the USA and Poland found that sowing herb seeds had no effect on plant species richness (total or vascular). Two replicated, controlled, before-and-after studies in a bog in New Zealand and a fen meadow in Poland each reported inconsistent effects of herb sowing on total plant species richness.
- *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 0%). Based on evidence from: fen meadows (four studies); fens (three studies); bogs (two studies); unspecified peatlands (one study).*

<https://www.conservationevidence.com/actions/1823>

● Introduce seeds of peatland trees/shrubs

- *Germination:* Two replicated studies in a bog in Germany and a fen in the USA reported germination of heather *Calluna vulgaris* and hoary willow *Salix candida* seeds, respectively, in at least some sown plots.
- *Survival:* The study in the bog Germany reported survival of some heather seedlings over two years. The study in the fen in the USA reported that all germinated willow seedlings died within one month.
- *Shrub cover:* Two studies (one replicated, randomized, paired, controlled) in bogs in New Zealand and Estonia reported that plots sown with shrub seeds, sometimes along with other interventions, developed greater cover of some shrubs than plots that were not sown: sown manuka *Leptospermum scoparium* or naturally colonizing heather *Calluna vulgaris* (but not sown cranberry *Oxycoccus palustris*). One replicated, randomized, paired, controlled study in a fen in the USA found that plots sown with shrub (and herb) seeds developed similar overall shrub cover to unsown plots within two years.
- *Overall vegetation cover:* Two replicated, randomized, paired, controlled studies in a bog in New Zealand and a fen in the USA



reported that plots sown with shrub (and herb) seeds developed greater total vegetation cover than unsown plots after two years. One site comparison study in bogs in Estonia reported that sowing shrub seeds, along with fertilization, had no effect on total vegetation cover after 25 years.

- *Overall plant richness/diversity:* One site comparison study in bogs in Estonia reported that sowing shrub seeds, along with fertilization, increased plant species richness. However, one replicated, randomized, paired, controlled study in a bog in New Zealand reported that plots sown with shrub seeds typically contained fewer plant species than plots that were not sown. One replicated, randomized, paired, controlled study in a fen in the USA found that sowing shrub (and herb) seeds had no effect on plant species richness.
- *Assessment: likely to be beneficial (effectiveness 45%; certainty 40%; harms 5%). Based on evidence from: bogs (three studies); fens (two studies).*

<https://www.conservationevidence.com/actions/1824>

6.12 Actions to complement planting

Based on the collated evidence, what is the current assessment of the effectiveness of actions to complement planting peatland vegetation?	
Likely to be beneficial	<ul style="list-style-type: none"> • Cover peatland with organic mulch (after planting) • Cover peatland with something other than mulch (after planting) • Reprofile/relandscape peatland (before planting)
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Add inorganic fertilizer (before/after planting)
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Introduce nurse plants (to aid focal peatland plants) • Irrigate peatland (before/after planting) • Create mounds or hollows (before planting) • Add fresh peat to peatland (before planting) • Remove vegetation that could compete with planted peatland vegetation • Add root-associated fungi to plants (before planting)
Likely to be ineffective or harmful	<ul style="list-style-type: none"> • Add lime (before/after planting)
No evidence found (no assessment)	<ul style="list-style-type: none"> • Add organic fertilizer (before/after planting) • Rewet peatland (before/after planting) • Remove upper layer of peat/soil (before planting) • Bury upper layer of peat/soil (before planting) • Encapsulate planted moss fragments in beads/gel • Use fences or barriers to protect planted vegetation • Protect or prepare vegetation before planting (other interventions)



Likely to be beneficial

● Cover peatland with organic mulch (after planting)

- *Germination*: One replicated, controlled, before-and-after study in a bog in Germany found that mulching after sowing seeds increased germination of two species (a grass and a shrub), but had no effect on three other herb species.
- *Survival*: Two replicated, paired, controlled studies in a fen in Sweden and a bog in the USA reported that mulching increased survival of planted vegetation (mosses or sedges). One replicated, paired, controlled study in Indonesia reported that mulching with oil palm fruits reduced survival of planted peat swamp tree seedlings.
- *Growth*: One replicated, randomized, paired, controlled, before-and-after study in a fen in the USA reported that mulching increased growth of transplanted water sedge *Carex aquatilis*.
- *Cover*: Six studies (including four replicated, randomized, paired, controlled, before-and-after) in bogs in Canada and the USA, and a fen in Sweden, found that mulching after planting increased vegetation cover (specifically total vegetation, total mosses/bryophytes, *Sphagnum* mosses or vascular plants after 1–3 growing seasons). Three replicated, randomized, paired, controlled, before-and-after studies in bogs in Canada found that mulching after planting had no effect on vegetation cover (*Sphagnum* mosses or fen-characteristic plants).
- *Assessment*: likely to be beneficial (effectiveness 60%; certainty 60%; harms 10%). Based on evidence from: bogs (nine studies); fens (two studies); tropical peat swamps (one study).

<https://www.conservationevidence.com/actions/1828>

● Cover peatland with something other than mulch (after planting)

- *Germination*: One replicated, controlled, before-and-after study in a bog in Germany reported mixed effects of fleece and fibre mats on germination of sown herb and shrub seeds (positive or no effect, depending on species).

- *Survival*: Two replicated, randomized, controlled studies examined the effect, on plant survival, of covering planted areas. One study in a fen in Sweden reported that shading increased survival of planted mosses. One study in a nursery in Indonesia reported that shading did not affect survival of most studied peat swamp tree species, but increased survival of some.
- *Growth*: Three replicated, randomized, controlled, before-and-after studies examined the effect, on plant growth, of covering planted areas. One study in a greenhouse in Switzerland found that covers, either transparent plastic or shading mesh, increased growth of planted *Sphagnum* moss. One study in a fen in Sweden found that shading with plastic mesh reduced growth of planted fen mosses. One study in a nursery in Indonesia reported that seedlings shaded with plastic mesh grew taller and thinner than unshaded seedlings.
- *Cover*: Two replicated and paired studies, in a fen in Sweden and a bog in Australia, reported that shading plots with plastic mesh increased planted moss cover. One study in a bog in Canada found that covering sown plots with plastic mesh, but not transparent sheets, increased *Sphagnum* moss abundance. Another study in a bog in Canada reported that shading sown plots with plastic mesh did not affect cover of vegetation overall, vascular plants or mosses.
- *Assessment*: likely to be beneficial (effectiveness 50%; certainty 50%; harms 10%). Based on evidence from: bogs (five studies); fens (two studies); tropical peat swamps (one study).

<https://www.conservationevidence.com/actions/1829>

● Reprofile/relandscape peatland (before planting)

- *Survival*: One replicated, paired, controlled study in a bog in Canada found that over one growing season, survival of sown *Sphagnum* mosses was higher in reprofiled basins than on raised plots.
- *Cover*: Two replicated, controlled, before-and-after studies in bogs in Canada found that reprofiled basins had higher *Sphagnum* cover than raised plots, 3–4 growing seasons after sowing *Sphagnum*-dominated vegetation fragments. One controlled study in a bog in Estonia reported that reprofiled and raised plots had similar *Sphagnum* cover, 1–2 years after sowing. All three studies found that

reprofiled and raised plots developed similar cover of other mosses/ bryophytes and vascular plants.

- *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 5%). Based on evidence from: bogs (four studies).*

<https://www.conservationevidence.com/actions/1833>

Trade-off between benefit and harms

● Add inorganic fertilizer (before/after planting)

- *Survival:* Two replicated, randomized, paired, controlled studies in bogs in Canada examined the effect, on plant survival, of adding inorganic fertilizer to areas planted with peatland plants. One study reported that fertilizer increased survival of two planted tree species. The other study found that fertilizer had no effect on three planted tree species and reduced survival of one.
- *Growth:* Five studies (three replicated, randomized, paired, controlled) in bogs in the UK, Germany and Canada found that fertilizer typically increased growth of planted mosses, herbs or trees. However, for some species or in some conditions, fertilizer had no effect on growth. One replicated, randomized, controlled, before-and-after study in a nursery in Indonesia found that fertilizer typically had no effect on growth of peat swamp tree seedlings.
- *Cover:* Three replicated, randomized, paired, controlled studies in bogs examined the effect, on vegetation cover, of adding inorganic fertilizer to areas planted with peatland plants. One study in Canada found that fertilizer increased total vegetation, vascular plant and bryophyte cover. Another study in Canada found that fertilizer increased cover of true sedges *Carex* spp. but had no effect on other vegetation. One study in New Zealand reported that fertilizer typically increased cover of a sown shrub and rush, but this depended on the chemical used and preparation of the peat.
- *Assessment: trade-off between benefit and harms (effectiveness 45%; certainty 40%; harms 20%). Based on evidence from: bogs (eight studies); tropical peat swamps (one study).*

<https://www.conservationevidence.com/actions/1826>

Unknown effectiveness (limited evidence)

● Introduce nurse plants (to aid focal peatland plants)

- *Survival*: One replicated, paired, controlled study in Malaysia reported that planting nurse trees did not affect survival of planted peat swamp tree seedlings (averaged across six species).
- *Cover*: Two replicated, randomized, paired, controlled, before-and-after studies in bogs in the USA and Canada found that planting nurse herbs had no effect on cover, after 2–3 years, of other planted vegetation (mosses/bryophytes, vascular plants or total cover).
- *Assessment*: unknown effectiveness – limited evidence (effectiveness 30%; certainty 38%; harms 1%). Based on evidence from: bogs (two studies); tropical peat swamps (one study).

<https://www.conservationevidence.com/actions/1830>

● Irrigate peatland (before/after planting)

- *Cover*: One replicated, paired, controlled, before-and-after study in a bog in Canada found that irrigation increased the number of *Sphagnum* moss shoots present 1–2 growing seasons after sowing *Sphagnum* fragments.
- *Assessment*: unknown effectiveness – limited evidence (effectiveness 60%; certainty 20%; harms 5%). Based on evidence from: bogs (one study).

<https://www.conservationevidence.com/actions/1832>

● Create mounds or hollows (before planting)

- *Growth*: One controlled study, in a peat swamp in Thailand, reported that trees planted into mounds of peat grew thicker stems than trees planted at ground level.
- *Cover*: Two replicated, randomized, paired, controlled, before-and-after studies in bogs in Canada found that roughening the peat surface (e.g. by harrowing or adding peat blocks) did not significantly affect cover of planted *Sphagnum* moss, after 1–3 growing seasons.
- *Assessment*: unknown effectiveness – limited evidence (effectiveness 30%; certainty 38%; harms 5%). Based on evidence from: bogs (two studies); tropical peat swamps (one study).

<https://www.conservationevidence.com/actions/1834>



● Add fresh peat to peatland (before planting)

- *Cover*: One replicated, controlled, before-and-after study in New Zealand reported that plots amended with fine peat supported higher cover of two sown plant species than the original (tilled) bog surface.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 45%; certainty 25%; harms 5%)*. Based on evidence from: bogs (one study).

<https://www.conservationevidence.com/actions/1837>

● Remove vegetation that could compete with planted peatland vegetation

- *Survival*: One controlled study in a bog the UK reported that some *Sphagnum* moss survived when sown, in gel beads, into a plot where purple moor grass *Molinia caerulea* had previously been cut. No moss survived in a plot where grass had not been cut.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 20%; harms 2%)*. Based on evidence from: bogs (one study).

<https://www.conservationevidence.com/actions/1840>

● Add root-associated fungi to plants (before planting)

- *Survival*: Two controlled studies (one also replicated, paired, before-and-after) in peat swamps in Indonesia found that adding root fungi did not affect survival of planted red balau *Shorea balangeran* or jelutong *Dyera polyphylla* in all or most cases. However, one fungal treatment increased red balau survival.
- *Growth*: Two replicated, controlled, before-and-after studies of peat swamp trees in Indonesia found that adding root fungi to seedlings, before planting, typically had no effect on their growth. However, one controlled study in Indonesia found that adding root fungi increased growth of red balau seedlings.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 30%; certainty 35%; harms 0%)*. Based on evidence from: tropical peat swamps (three studies).

<https://www.conservationevidence.com/actions/1841>

Likely to be ineffective or harmful

● Add lime (before/after planting)

- *Survival*: One replicated, controlled study in the Netherlands reported that liming reduced survival of planted fen herbs after two growing seasons. One replicated, randomized, paired, controlled study in Sweden found that liming increased survival of planted fen mosses over one season.
- *Growth*: Two controlled, before-and-after studies found that liming did not increase growth of planted peatland vegetation: for two *Sphagnum* moss species in bog pools in the UK, and for most species of peat swamp tree in a nursery in Indonesia. One replicated, controlled, before-and-after study in Sweden found that liming increased growth of planted fen mosses.
- *Cover*: Of two replicated, randomized, paired, controlled studies, one in a fen in Sweden found that liming increased cover of sown mosses. The other, in a bog in Canada, found that liming plots sown with mixed fen vegetation did not affect vegetation cover (total, vascular plants or bryophytes).
- *Assessment*: likely to be ineffective or harmful (effectiveness 35%; certainty 40%; harms 20%). Based on evidence from: bogs (two studies); fens (two studies); fen meadows (one study); tropical peat swamps (one study).

<https://www.conservationevidence.com/actions/1825>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Add organic fertilizer (before/after planting)
- Rewet peatland (before/after planting)
- Remove upper layer of peat/soil (before planting)
- Bury upper layer of peat/soil (before planting)
- Encapsulate planted moss fragments in beads/gel
- Use fences or barriers to protect planted vegetation
- Protect or prepare vegetation before planting (other interventions).

6.13 Habitat protection

Based on the collated evidence, what is the current assessment of the effectiveness of actions to protect peatland habitats?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Legally protect peatlands
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Pay landowners to protect peatlands ● Increase 'on-the-ground' protection (e.g. rangers)
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Create legislation for 'no net loss' of wetlands ● Adopt voluntary agreements to protect peatlands ● Allow sustainable use of peatlands

Likely to be beneficial

● Legally protect peatlands

- *Peatland habitat*: Two studies in Indonesia reported that peat swamp forest was lost from within the boundaries of national parks. However, one of these studies reported that forest loss was greater outside the national park. One before-and-after study in China reported that peatland area initially decreased following legal protection, but increased in the longer term.
- *Plant community composition*: One before-and-after study in a bog in Denmark reported that the plant community composition changed over 161 years of protection. Woody plants became more abundant.
- *Vegetation cover*: One site comparison study in Chile found that protected peatland had greater vegetation cover (total, herbs and shrubs) than adjacent grazed and moss-harvested peatland.

- *Overall plant richness/diversity:* One before-and-after study in Denmark reported that the number of plant species in a protected bog fluctuated over time, with no clear trend. One site comparison study in Chile found that protected peatland had lower plant richness and diversity, but also fewer non-native species, than adjacent grazed and harvested peatland.
- *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 1%). Based on evidence from: tropical peat swamps (two studies); bogs (one study); unspecified peatlands (two studies).*

<https://www.conservationevidence.com/actions/1796>

Unknown effectiveness (limited evidence)

● Pay landowners to protect peatlands

- *Peatland habitat:* One review reported that agri-environment schemes in the UK had mixed effects on bogs, protecting the area of bog habitat in three of six cases.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 10%). Based on evidence from: bogs (one study).*

<https://www.conservationevidence.com/actions/1799>

● Increase ‘on the ground’ protection (e.g. rangers)

- *Behaviour change:* One before-and-after study in a peat swamp forest in Indonesia reported that the number of illegal sawmills decreased over two years of anti-logging patrols.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 20%; harms 0%). Based on evidence from: tropical peat swamps (one study).*

<https://www.conservationevidence.com/actions/1800>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Create legislation for ‘no net loss’ of wetlands
- Adopt voluntary agreements to protect peatlands
- Allow sustainable use of peatlands.

6.14 Education and awareness

Based on the collated evidence, what is the current assessment of the effectiveness of actions to educate/raise awareness about peatlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Raise awareness amongst the public (general) ● Provide education or training programmes about peatlands or peatland management ● Lobby, campaign or demonstrate to protect peatlands
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Raise awareness amongst the public (wild fire) ● Raise awareness amongst the public (problematic species) ● Raise awareness through engaging volunteers in peatland management or monitoring

Unknown effectiveness (limited evidence)

● Raise awareness amongst the public (general)

- *Behaviour change:* One before-and-after study in the UK reported that following awareness-raising activities (e.g. publishing reports, organizing seminars and using education volunteers in garden centres), the percentage of the public buying peat-free compost increased.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 25%; harms 0%). Based on evidence from: unspecified peatlands (one study).*

<https://www.conservationevidence.com/actions/1844>

● Provide education or training programmes about peatlands or peatland management

- *Behaviour change*: One study in peat swamps in Indonesia reported that over 3,500 households adopted sustainable farming practices following workshops about sustainable farming. One before-and-after study in peat swamps in Indonesia reported that a training course increased the quality of rubber produced by local farmers.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 30%; harms 0%)*. Based on evidence from: tropical peat swamps (two studies).

<https://www.conservationevidence.com/actions/1848>

● Lobby, campaign or demonstrate to protect peatlands

- *Peatland protection*: Two studies in the UK reported that the area of protected peatland increased following pressure from a campaign group (including business meetings, parliamentary debates, publishing reports and public engagement).
- *Behaviour change*: One study in the UK reported that following pressure from the same campaign group, major retailers stopped buying compost containing peat from important peatland areas and horticultural companies began marketing peat-free compost.
- *Attitudes/awareness*: One study in the UK reported that following pressure from the same campaign group, garden centres and local governments signed voluntary peatland conservation agreements.
- *Assessment: unknown effectiveness – limited evidence (effectiveness 60%; certainty 35%; harms 0%)*. Based on evidence from: unspecified peatlands (two studies).

<https://www.conservationevidence.com/actions/1849>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Raise awareness amongst the public (wild fire)
- Raise awareness amongst the public (problematic species)
- Raise awareness through engaging volunteers in peatland management or monitoring.

7. PRIMATE CONSERVATION

Jessica Junker, Hjalmar S. Kühl, Lisa Orth, Rebecca K. Smith, Silviu O. Petrovan & William J. Sutherland

Expert assessors

Graham L. Banes, University of Wisconsin-Madison, USA

Sergio Marrocoli, Max Planck Institute for Evolutionary Anthropology, Germany

Sarah Papworth, Royal Holloway University of London, UK

Silviu O. Petrovan, University of Cambridge, UK

Andrew J. Plumptre, Wildlife Conservation Society, Uganda

Ricardo Rocha, University of Cambridge, UK

Joanna M. Setchell, Durham University, UK

Kathy Slater, Operation Wallacea, UK

Erin Wessling, Max Planck Institute for Evolutionary Anthropology, Germany

Liz Williamson, University of Stirling, UK

Scope of assessment: for wild primate species across the world.

Assessed: 2017.

Effectiveness measure is the median % score for effectiveness.

Certainty measure is the median % certainty of evidence for effectiveness, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects to the group of species of concern.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

7.1 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for residential and commercial development?	
Likely to be beneficial	<ul style="list-style-type: none">● Remove and relocate 'problem' animals
No evidence found (no assessment)	<ul style="list-style-type: none">● Relocate primates to non-residential areas● Discourage the planting of fruit trees and vegetable gardens on the urban edge

Likely to be beneficial

● Remove and relocate 'problem' animals

Three studies, including one replicated, before-and-after trial, in India, Kenya, the Republic of Congo and Gabon found that most primates survived the translocation. One study found that all translocated rhesus monkeys remained at the release site for at least four years. Another study showed that after 16 years, 66% of olive baboons survived and survival rate was similar to wild study groups. The third study showed that 84% of gorillas released in the Republic of Congo and Gabon survived for at least four years. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 10%).*

<https://www.conservationevidence.com/actions/1422>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Relocate primates to non-residential areas
- Discourage the planting of fruit trees and vegetable gardens on the urban edge biodiversity-friendly farming.

7.2 Threat: Agriculture

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for agriculture?	
Likely to be beneficial	<ul style="list-style-type: none"> • Humans chase primates using random loud noises
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Prohibit (livestock) farmers from entering protected areas • Use nets to keep primates out of fruit trees
No evidence found (no assessment)	<ul style="list-style-type: none"> • Create natural habitat islands within agricultural land • Use fences as biological corridors for primates • Provide sacrificial rows of crops on outer side of fields • Compensate farmers for produce loss caused by primates • Pay farmers to cover the costs of non-harmful strategies to deter primates • Retain nesting trees/shelter for primates within agricultural fields • Plant nesting trees/shelter for primates within agricultural fields • Regularly remove traps and snares around agricultural fields • Certify farms and market their products as 'primate friendly' • Farm more intensively and effectively in selected areas and spare more natural land • Install mechanical barriers to deter primates (e.g. fences, ditches)

	<ul style="list-style-type: none">● Use of natural hedges to deter primates● Use of unpalatable buffer crops● Change of crop (i.e. to a crop less palatable to primates)● Plant crops favoured by primates away from primate areas● Destroy habitat within buffer zones to make them unusable for primates● Use GPS and/or VHF tracking devices on individuals of problem troops to provide farmers with early warning of crop raiding● Chase crop-raiding primates using dogs● Train langur monkeys to deter rhesus macaques● Use loud-speakers to broadcast sounds of potential threats (e.g. barking dogs, explosions, gunshots)● Use loud-speakers to broadcast primate alarm calls● Strategically lay out the scent of a primate predator (e.g. leopard, lion)● Humans chase primates using bright light
--	--

Likely to be beneficial

● Humans chase primates using random loud noise

One controlled, replicated, before-and-after study in Indonesia found that in areas where noise deterrents were used, along with tree nets, crop raiding by orangutans was reduced. One study in the Democratic Republic Congo found that chasing gorillas and using random noise resulted in the return of gorillas from plantation to areas close to protected forest. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1449>

Unknown effectiveness (limited evidence)

● Prohibit (livestock) farmers from entering protected areas

One before-and-after site comparison study in Rwanda found that numbers of young gorillas increased after removal of cattle from a protected area, alongside other interventions. One before-and-after study in Rwanda, Uganda, and the Democratic Republic of Congo found that gorilla numbers declined following the removal of livestock, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1432>

● Use nets to keep primates out of fruit trees

A controlled, replicated, before-and-after study in Indonesia found that areas where nets were used to protect crop trees, crop-raiding by orangutans was reduced. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 30%; harms 20%).*

<https://www.conservationevidence.com/actions/1442>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Create natural habitat islands within agricultural land
- Use fences as biological corridors for primates
- Provide sacrificial rows of crops on outer side of fields
- Compensate farmers for produce loss caused by primates
- Pay farmers to cover the costs of non-harmful strategies to deter primates
- Retain nesting trees/shelter for primates within agricultural fields
- Plant nesting trees/shelter for primates within agricultural fields
- Regularly remove traps and snares around agricultural fields

- Certify farms and market their products as 'primate friendly'
- Farm more intensively and effectively in selected areas and spare more natural land
- Install mechanical barriers to deter primates (e.g. fences, ditches)
- Use of natural hedges to deter primates
- Use of unpalatable buffer crops
- Change of crop (i.e. to a crop less palatable to primates)
- Plant crops favoured by primates away from primate areas
- Destroy habitat within buffer zones to make them unusable for primates
- Use GPS and/or VHF tracking devices on individuals of problem troops to provide farmers with early warning of crop raiding
- Chase crop-raiding primates using dogs
- Train langur monkeys to deter rhesus macaques
- Use loud-speakers to broadcast sounds of potential threats (e.g. barking dogs, explosions, gunshots)
- Use loud-speakers to broadcast primate alarm calls
- Strategically lay out the scent of a primate predator (e.g. leopard, lion)
- Humans chase primates using bright light.

7.3 Threat: Energy production and mining

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for energy and production mining?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Minimize ground vibrations caused by open cast mining activities• Establish no-mining zones in/near watersheds so as to preserve water levels and water quality• Use 'set-aside' areas of natural habitat for primate protection within mining area• Certify mines and market their products as 'primate friendly' (e.g. ape-friendly cellular phones)• Create/preserve primate habitat on islands before dam construction

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Minimize ground vibrations caused by open cast mining activities
- Establish no-mining zones in/near watersheds so as to preserve water levels and water quality
- Use 'set-aside' areas of natural habitat for primate protection within mining area
- Certify mines and market their products as 'primate friendly' (e.g. ape-friendly cellular phones)
- Create/preserve primate habitat on islands before dam construction.

7.4 Threat: Transportation and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for transportation and service corridors?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Install rope or pole (canopy) bridges
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Install green bridges (overpasses) ● Implement speed limits in particular areas (e.g. with high primate densities) to reduce vehicle collisions with primates ● Reduce road widths ● Impose fines for breaking the speed limit or colliding with primates ● Avoid building roads in key habitat or migration routes ● Implement a minimum number of roads (and minimize secondary roads) needed to reach mining extraction sites ● Re-use old roads rather than building new roads ● Re-route vehicles around protected areas ● Install speed bumps to reduce vehicle collisions with primates ● Provide adequate signage of presence of primates on or near roads



Likely to be beneficial

● Install rope or pole (canopy) bridges

One before-and-after study in Belize study found that howler monkey numbers increased after pole bridges were constructed over man-made gaps. Two studies in Brazil and Madagascar found that primates used pole bridges to cross roads and pipelines. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1457>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Install green bridges (overpasses)
- Implement speed limits in particular areas (e.g. with high primate densities) to reduce vehicle collisions with primates
- Reduce road widths
- Impose fines for breaking the speed limit or colliding with primates
- Avoid building roads in key habitat or migration routes
- Implement a minimum number of roads (and minimize secondary roads) needed to reach mining extraction sites
- Re-use old roads rather than building new roads
- Re-route vehicles around protected areas
- Install speed bumps to reduce vehicle collisions with primates
- Provide adequate signage of presence of primates on or near roads.

7.5 Threat: Biological resource use

7.5.1 Hunting

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for hunting?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Conduct regular anti-poaching patrols ● Regularly de-activate/remove ground snares ● Provide better equipment (e.g. guns) to anti-poaching ranger patrols ● Implement local no-hunting community policies/traditional hunting ban ● Implement community control of patrolling, banning hunting and removing snares
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Strengthen/support/re-install traditions/tabooes that forbid the killing of primates ● Implement monitoring surveillance strategies (e.g. SMART) or use monitoring data to improve effectiveness of wildlife law enforcement patrols ● Provide training to anti-poaching ranger patrols
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Implement no-hunting seasons for primates ● Implement sustainable harvesting of primates (e.g. with permits, resource access agreements) ● Encourage use of traditional hunting methods rather than using guns ● Implement road blocks to inspect cars for illegal primate bushmeat ● Provide medicine to local communities to control killing of primates for medicinal purposes



	<ul style="list-style-type: none"> ● Introduce ammunition tax ● Inspect bushmeat markets for illegal primate species ● Inform hunters of the dangers (e.g., disease transmission) of wild primate meat
--	---

Likely to be beneficial

● Conduct regular anti-poaching patrols

Two of three studies found that gorilla populations increased after regular anti-poaching patrols were conducted, alongside other interventions. One study in Ghana found a decline in gorilla populations. One review on gorillas in Uganda found that no gorillas were killed after an increase in anti-poaching patrols. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1471>

● Regularly de-activate/remove ground snares

One of two studies found that the number of gorillas increased in an area patrolled for removing snares, alongside other interventions. One study in the Democratic Republic of Congo, Rwanda, and Uganda found that gorilla populations declined despite snare removal. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1475>

● Provide better equipment (e.g. guns) to anti-poaching ranger patrols

Two studies in the Democratic Republic of Congo and Rwanda found that gorilla populations increased after providing anti-poaching guards with better equipment, alongside other interventions. One study in Uganda found that no gorillas were killed after providing game guards with better equipment. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1476>

● **Implement local no-hunting community policies/ traditional hunting ban**

Four studies, one of which had multiple interventions, in the Democratic Republic of Congo, Belize, Cameroon and Nigeria found that primate populations increased in areas where there were bans on hunting or where hunting was reduced due to local taboos. One study found that very few primates were killed in a sacred site in China where it is forbidden to kill wildlife. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1478>

● **Implement community control of patrolling, banning hunting and removing snares**

Two site comparison studies found that there were more gorillas and chimpanzees in an area managed by a community conservation organisation than in areas not managed by local communities and community control was more effective at reducing illegal primate hunting compared to the nearby national park. A before-and-after study in Cameroon found that no incidents of gorilla poaching occurred over three years after implementation of community control and monitoring of illegal activities. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1482>

Unknown effectiveness (limited evidence)

● **Strengthen/support/re-install traditions/taboo that forbid the killing of primates**

One site comparison study in Laos found that Laotian black crested gibbons occurred at higher densities in areas where they were protected by a local hunting taboo compared to sites where there was no taboo. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1479>



● **Implement monitoring surveillance strategies (e.g. SMART) or use monitoring data to improve effectiveness of wildlife law enforcement patrols**

One before-and-after study in Nigeria found that more gorillas and chimpanzees were observed after the implementation of law enforcement and a monitoring system. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1481>

● **Provide training to anti-poaching ranger patrols**

Two before-and-after studies in Rwanda and India found that primate populations increased in areas where anti-poaching staff received training, alongside other interventions. Two studies in Uganda and Cameroon found that no poaching occurred following training of anti-poaching rangers, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 70%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1477>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Implement no-hunting seasons for primates
- Implement sustainable harvesting of primates (e.g. with permits, resource access agreements)
- Encourage use of traditional hunting methods rather than using guns
- Implement road blocks to inspect cars for illegal primate bushmeat
- Provide medicine to local communities to control killing of primates for medicinal purposes
- Introduce ammunition tax
- Inspect bushmeat markets for illegal primate species
- Inform hunters of the dangers (e.g., disease transmission) of wild primate meat.

7.5.2 Substitution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for substitution?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Use selective logging instead of clear-cutting ● Avoid/minimize logging of important food tree species for primates
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Use patch retention harvesting instead of clear-cutting ● Implement small and dispersed logging compartments ● Use shelter wood cutting instead of clear-cutting ● Leave hollow trees in areas of selective logging for sleeping sites ● Clear open patches in the forest ● Thin trees within forests ● Coppice trees ● Manually control or remove secondary mid-storey and ground-level vegetation ● Avoid slashing climbers/lianas, trees housing them, hemi-epiphytic figs, and ground vegetation ● Incorporate forested corridors or buffers into logged areas ● Close non-essential roads as soon as logging operations are complete ● Use 'set-asides' for primate protection within logging area ● Work inward from barriers or boundaries (e.g. river) to avoid pushing primates toward an impassable barrier or inhospitable habitat ● Reduce the size of forestry teams to include employees only (not family members) ● Certify forest concessions and market their products as 'primate friendly' ● Provide domestic meat to workers of the logging company to reduce hunting

Unknown effectiveness (limited evidence)

● Use selective logging instead of clear-cutting

One of two site comparison studies in Africa found that primate abundance was higher in forests that had been logged at low intensity compared to forest logged at high intensity. One study in Uganda found that primate abundances were similar in lightly and heavily logged forests. One study in Madagascar found that the number of lemurs increased following selective logging. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 35%; harms 30%).*

<https://www.conservationevidence.com/actions/1485>

● Avoid/minimize logging of important food tree species for primates

One before-and-after study in Belize found that black howler monkey numbers increased over a 13 year period after trees important for food for the species were preserved, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1494>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use patch retention harvesting instead of clear-cutting
- Implement small and dispersed logging compartments
- Use shelter wood cutting instead of clear-cutting
- Leave hollow trees in areas of selective logging for sleeping sites
- Clear open patches in the forest
- Thin trees within forests
- Coppice trees
- Manually control or remove secondary mid-storey and ground-level vegetation.

- Avoid slashing climbers/lianas, trees housing them, hemi-epiphytic figs, and ground vegetation
- Incorporate forested corridors or buffers into logged areas
- Close non-essential roads as soon as logging operations are complete
- Use 'set-asides' for primate protection within logging area
- Work inward from barriers or boundaries (e.g. river) to avoid pushing primates toward an impassable barrier or inhospitable habitat
- Reduce the size of forestry teams to include employees only (not family members)
- Certify forest concessions and market their products as 'primate friendly'
- Provide domestic meat to workers of the logging company to reduce hunting.

7.6 Threat: Human intrusions and disturbance

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for human intrusions and disturbance?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Implement a 'no-feeding of wild primates' policy ● Put up signs to warn people about not feeding primates ● Resettle illegal human communities (i.e. in a protected area) to another location
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Build fences to keep humans out ● Restrict number of people that are allowed access to the site ● Install 'primate-proof' garbage bins ● Do not allow people to consume food within natural areas where primates can view them

Unknown effectiveness (limited evidence)

● Implement a 'no-feeding of wild primates' policy

A controlled before-and-after study in Japan found that reducing food provisioning of macaques progressively reduced productivity and reversed population increases and crop and forest damage. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1502>

● Put up signs to warn people about not feeding primates

One review study in Japan found that after macaque feeding by tourists was banned and advertised, the number of aggressive incidents between people and macaques decreased as well as the number of road collisions with macaques that used to be fed from cars. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1507>

● Resettle illegal human communities (i.e. in a protected area) to another location

One review on gorillas in Uganda found that no more gorillas were killed after human settlers were relocated outside the protected area, alongside other interventions. One before-and-after study in the Republic of Congo found that most reintroduced chimpanzees survived over five years after human communities were resettled, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 65%; certainty 15%; harms 0%).*

<https://www.conservationevidence.com/actions/1515>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Build fences to keep humans out
- Restrict number of people that are allowed access to the site
- Install 'primate-proof' garbage bins
- Do not allow people to consume food within natural areas where primates can view them.

7.7 Threat: Natural system modifications

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for natural system modifications?

No evidence found (no assessment)

- Use prescribed burning within the context of home range size and use
- Protect important food/nest trees before burning

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use prescribed burning within the context of home range size and use
- Protect important food/nest trees before burning.

7.8 Threat: Invasive and other problematic species and genes

7.8.1 Problematic animal/plant species and genes

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for problematic animal/plant species and genes?

No evidence found (no assessment)	<ul style="list-style-type: none">• Reduce primate predation by non-primate species through exclusion (e.g. fences) or translocation• Reduce primate predation by other primate species through exclusion (e.g. fences) or translocation• Control habitat-altering mammals (e.g. elephants) through exclusion (e.g. fences) or translocation• Control inter-specific competition for food through exclusion (e.g. fences) or translocation• Remove alien invasive vegetation where the latter has a clear negative effect on the primate species in question• Prevent gene contamination by alien primate species introduced by humans, through exclusion (e.g. fences) or translocation
--	---



No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce primate predation by non-primate species through exclusion (e.g. fences) or translocation
- Reduce primate predation by other primate species through exclusion (e.g. fences) or translocation
- Control habitat-altering mammals (e.g. elephants) through exclusion (e.g. fences) or translocation
- Control inter-specific competition for food through exclusion (e.g. fences) or translocation
- Remove alien invasive vegetation where the latter has a clear negative effect on the primate species in question
- Prevent gene contamination by alien primate species introduced by humans, through exclusion (e.g. fences) or translocation.

7.8.2 Disease transmission

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for disease transmission?	
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Preventative vaccination of habituated or wild primates
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Wear face-masks to avoid transmission of viral and bacterial diseases to primates • Keep safety distance to habituated animals • Limit time that researchers/tourists are allowed to spend with habituated animals • Implement quarantine for primates before reintroduction/translocation • Ensure that researchers/tourists are up-to-date with vaccinations and healthy • Regularly disinfect clothes, boots etc.

	<ul style="list-style-type: none"> ● Treat sick/injured animals ● Remove/treat external/internal parasites to increase reproductive success/survival ● Conduct veterinary screens of animals before reintroducing/translocating them ● Implement continuous health monitoring with permanent vet on site ● Detect and report dead primates and clinically determine their cause of death to avoid disease transmission
<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Implement quarantine for people arriving at, and leaving the site ● Wear gloves when handling primate food, tool items, etc. ● Control ‘reservoir’ species to reduce parasite burdens/pathogen sources ● Avoid contact between wild primates and human-raised primates ● Implement a health programme for local communities

Trade-off between benefit and harms

● Preventative vaccination of habituated or wild primates

Three before-and-after studies in the Republic of Congo and Gabon, two focusing on chimpanzees and one on gorillas, found that most reintroduced individuals survived over 3.5-10 years after being vaccinated, alongside other interventions. One before-and-after study in Puerto Rico found that annual mortality of introduced rhesus macaques decreased after a preventive tetanus vaccine campaign, alongside other interventions. *Assessment: trade-offs between benefits and harms (effectiveness 70%; certainty 40%; harms 30%).*

<https://www.conservationevidence.com/actions/1549>



Unknown effectiveness (limited evidence)

● Wear face-masks to avoid transmission of viral and bacterial diseases to primates

One before-and-after study in Rwanda, Uganda and the Democratic Republic of Congo found that gorilla numbers increased while being visited by researchers and visitors wearing face-masks, alongside other interventions. One study in Uganda found that a confiscated chimpanzee was successfully reunited with his mother after being handled by caretakers wearing face-masks, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 5%; harms 0%).*

<https://www.conservationevidence.com/actions/1537>

● Keep safety distance to habituated animals

One before-and-after study in the Republic of Congo found that most reintroduced chimpanzees survived over five years while being routinely followed from a safety distance, alongside other interventions. One before-and-after study in Rwanda, Uganda and the Democratic Republic of Congo found that gorilla numbers increased while being routinely visited from a safety distance, alongside other interventions. However, one study in Malaysia found that orangutan numbers declined while being routinely visited from a safety distance. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1538>

● Limit time that researchers/tourists are allowed to spend with habituated animals

One before-and-after study in Rwanda, Uganda and the Democratic Republic of Congo found that gorilla numbers increased while being routinely visited during limited time, alongside other interventions. One controlled study in Indonesia found that the behaviour of orangutans that spent limited time with caretakers was more similar to the behaviour of wild orangutans than that of individuals that spent more time with caretakers. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1539>

● **Implement quarantine for primates before reintroduction/translocation**

Six studies, including four before-and-after studies, in Brazil, Madagascar, Malaysia and Indonesia have found that most reintroduced primates did not survive or their population size decreased over periods ranging from months up to seven years post-release, despite being quarantined before release, alongside other interventions. However, two before-and-after studies in Indonesia, the Republic of Congo and Gabon found that most orangutans and gorillas that underwent quarantine survived over a period ranging from three months to 10 years. One before-and-after study in Uganda found that one reintroduced chimpanzee repeatedly returned to human settlements after being quarantined before release alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1541>

● **Ensure that researchers/tourists are up-to-date with vaccinations and healthy**

One before-and-after study in Rwanda, Uganda and the Republic of Congo found that gorilla numbers increased while being visited by healthy researchers and visitors, alongside other interventions. However, one controlled study in Malaysia found that orangutan numbers decreased despite being visited by healthy researchers and visitors, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1546>

● **Regularly disinfect clothes, boots etc.**

One controlled, before-and-after study in Rwanda, Uganda and the Democratic Republic of Congo found that gorilla numbers increased while being regularly visited by researchers and visitors whose clothes were disinfected, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1547>



● **Treat sick/injured animals**

Eight studies, including four before-and-after studies, in Brazil, Malaysia, Liberia, the Democratic Republic of Congo, The Gambia and South Africa found that most reintroduced or translocated primates that were treated when sick or injured, alongside other interventions, survived being released and up to at least five years. However, five studies, including one review and four before-and-after studies, in Brazil, Thailand, Malaysia and Madagascar found that most reintroduced or translocated primates did not survive or their numbers declined despite being treated when sick or injured, alongside other interventions. One study in Uganda found that several infected gorillas were medically treated after receiving treatment, alongside other interventions. One study in Senegal found that one chimpanzee was reunited with his mother after being treated for injuries, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1550>

● **Remove/treat external/internal parasites to increase reproductive success/survival**

Five studies, including four before-and-after studies, in the Republic of Congo, The Gambia and Gabon found that most reintroduced or translocated primates that were treated for parasites, alongside other interventions, survived periods of at least five years. However, four studies, including one before-and-after study, in Brazil, Gabon and Vietnam found that most reintroduced primates did not survive or their numbers declined after being treated for parasites, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 5%; harms 0%).*

<https://www.conservationevidence.com/actions/1551>

● **Conduct veterinary screens of animals before reintroducing/translocating them**

Twelve studies, including seven before-and-after studies, in Brazil, Malaysia, Indonesia, Liberia, the Republic of Congo, Guinea, Belize, French Guiana and Madagascar found that most reintroduced or translocated

primates that underwent pre-release veterinary screens, alongside other interventions, survived, in some situations, up to at least five years or increased in population size. However, 10 studies, including six before-and-after studies, in Brazil, Malaysia, French Guiana, Madagascar, Kenya, South Africa and Vietnam found that most reintroduced or translocated primates did not survive or their numbers declined after undergoing pre-release veterinary screens, alongside other interventions. One before-and-after study in Uganda, found that one reintroduced chimpanzee repeatedly returned to human settlements after undergoing pre-release veterinary screens, alongside other interventions. One controlled study in Indonesia found that gibbons that underwent pre-release veterinary screens, alongside other interventions, behaved similarly to wild gibbons. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1553>

● **Implement continuous health monitoring with permanent vet on site**

One controlled, before-and-after study in Rwanda, Uganda and the Republic of Congo found that numbers of gorillas that were continuously monitored by vets, alongside other interventions, increased over 41 years. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1554>

● **Detect and report dead primates and clinically determine their cause of death to avoid disease transmission**

One controlled, before-and-after study in Rwanda, Uganda and the Republic of Congo found that numbers of gorillas that were continuously monitored by vets, alongside other interventions, increased over 41 years. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1556>



No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Implement quarantine for people arriving at, and leaving the site
- Wear gloves when handling primate food, tool items, etc.
- Control 'reservoir' species to reduce parasite burdens/pathogen sources
- Avoid contact between wild primates and human-raised primates
- Implement a health programme for local communities.

7.9 Threat: Pollution

7.9.1 Garbage/solid waste

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for garbage and solid waste?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Reduce garbage/solid waste to avoid primate injuries• Remove human food waste that may potentially serve as food sources for primates to avoid disease transmission and conflict with humans

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce garbage/solid waste to avoid primate injuries
- Remove human food waste that may potentially serve as food sources for primates to avoid disease transmission and conflict with humans.

7.9.2 Excess energy

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for excess energy?

No evidence found (no assessment)	<ul style="list-style-type: none">• Reduce noise pollution by restricting development activities to certain times of the day/night
--	--

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Reduce noise pollution by restricting development activities to certain times of the day/night.

7.10 Education and Awareness

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for education and awareness?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Educate local communities about primates and sustainable use ● Involve local community in primate research and conservation management ● Regularly play TV and radio announcements to raise primate conservation awareness ● Implement multimedia campaigns using theatre, film, print media, discussions
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Install billboards to raise primate conservation awareness ● Integrate local religion/taboo into conservation education

Unknown effectiveness (limited evidence)

● Educate local communities about primates and sustainable use

One before-and-after study in Cameroon found that numbers of drills increased after the implementation of an education programme, alongside one other intervention. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 0%; harms 0%).*

<https://www.conservationevidence.com/actions/1563>

- **Involve local community in primate research and conservation management**

One before-and-after study in Rwanda, Uganda and the Democratic Republic of Congo found that gorilla numbers decreased despite the implementation of an environmental education programme, alongside other interventions. However, one before-and-after study in Cameroon found that gorilla poaching stopped after the implementation of a community-based monitoring scheme, alongside other interventions. One before-and-after study in Belize found that numbers of howler monkeys increased while local communities were involved in the management of the sanctuary, alongside other interventions. One before-and-after study in Uganda found that a reintroduced chimpanzee repeatedly returned to human settlements despite the involvement of local communities in the reintroduction project, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1565>

- **Regularly play TV and radio announcements to raise primate conservation awareness**

One before-and-after study in Congo found that most reintroduced chimpanzees whose release was covered by media, alongside other interventions, survived over five years. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 5%; harms 0%).*

<https://www.conservationevidence.com/actions/1569>

- **Implement multimedia campaigns using theatre, film, print media, and discussions**

Three before-and-after studies in Belize and India found that primate numbers increased after the implementation of education programs, alongside other interventions. Three before-and-after studies found that the knowledge about primates increased after the implementation of education programmes. One before-and-after study in Madagascar found that lemur poaching appeared to have ceased after the distribution of conservation books in schools. One study in four African countries found that large numbers of people were informed about gorillas through multimedia

campaigns using theatre and film. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1571>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Install billboards to raise primate conservation awareness
- Integrate local religion/taboo into conservation education.

7.11 Habitat protection

7.11.1 Habitat protection

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat protection?	
Likely to be beneficial	<ul style="list-style-type: none">● Create/protect habitat corridors
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Legally protect primate habitat● Establish areas for conservation which are not protected by national or international legislation (e.g. private sector standards and codes)● Create/protect forest patches in highly fragmented landscapes
No evidence found (no assessment)	<ul style="list-style-type: none">● Create buffer zones around protected primate habitat● Demarcate and enforce boundaries of protected areas

Likely to be beneficial

● Create/protect habitat corridors

One before-and-after study in Belize found that howler monkey numbers increased after the protection of a forest corridor, alongside other interventions. *Assessment: likely to be beneficial (effectiveness 65%; certainty 41%; harms 0%).*

<https://www.conservationevidence.com/actions/1580>

Unknown effectiveness (limited evidence)

● Legally protect primate habitat

Two reviews and a before-and-after study in China found that primate numbers increased or their killing was halted after their habitat became legally protected, alongside other interventions. However, one before-and-after study in Kenya found that colobus and mangabey numbers decreased despite the area being declared legally protected, alongside other interventions. Two before-and-after studies found that most chimpanzees and gorillas reintroduced to areas that received legal protection, alongside other interventions, survived over 4–5 years. However, one before-and-after study in Brazil found that most golden lion tamarins did not survive over seven years despite being reintroduced to a legally protected area, alongside other interventions, yet produced offspring that partly compensated the mortality. One controlled, site comparison study in Mexico found that howler monkeys in protected areas had lower stress levels than individuals living in unprotected forest fragments. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1578>

● Establish areas for conservation which are not protected by national or international legislation (e.g. private sector standards and codes)

Two before-and-after studies in Rwanda, Republic of Congo and Belize found that gorilla and howler monkey numbers increased after the implementation of a conservation project funded by a consortium of organizations or after being protected by local communities, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1579>

● Create/protect forest patches in highly fragmented landscapes

One before-and-after study in Belize found that howler monkey numbers increased after the protection of forest along property boundaries and

across cleared areas, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1581>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Create buffer zones around protected primate habitat
- Demarcate and enforce boundaries of protected areas.

7.11.2 Habitat creation or restoration

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat creation or restoration?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Plant indigenous trees to re-establish natural tree communities in clear-cut areas
No evidence found (no assessment)	<ul style="list-style-type: none"> • Restore habitat corridors • Plant indigenous fast-growing trees (will not necessarily resemble original community) in clear-cut areas • Use weeding to promote regeneration of indigenous tree communities

Unknown effectiveness (limited evidence)

● Plant indigenous trees to re-establish natural tree communities in clear-cut areas

One site comparison study in Kenya found that group densities of two out of three primate species were lower in planted forests than in natural forests. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 5%; harms 0%).*

<https://www.conservationevidence.com/actions/1584>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restore habitat corridors
- Plant indigenous fast-growing trees (will not necessarily resemble original community) in clear-cut areas
- Use weeding to promote regeneration of indigenous tree communities.

7.12 Species management

7.12.1 Species management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for species management?	
Likely to be beneficial	<ul style="list-style-type: none">● Guard habituated primate groups to ensure their safety/well-being
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Habituate primates to human presence to reduce stress from tourists/researchers etc.● Implement legal protection for primate species under threat
No evidence found (no assessment)	<ul style="list-style-type: none">● Implement birth control to stabilize primate community/population size

Likely to be beneficial

● Guard habituated primate groups to ensure their safety/well-being

One study in Rwanda, Uganda and the Congo found that a population of mountain gorillas increased after being guarded against poachers, alongside other interventions. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1523>

Unknown effectiveness (limited evidence)

● Habituate primates to human presence to reduce stress from tourists/researchers etc.

Two studies in Central Africa and Madagascar found that primate populations increased or were stable following habituation to human presence, alongside other interventions. One study in Brazil found that golden lion tamarin populations declined following habituation to human presence, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 20%; harms 10%).*

<https://www.conservationevidence.com/actions/1519>

● Implement legal protection for primate species under threat

Three of four studies in India, South East Asia, and West Africa found that primate populations declined after the respective species were legally protected, alongside other interventions. One of four studies in India found that following a ban on export of rhesus macaques, their population increased. One study in Malaysia found that a minority of introduced gibbons survived after implementing legal protection, along with other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1524>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Implement birth control to stabilize primate community/population size.

7.12.2 Species recovery

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for species recovery?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Regularly and continuously provide supplementary food to primates ● Regularly provide supplementary food to primates during resource scarce periods only ● Provide supplementary food for a certain period of time only ● Provide additional sleeping platforms/nesting sites for primates ● Provide artificial water sources
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Provide salt licks for primates ● Provide supplementary food to primates through the establishment of prey populations

Unknown effectiveness (limited evidence)

● Regularly and continuously provide supplementary food to primates

Two of four studies found that primate populations increased after regularly providing supplementary food, alongside other interventions, while two of four studies found that populations declined. Four of four studies found that the majority of primates survived after regularly providing supplementary food, alongside other interventions. One study found that introduced lemurs had different diets to wild primates after regularly being providing supplementary food, along with other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 30%; harms 60%).*

<https://www.conservationevidence.com/actions/1526>

● Regularly provide supplementary food to primates during resource scarce periods only

Two studies found that the majority of primates survived after supplementary feeding in resource scarce periods, alongside other

interventions. One study in Madagascar found that the diet of introduced lemurs was similar to that of wild lemurs after supplementary feeding in resource scarce periods, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%; harms 10%).*

<https://www.conservationevidence.com/actions/1527>

● **Provide supplementary food for a certain period of time only**

Six of eleven studies found that a majority of primates survived after supplementary feeding, alongside other interventions. Five of eleven studies found that a minority of primates survived. One of two studies found that a reintroduced population of primates increased after supplementary feeding for two months immediately after reintroduction, alongside other interventions. One study found that a reintroduced population declined. Two studies found that abandoned primates rejoined wild groups after supplementary feeding, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 0%; harms 0%).*

<https://www.conservationevidence.com/actions/1527>

● **Provide additional sleeping platforms/nesting sites for primates**

One study found that a translocated golden lion tamarin population declined despite providing artificial nest boxes, alongside other interventions. One of two studies found that the majority of gorillas survived for at least seven years after nesting platforms were provided, alongside other interventions. One of two studies found that a minority of tamarins survived for at least seven years after artificial nest boxes were provided, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 0%; harms 0%).*

<https://www.conservationevidence.com/actions/1530>

● **Provide artificial water sources**

Three of five studies found that a minority of primates survived for between 10 months and seven years when provided with supplementary water, alongside other interventions. Two of five studies found that a majority of

primates survived for between nine and ten months, when provided with supplementary water, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 20%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1531>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide salt licks for primates
- Provide supplementary food to primates through the establishment of prey populations.

7.12.3 Species reintroduction

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for species reintroduction?	
Likely to be beneficial	<ul style="list-style-type: none"> • Reintroduce primates into habitat where the species is absent
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Translocate (capture and release) wild primates from development sites to natural habitat elsewhere • Translocate (capture and release) wild primates from abundant population areas to non-inhabited environments • Allow primates to adapt to local habitat conditions for some time before introduction to the wild • Reintroduce primates in groups • Reintroduce primates as single/multiple individuals • Reintroduce primates into habitat where the species is present • Reintroduce primates into habitat with predators • Reintroduce primates into habitat without predators

Likely to be beneficial

● **Reintroduce primates into habitat where the species is absent**

One of two studies found that primate populations increased after reintroduction into habitat where the species was absent, alongside other interventions. One study in Thailand found that lar gibbon populations declined post-reintroduction. One study in Indonesia found that a orangutan population persisted for at least four years after reintroduction. Eight of ten studies found that a majority of primates survived after reintroduction into habitat where the species was absent, alongside other interventions. Two studies in Malaysia and Vietnam found that a minority of primates survived after reintroduction into habitat where the species was absent, alongside other interventions. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1590>

Unknown effectiveness (limited evidence)

● **Translocate (capture and release) wild primates from development sites to natural habitat elsewhere**

Four studies found that the majority of primates survived following translocation from a development site to natural habitat, alongside other interventions. One study in French Guyana found that a minority of primates survived for at least 18 months. One study in India found that rhesus macaques remained at sites where they were released following translocation from a development site to natural habitat, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 60%; certainty 30%; harms 10%).*

<https://www.conservationevidence.com/actions/1558>

● **Translocate (capture and release) wild primates from abundant population areas to non-inhabited environments**

One study in Belize found that the majority of howler monkeys survived for at least 10 months after translocation from abundant population areas

to an uninhabited site, along with other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1559>

● **Allow primates to adapt to local habitat conditions for some time before introduction to the wild**

Two of three studies found that primate populations declined despite allowing individuals to adapt to local habitat conditions before introduction into the wild, along with other interventions. One study in Belize found an increase in introduced howler monkey populations. Ten of 17 studies found that a majority of primates survived after allowing them to adapt to local habitat conditions before introduction into the wild, along with other interventions. Six studies found that a minority of primates survived and one study found that half of primates survived. One study found that a reintroduced chimpanzee repeatedly returned to human settlements after allowing it to adapt to local habitat conditions before introduction into the wild, along with other interventions. One study found that after allowing time to adapt to local habitat conditions, a pair of reintroduced Bornean agile gibbons had a similar diet to wild gibbons. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1564>

● **Reintroduce primates in groups**

Two of four studies found that populations of introduced primates declined after reintroduction in groups, alongside other interventions, while two studies recorded increases in populations. Two studies found that primate populations persisted for at least five to 55 years after reintroduction in groups, alongside other interventions. Seven of fourteen studies found that a majority of primates survived after reintroduction in groups, alongside other interventions. Seven of fourteen studies found that a minority of primates survived after reintroduction in groups, alongside other interventions. One study found that introduced primates had a similar diet to a wild population. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1567>

● **Reintroduce primates as single/multiple individuals**

Three of four studies found that populations of reintroduced primates declined after reintroduction as single/multiple individuals, alongside other interventions. One study in Tanzania found that the introduced chimpanzee population increased in size. Three of five studies found that a minority of primates survived after reintroduction as single/multiple individuals, alongside other interventions. One study found that a majority of primates survived and one study found that half of primates survived. Two of two studies in Brazil and Senegal found that abandoned primates were successfully reunited with their mothers after reintroduction as single/multiple individuals, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 20%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1589>

● **Reintroduce primates into habitat where the species is present**

One of two studies found that primate populations increased after reintroduction into habitat where the species was absent, alongside other interventions. One study in Malaysia found that an introduced orangutan population declined post-reintroduction. One study found that a primate population persisted for at least four years after reintroduction. Eight of ten studies found that a majority of primates survived after reintroduction into habitat where the species was absent, alongside other interventions. Two studies found that a minority of primates survived after reintroduction into habitat where the species was present, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1591>

● **Reintroduce primates into habitat with predators**

Eight of fourteen studies found that a majority of reintroduced primates survived after reintroduction into habitat with predators, alongside other interventions. Six studies found that a minority of primates survived. One study found that an introduced primate population increased after reintroduction into habitat with predators, alongside other interventions.

Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 10%; harms 0%).

<https://www.conservationevidence.com/actions/1593>

● Reintroduce primates into habitat without predators

One study in Tanzania found that a population of reintroduced chimpanzees increased over 16 years following reintroduction into habitat without predators. *Assessment: unknown effectiveness — limited evidence (effectiveness 50%; certainty 5%; harms 0%).*

<https://www.conservationevidence.com/actions/1592>

7.12.4 *Ex-situ* conservation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for <i>ex-situ</i> conservation?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Captive breeding and reintroduction of primates into the wild: born and reared in cages ● Captive breeding and reintroduction of primates into the wild: limited free-ranging experience ● Captive breeding and reintroduction of primates into the wild: born and raised in a free-ranging environment ● Rehabilitate injured/orphaned primates ● Fostering appropriate behaviour to facilitate rehabilitation

Unknown effectiveness (limited evidence)

● Captive breeding and reintroduction of primates into the wild: born and reared in cages

One study in Brazil found that the majority of reintroduced golden lion tamarins which were born and reared in cages, alongside other interventions, did not survive over seven years.

Two of two studies in Brazil and French Guiana found that more reintroduced primates that were born and reared in cages, alongside other interventions, died post-reintroduction compared to wild-born monkeys. *Assessment: unknown effectiveness — limited evidence (effectiveness 0%; certainty 15%; harms 0%).*

<https://www.conservationevidence.com/actions/1594>

● **Captive breeding and reintroduction of primates into the wild: limited free-ranging experience**

One of three studies found that the majority of captive-bred primates, with limited free-ranging experience and which were reintroduced in the wild, alongside other interventions, had survived. One study in Madagascar found that a minority of captive-bred lemurs survived reintroduction over five years. One study found that reintroduced lemurs with limited free-ranging experience had a similar diet to wild primates. Reintroduction was undertaken alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1595>

● **Captive breeding and reintroduction of primates into the wild: born and raised in a free-ranging environment**

One study in Brazil found that the majority of golden lion tamarins survived for at least four months after being raised in a free-ranging environment, alongside other interventions. One study found that the diet of lemurs that were born and raised in a free-ranging environment alongside other interventions, overlapped with that of wild primates. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1596>

● **Rehabilitate injured/orphaned primates**

Six of eight studies found that the majority of introduced primates survived after rehabilitation of injured or orphaned individuals, alongside other interventions. One study found that a minority of introduced primates survived, and one study found that half of primates survived. One of two studies found that an introduced chimpanzee population increased in size after rehabilitation of injured or orphaned individuals, alongside other

interventions. One study found that an introduced rehabilitated or injured primate population declined. One review found that primates living in sanctuaries had a low reproduction rate. One study found that introduced primates had similar behaviour to wild primates after rehabilitation of injured or orphaned individuals, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1597>

● **Fostering appropriate behaviour to facilitate rehabilitation**

Three of five studies found that a minority of primates survived after they were fostered to encourage behaviour appropriate to facilitate rehabilitation, alongside other interventions. Two studies found that the majority of reintroduced primates fostered to facilitate rehabilitation along other interventions survived. Three studies found that despite fostering to encourage behaviour appropriate to facilitate rehabilitation, alongside other interventions, primates differed in their behaviour to wild primates. *Assessment: unknown effectiveness – limited evidence (effectiveness 10%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1600>

7.13 Livelihood; economic and other incentives

7.13.1 Provide benefits to local communities for sustainably managing their forest and its wildlife

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for providing benefits to local communities for sustainably managing their forest and its wildlife?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Provide monetary benefits to local communities for sustainably managing their forest and its wildlife (e.g. REDD, employment)● Provide non-monetary benefits to local communities for sustainably managing their forest and its wildlife (e.g. better education, infrastructure development)



Unknown effectiveness (limited evidence)

- **Provide monetary benefits to local communities for sustainably managing their forest and its wildlife (e.g. REDD, employment)**

One before-and-after study in Belize found that howler monkey numbers increased after the provision of monetary benefits to local communities alongside other interventions. However, one before-and-after study in Rwanda, Uganda and the Congo found that gorilla numbers decreased despite the implementation of development projects in nearby communities, alongside other interventions. One before-and-after study in Congo found that most chimpanzees reintroduced to an area where local communities received monetary benefits, alongside other interventions, survived over five years. *Assessment: unknown effectiveness – limited evidence (effectiveness 50%; certainty 25%; harms 0%).*

<https://www.conservationevidence.com/actions/1509>

- **Provide non-monetary benefits to local communities for sustainably managing their forest and its wildlife (e.g. better education, infrastructure development)**

One before-and-after study India found that numbers of gibbons increased in areas where local communities were provided alternative income, alongside other interventions. One before-and-after study in Congo found that most chimpanzees reintroduced survived over seven years in areas where local communities were provided non-monetary benefits, alongside other interventions. *Assessment: unknown effectiveness – limited evidence (effectiveness 40%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1510>

7.13.2 Long-term presence of research/tourism project

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for the long-term presence of research/tourism project?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Run research project and ensure permanent human presence at site
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Run tourism project and ensure permanent human presence at site
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Permanent presence of staff/managers

Likely to be beneficial

- **Run research project and ensure permanent human presence at site**

Three before-and-after studies, in Rwanda, Uganda, Congo and Belize found that numbers of gorillas and howler monkeys increased while populations were continuously monitored by researchers, alongside other interventions. One before-and-after study in Kenya found that troops of translocated baboons survived over 16 years post-translocation while being continuously monitored by researchers, alongside other interventions. One before-and-after study in the Congo found that most reintroduced chimpanzees survived over 3.5 years while being continuously monitored by researchers, alongside other interventions. However, one before-and-after study in Brazil found that most reintroduced tamarins did not survive over 7 years, despite being continuously monitored by researchers, alongside other interventions; but tamarins reproduced successfully. One review on gorillas in Uganda found that no individuals were killed while gorillas were continuously being monitored by researchers, alongside other interventions. *Assessment: likely to be beneficial (effectiveness 61%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1511>



Trade-off between benefit and harms

● Run tourism project and ensure permanent human presence at site

Six studies, including four before-and-after studies, in Rwanda, Uganda, Congo and Belize found that numbers of gorillas and howler monkeys increased after local tourism projects were initiated, alongside other interventions. However, two before-and-after studies in Kenya and Madagascar found that numbers of colobus and mangabeys and two of three lemur species decreased after implementing tourism projects, alongside other interventions. One before-and-after study in China found that exposing macaques to intense tourism practices, especially through range restrictions to increase visibility for tourists, had increased stress levels and increased infant mortality, peaking at 100% in some years. *Assessment: trade-off between benefit and harms (effectiveness 40%; certainty 40%; harms 40%).*

<https://www.conservationevidence.com/actions/1512>

Unknown effectiveness (limited evidence)

● Permanent presence of staff/managers

Two before-and-after studies in the Congo and Gabon found that most reintroduced chimpanzees and gorillas survived over a period of between nine months to five years while having permanent presence of reserve staff. One before-and-after study in Belize found that numbers of howler monkeys increased after permanent presence of reserve staff, alongside other interventions. However, one before-and-after study in Kenya found that numbers of colobus and mangabeys decreased despite permanent presence of reserve staff, alongside other interventions. *Assessment: unknown effectiveness — limited evidence (effectiveness 40%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1517>

8. SHRUBLAND AND HEATHLAND CONSERVATION

Philip A. Martin, Ricardo Rocha, Rebecca K. Smith & William J. Sutherland

Expert assessors

Andrew Bennet, La Trobe University, Australia

Brian van Wilgen, Stellenbosch University, South Africa

Rob Marrs, University of Liverpool, UK

Chris Diek, Royal Society for the Protection of Birds, UK

G. Matt Davies, Ohio State University, USA

David Le Maitre, CSIR, UK

Giles Groome, Consultant Ecologist, UK

Isabel Barrio, University of Iceland, Iceland

James Adler, Surrey Wildlife Trust, UK

Jon Keeley, US Geological Survey, Western Ecological Research Center and Department of Ecology and Evolutionary Biology, University of California, USA

Jonty Denton, Consultant Ecologist, UK

Penny Anderson, Penny Anderson Associates Limited, UK

Scope of assessment: for the conservation of shrubland and heathland habitats (not specific species within these habitats).

Assessed: 2017.

Effectiveness measure is the median % score for effectiveness.

Certainty measure is the median % certainty of evidence, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects on the shrubland and heathland habitats of concern.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target habitat for each intervention. The assessment may therefore refer to different habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target habitats or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

8.1 Threat: Residential and commercial development

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of residential and commercial development in shrublands and heathlands?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Remove residential or commercial development• Maintain/create habitat corridors in developed areas

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Remove residential or commercial development
- Maintain/create habitat corridors in developed areas.

8.2 Threat: Agriculture and aquaculture

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of agriculture and aquaculture in shrublands and heathlands?

Beneficial	<ul style="list-style-type: none">● Reduce number of livestock
Likely to be beneficial	<ul style="list-style-type: none">● Use fences to exclude livestock from shrublands
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Change type of livestock● Shorten the period in which livestock can graze

Beneficial

● **Reduce number of livestock**

Two before-and-after trials in the UK and South Africa and one replicated, controlled study in the UK found that reducing or stopping grazing increased the abundance or cover of shrubs. Two site comparison studies in the UK found that cover of common heather declined in sites with high livestock density, but increased in sites with low livestock density. One site comparison study in the Netherlands found that dwarf shrub cover was higher in ungrazed sites. One replicated, randomized, before-and-after study in Spain found that reducing grazing increased the cover of western gorse. One randomized, controlled trial and one before-and-after trial in the USA found that stopping grazing did not increase shrub abundance. One site comparison study in France found that ungrazed sites had higher cover

of ericaceous shrubs, but lower cover of non-ericaceous shrubs than grazed sites. One site comparison study in the UK found that reducing grazing had mixed effects on shrub cover. One replicated, randomized, controlled study in the UK found that reducing grazing increased vegetation height. However, one replicated, controlled, paired, site comparison study in the UK found that reducing grazing led to a reduction in the height of heather plants. Two site comparison studies in France and the Netherlands found that ungrazed sites had a lower number of plant species than grazed sites. One replicated, controlled, paired, site comparison study in Namibia and South Africa found that reducing livestock numbers increased plant cover and the number of plant species. One controlled study in Israel found that reducing grazing increased plant biomass. However, one randomized, site comparison on the island of Gomera, Spain found that reducing grazing did not increase plant cover and one replicated, controlled study in the UK found that the number of plant species did not change. One replicated, controlled study in the UK found no change in the cover of rush or herbaceous species as a result of a reduction in grazing. Two site comparison studies in France and the Netherlands found that grass cover and sedge cover were lower in ungrazed sites than in grazed sites. One randomized, controlled study in the USA found a mixed effect of reducing grazing on grass cover. *Assessment: Beneficial (effectiveness 65%, certainty 70%, harms 10%).*

<https://www.conservationevidence.com/actions/1607>

Likely to be beneficial

● Use fences to exclude livestock from shrublands

Two replicated, controlled, randomized studies (one of which was also a before-and-after trial) and one controlled before-and-after trial in the UK found that using fences to exclude livestock increased shrub cover or abundance. Two replicated, controlled, randomized studies in Germany and the UK found that using fences increased shrub biomass or the biomass and height of individual heather plants. Two controlled studies (one of which was a before-and-after study) in Denmark and the UK found that heather presence or cover was higher in fenced areas than in areas that were not fenced. However, one site comparison study in the USA found that using fences led to decreased cover of woody plants. Three replicated, controlled

studies (one of which was a before and after study) in the USA and the UK found that fencing either had a mixed effect on shrub cover or did not alter shrub cover. One randomized, replicated, controlled, paired study in the UK found that using fences to exclude livestock did not alter the number of plant species, but did increase vegetation height and biomass. One controlled, before-and-after study in the UK found that fenced areas had lower species richness than unfenced areas. One randomized, replicated, controlled, before-and-after trial in the UK and one site comparison study in the USA found that using fences to exclude livestock led to a decline in grass cover. However, four controlled studies (one of which a before-and-after trial) in the USA, the UK, and Finland found that using fences did not alter cover of grass species. One site comparison study in the USA and one replicated, controlled study in the UK recorded an increase in grass cover. One controlled study in Finland found that using fences to exclude livestock did not alter the abundance of herb species and one site comparison in the USA found no difference in forb cover between fenced and unfenced areas. One replicated, controlled study in the USA found fencing had a mixed effect on herb cover. *Assessment: likely to be beneficial (effectiveness 51%; certainty 60%; harms 10%).*

<https://www.conservationevidence.com/actions/1545>

Unknown effectiveness (limited evidence)

● **Change type of livestock**

Two replicated, before-and-after studies and one controlled study in Spain and the UK found changing the type of livestock led to mixed effects on shrub cover. However, in two of these studies changing the type of livestock reduced the cover of herbaceous species. One replicated, controlled, before-and-after study in the UK found that grazing with both cattle and sheep, as opposed to grazing with sheep, reduced cover of purple moor grass, but had no effect on four other plant species. *Assessment: unknown effectiveness (effectiveness 40%; certainty 29%; harms 5%).*

<https://www.conservationevidence.com/actions/1608>

● **Shorten the period during which livestock can graze**

One replicated, controlled, before-and-after study in the UK found that shortening the period in which livestock can graze had mixed effects on heather, bilberry, crowberry, and grass cover. One replicated, randomized, controlled study in the UK found that grazing in only winter or summer did not affect the heather or grass height compared to year-round grazing. *Assessment: unknown effectiveness (effectiveness 32%; certainty 20%; harms 2%).*

<https://www.conservationevidence.com/actions/1609>

8.3 Threat: Energy production and mining

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of energy production and mining in shrublands and heathlands?

**No evidence found
(no assessment)**

- Maintain/create habitat corridors in areas of energy production or mining

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain/create habitat corridors in areas of energy production or mining.

8.4 Threat: Biological resource use

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of biological resource use in shrublands and heathlands?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Legally protect plant species affected by gathering• Place signs to deter gathering of shrubland species• Reduce frequency of prescribed burning

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Legally protect plant species affected by gathering
- Place signs to deter gathering of shrubland species
- Reduce the frequency of prescribed burning.

8.5 Threat: Transportation and service corridors

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of transportation and service corridors in shrublands and heathlands?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Maintain habitat corridors over or under roads and other transportation corridors• Create buffer zones besides roads and other transportation corridors

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Maintain habitat corridors over or under roads and other transportation corridors
- Create buffer zones besides roads and other transportation corridors.

8.6 Threat: Human intrusions and disturbance

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of human intrusions and disturbance in shrublands and heathlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Re-route paths to reduce habitat disturbance
No evidence found (no assessment)	<ul style="list-style-type: none">• Use signs and access restrictions to reduce disturbance• Plant spiny shrubs to act as barriers to people

Unknown effectiveness (limited evidence)

● Re-route paths to reduce habitat disturbance

One before-and-after trial in Australia found that closing paths did not alter shrub cover, but did increase the number of plant species in an alpine shrubland. *Assessment: unknown effectiveness (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1619>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use signs and access restrictions to reduce disturbance
- Plant spiny shrubs to act as barriers to people.

8.7 Threat: Natural system modifications

8.7.1 Modified fire regime

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of a modified fire regime in shrublands and heathlands?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Use prescribed burning to mimic natural fire cycle• Use prescribed burning to reduce the potential for large wild fires• Cut strips of vegetation to reduce the spread of fire

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use prescribed burning to mimic natural fire cycle
- Use prescribed burning to reduce the potential for large wild fires
- Cut strips of vegetation to reduce the spread of fire.

8.7.2 Modified vegetation management

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of a modified vegetation management in shrublands and heathlands?

Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Reinstatement of traditional burning practices ● Use cutting/mowing to mimic grazing ● Increase number of livestock
---	---

Unknown effectiveness (limited evidence)

● Reinstatement of traditional burning practices

One before and after study in the UK found that prescribed burning initially decreased the cover of most plant species, but that their cover subsequently increased. A systematic review of five studies from the UK found that prescribed burning did not alter species diversity. A replicated, controlled study in the UK found that regeneration of heather was similar in cut and burned areas. A systematic review of five studies, from Europe found that prescribed burning did not alter grass cover relative to heather cover. *Assessment: unknown effectiveness (effectiveness 40%; certainty 30%; harms 12%).*

<https://www.conservationevidence.com/actions/1625>

● Use cutting/mowing to mimic grazing

One systematic review of three studies in lowland heathland in North Western Europe found that mowing did not alter heather abundance relative to grass abundance. A site comparison in Italy found that mowing increased heather cover. Two replicated, randomized, before-and-after trials in Spain (one of which was controlled) found that using cutting to mimic grazing reduced heather cover. One replicated, randomized, controlled, before-and-after trial in Spain found that cutting increased the number of plant species. However, a replicated, randomized, before-and-after trial found that the number of plant species only increased in a minority of cases. One replicated, randomized, before-and-after trial in Spain found that cutting to

mimic grazing increased grass cover. A site comparison in Italy found that mowing increased grass cover. One site comparison study in Italy found a reduction in tree cover. *Assessment: unknown effectiveness (effectiveness 30%; certainty 25%; harms 10%).*

<https://www.conservationevidence.com/actions/1627>

● **Increase number of livestock**

Two site comparison studies in the UK found that cover of common heather declined in sites with a high density of livestock. One site comparison in the Netherlands found that dwarf shrub cover was lower in grazed areas than in ungrazed areas. One before-and-after study in Belgium found that grazing increased cover of heather. One site comparison in France found that areas grazed by cattle had higher cover of non-ericaceous shrubs, but lower cover of ericaceous shrubs. One before-and-after study in the Netherlands found that increasing the number of livestock resulted in an increase in the number of common heather and cross-leaved heath seedlings. One randomized, replicated, paired, controlled study in the USA found that increasing the number of livestock did not alter shrub cover. One replicated, site comparison study and one before-and-after study in the UK and Netherlands found that increasing grazing had mixed effects on shrub and heather cover. Three site comparisons in France, the Netherlands and Greece found that grazed areas had a higher number of plant species than ungrazed areas. One before-and-after study in Belgium found that the number of plant species did not change after the introduction of grazing. One replicated, before-and-after study in the Netherlands found a decrease in the number of plant species. One before-and-after study in the Netherlands found that increasing the number of livestock resulted in a decrease in vegetation height. One replicated, before-and-after trial in France found that grazing to control native woody species increased vegetation cover in one of five sites but did not increase vegetation cover in four of five sites. A systematic review of four studies in North Western Europe found that increased grazing intensity increased the cover of grass species, relative to heather species. One before-and-after study and two site comparisons in the Netherlands and France found areas with high livestock density had higher grass and sedge cover than ungrazed areas. One randomized, replicated, paired, controlled study in the USA found

that increasing the number of livestock reduced grass and herb cover. One before-and-after study in Spain found that increasing the number of ponies in a heathland site reduced grass height. One replicated, site comparison in the UK and one replicated before-and-after study in the Netherlands found that increasing cattle had mixed effects on grass and herbaceous species. *Assessment: unknown effectiveness (effectiveness 30%; certainty 30%; harms 20%).*

<https://www.conservationevidence.com/actions/1628>

8.8 Threat: Invasive and other problematic species

8.8.1 Problematic tree species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of invasive and other problematic tree species in shrublands and heathlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Apply herbicide to trees ● Cut trees ● Cut trees and remove leaf litter ● Cut trees and remove tree seedlings ● Use prescribed burning to control trees ● Use grazing to control trees ● Cut trees and apply herbicide ● Cut trees and use prescribed burning ● Increase number of livestock and use prescribed burning to control trees
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Mow/cut shrubland to control trees ● Cut trees and increase livestock numbers



Unknown effectiveness (limited evidence)

● Apply herbicide to trees

One replicated, controlled, before-and-after study in South Africa found that using herbicide to control trees increased plant diversity but did not increase shrub cover. One randomized, replicated, controlled study in the UK found that herbicide treatment of trees increased the abundance of common heather seedlings. *Assessment: unknown effectiveness (effectiveness 40%; certainty 35%; harms 10%).*

<https://www.conservationevidence.com/actions/1629>

● Cut trees

One randomized, replicated, controlled study in the UK found that cutting birch trees increased density of heather seedlings but not that of mature common heather plants. One replicated, controlled study in South Africa found that cutting non-native trees increased herbaceous plant cover but did not increase cover of native woody plants. One site comparison study in South Africa found that cutting non-native Acacia trees reduced shrub and tree cover. *Assessment: unknown effectiveness (effectiveness 37%; certainty 30%; harms 3%).*

<https://www.conservationevidence.com/actions/1630>

● Cut trees and remove leaf litter

One before-and-after trial in the Netherlands found that cutting trees and removing the litter layer increased the cover of two heather species and of three grass species. *Assessment: unknown effectiveness (effectiveness 45%; certainty 10%; harms 3%).*

<https://www.conservationevidence.com/actions/1631>

● Cut trees and remove seedlings

A controlled, before-and-after study in South Africa found that cutting orange wattle trees and removing seedlings of the same species increased plant diversity and shrub cover. *Assessment: unknown effectiveness (effectiveness 62%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1632>

● **Use prescribed burning to control trees**

One randomized, replicated, controlled, before-and-after trial in the USA found that burning to control trees did not change cover of two of three grass species. One randomized, controlled study in Italy found that prescribed burning to control trees reduced cover of common heather, increased cover of purple moor grass, and had mixed effects on the basal area of trees. *Assessment: unknown effectiveness (effectiveness 10%; certainty 20%; harms 22%).*

<https://www.conservationevidence.com/actions/1721>

● **Use grazing to control trees**

One randomized, controlled, before-and-after study in Italy found that grazing to reduce tree cover reduced cover of common heather and the basal area of trees, but did not alter cover of purple moor grass. *Assessment: unknown effectiveness (effectiveness 20%; certainty 10%; harms 5%).*

<https://www.conservationevidence.com/actions/1634>

● **Cut trees and apply herbicide**

One controlled study in the UK found that cutting trees and applying herbicide increased the abundance of heather seedlings. However, one replicated, controlled study in the UK found that cutting silver birch trees and applying herbicide did not alter cover of common heather when compared to cutting alone. Two controlled studies (one of which was a before-and-after study) in South Africa found that cutting of trees and applying herbicide did not increase shrub cover. Two controlled studies in South Africa found that cutting trees and applying herbicide increased the total number of plant species and plant diversity. One replicated, controlled study in the UK found that cutting and applying herbicide reduced cover of silver birch trees. *Assessment: unknown effectiveness (effectiveness 45%; certainty 35%; harms 3%).*

<https://www.conservationevidence.com/actions/1636>



● **Cut trees and use prescribed burning**

One replicated, before-and-after trial in the USA found that cutting western juniper trees and using prescribed burning increased the cover of herbaceous plants. One replicated, randomized, controlled, before-and-after trial in the USA found that cutting western juniper trees and using prescribed burning increased cover of herbaceous plants but had no effect on the cover of most shrubs. One controlled study in South Africa found that cutting followed by prescribed burning reduced the cover of woody plants but did not alter herbaceous cover. *Assessment: unknown effectiveness (effectiveness 40%; certainty 35%; harms 5%).*

<https://www.conservationevidence.com/actions/1637>

● **Increase number of livestock and use prescribed burning to control trees**

One randomized, controlled, before-and-after study in Italy found that using prescribed burning and grazing to reduce tree cover reduced the cover of common heather and the basal area of trees. However, it did not alter the cover of purple moor grass. *Assessment: unknown effectiveness (effectiveness 2%; certainty 12%; harms 12%).*

<https://www.conservationevidence.com/actions/1722>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Cut/mow shrubland to control trees
- Cut trees and increase livestock numbers.

8.8.2 Problematic grass species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of invasive and other problematic grass species in shrublands and heathlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Cut/mow to control grass ● Cut/mow to control grass and sow seed of shrubland plants ● Rake to control grass ● Cut/mow and rotovate to control grass ● Apply herbicide and sow seeds of shrubland plants to control grass ● Apply herbicide and remove plants to control grass ● Use grazing to control grass ● Use prescribed burning to control grass ● Cut and use prescribed burning to control grass ● Use herbicide and prescribed burning to control grass ● Strip turf to control grass ● Rotovate to control grass ● Add mulch to control grass ● Add mulch to control grass and sow seed ● Cut/mow, rotovate and sow seed to control grass
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Use herbicide to control grass

Unknown effectiveness (limited evidence)

● Cut/mow to control grass

One controlled study in the UK found that mowing increased the number of heathland plants in one of two sites. The same study found that the presence of a small minority of heathland plants increased, but the presence of non-heathland plants did not change. Three replicated, controlled studies in the UK and the USA found that cutting to control grass did not alter cover of common heather or shrub seedling abundance. One replicated, controlled

study in the UK found that cutting to control purple moor grass reduced vegetation height, had mixed effects on purple moor grass cover and the number of plant species, and did not alter cover of common heather. Two randomized, controlled studies in the USA found that mowing did not increase the cover of native forb species. Both studies found that mowing reduced grass cover but in one of these studies grass cover recovered over time. One replicated, controlled study in the UK found that mowing did not alter the abundance of wavy hair grass relative to rotovating or cutting turf. *Assessment: unknown effectiveness (effectiveness 22%; certainty 35%; harms 5%).*

<https://www.conservationevidence.com/actions/1638>

● **Cut/mow to control grass and sow seed of shrubland plants**

One randomized, replicated, controlled study in the USA found that the biomass of sagebrush plants in areas where grass was cut and seeds sown did not differ from areas where grass was not cut, but seeds were sown. One randomized controlled study in the USA found that cutting grass and sowing seeds increased shrub seedling abundance and reduced grass cover. One randomized, replicated, controlled study in the USA found that sowing seeds and mowing did not change the cover of non-native plants or the number of native plant species. *Assessment: unknown effectiveness (effectiveness 31%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1639>

● **Rake to control grass**

A randomized, replicated, controlled, paired study in the USA found that cover of both invasive and native grasses, as well as forbs was lower in areas that were raked than in areas that were not raked, but that the number of annual plants species did not differ. *Assessment: unknown effectiveness (effectiveness 30%; certainty 20%; harms 12%).*

<https://www.conservationevidence.com/actions/1640>

● **Cut/mow and rotovate to control grass**

One controlled study in the UK found that mowing followed by rotovating increased the number of heathland plant species in one of two sites. The same study found that the presence of a minority of heathland

and non-heathland species increased. *Assessment: unknown effectiveness (effectiveness 22%; certainty 15%; harms 7%).*

<https://www.conservationevidence.com/actions/1641>

● **Apply herbicide and sow seeds of shrubland plants to control grass**

One randomized, controlled study in the USA found that areas where herbicide was sprayed and seeds of shrubland species were sown had more shrub seedlings than areas that were not sprayed or sown with seeds. One randomized, replicated, controlled study in the USA found that spraying with herbicide and sowing seeds of shrubland species did not increase the cover of native plant species, but did increase the number of native plant species. One of two studies in the USA found that spraying with herbicide and sowing seeds of shrubland species reduced non-native grass cover. One study in the USA found that applying herbicide and sowing seeds of shrubland species did not reduce the cover of non-native grasses. *Assessment: unknown effectiveness (effectiveness 35%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1644>

● **Apply herbicide and remove plants to control grass**

One randomized, replicated, controlled, paired study in the USA found that areas sprayed with herbicide and weeded to control non-native grass cover had higher cover of native grasses and forbs than areas that were not sprayed or weeded, but not a higher number of native plant species. The same study found that spraying with herbicide and weeding reduced non-native grass cover. *Assessment: unknown effectiveness (effectiveness 42%; certainty 20%; harms 2%).*

<https://www.conservationevidence.com/actions/1645>

● **Use grazing to control grass**

One replicated, controlled, before-and-after study in the Netherlands found that grazing to reduce grass cover had mixed effects on cover of common heather and cross-leaved heath. One replicated, controlled, before-and-after study in the Netherlands found that cover of wavy-hair grass increased and one before-and-after study in Spain found a reduction

in grass height. *Assessment: unknown effectiveness (effectiveness 32%; certainty 17%; harms 10%).*

<https://www.conservationevidence.com/actions/1646>

● Use prescribed burning to control grass

One replicated controlled, paired, before-and-after study in the UK found that prescribed burning to reduce the cover of purple moor grass, did not reduce its cover but did reduce the cover of common heather. One randomized, replicated, controlled study in the UK found that prescribed burning initially reduced vegetation height, but this recovered over time. *Assessment: unknown effectiveness (effectiveness 0%; certainty 20%; harms 15%).*

<https://www.conservationevidence.com/actions/1723>

● Cut and use prescribed burning to control grass

One randomized, replicated, controlled, paired, before-and-after study in the UK found that burning and cutting to reduce the cover of purple moor grass reduced cover of common heather but did not reduce cover of purple moor grass. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 10%).*

<https://www.conservationevidence.com/actions/1724>

● Use herbicide and prescribed burning to control grass

One randomized, replicated, controlled, paired, before-and-after study in the UK found that burning and applying herbicide to reduce the cover of purple moor grass reduced cover of common heather but did not reduce cover of purple moor grass. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 20%).*

<https://www.conservationevidence.com/actions/1725>

● Strip turf to control grass

One controlled study in the UK found that cutting and removing turf increased the number of heathland plants. The same study found that the presence of a small number of heathland plants increased, and that the presence of a small number of non-heathland plants decreased. One

replicated, controlled study in the UK found that presence of heather was similar in areas where turf was cut and areas that were mown or rotovated. One replicated, controlled study in the UK found that the presence of wavy hair grass was similar in areas where turf was cut and those that were mown or rotovated. *Assessment: unknown effectiveness (effectiveness 32%; certainty 25%; harms 2%).*

<https://www.conservationevidence.com/actions/1647>

● **Rotovate to control grass**

One replicated, controlled study in the UK found that rotovating did not alter the presence of heather compared to mowing or cutting. The same study found that wavy hair grass presence was not altered by rotovating, relative to areas that were mown or cut. *Assessment: unknown effectiveness (effectiveness 0%; certainty 5%; harms 0%).*

<https://www.conservationevidence.com/actions/1648>

● **Add mulch to control grass**

One randomized, controlled study in the USA found that areas where mulch was used to control grass cover had a similar number of shrub seedlings to areas where mulch was not applied. The same study found that mulch application did not reduce grass cover. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1649>

● **Add mulch to control grass and sow seed**

One randomized, controlled study in the USA found that adding mulch, followed by seeding with shrub seeds, increased the seedling abundance of one of seven shrub species but did not reduce grass cover. *Assessment: unknown effectiveness (effectiveness 5%; certainty 7%; harms 0%).*

<https://www.conservationevidence.com/actions/1650>

● **Cut/mow, rotovate and sow seeds to control grass**

One replicated, controlled study in the UK found that rotovating did not alter the presence of heather compared to mowing or cutting. The same

study found that wavy hair grass presence was not altered by rotovating, relative to areas that were mown or cut. *Assessment: unknown effectiveness (effectiveness 50%; certainty 12%; harms 1%).*

<https://www.conservationevidence.com/actions/1651>

Unlikely to be beneficial

● Use herbicide to control grass

Two randomized, controlled studies in the UK and the USA found that spraying with herbicide did not affect the number of shrub or heathland plant seedlings. One of these studies found that applying herbicide increased the abundance of one of four heathland plants, but reduced the abundance of one heathland species. However, one randomized, controlled study in the UK found that applying herbicide increased cover of heathland species. One randomized, replicated, controlled study in the UK reported no effect on the cover of common heather. One randomized, replicated study in the UK reported mixed effects of herbicide application on shrub cover. Two randomized, controlled studies in the USA and the UK found that herbicide application did not change the cover of forb species. However, one randomized, controlled, study in the USA found that herbicide application increased native forb cover. Four of five controlled studies (two of which were replicated) in the USA found that grass cover or non-native grass cover were lower in areas where herbicides were used to control grass than areas where herbicide was not used. Two randomized, replicated, controlled studies in the UK found that herbicide reduced cover of purple moor grass, but not cover of three grass/reed species. Two randomized, controlled studies in the UK found that herbicide application did not reduce grass cover. *Assessment: unlikely to be beneficial (effectiveness 32%; certainty 40%; harms 7%).*

<https://www.conservationevidence.com/actions/1643>

8.8.3 Bracken

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of bracken in shrublands and heathlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Use herbicide to control bracken ● Cut to control bracken ● Cut and apply herbicide to control bracken ● Cut bracken and rotovate ● Use 'bracken bruiser' to control bracken ● Use herbicide and remove leaf litter to control bracken
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Cut and burn bracken ● Use herbicide and sow seed of shrubland plants to control bracken ● Increase grazing intensity to control bracken ● Use herbicide and increase livestock numbers to control bracken

Unknown effectiveness (limited evidence)

● Use herbicide to control bracken

One controlled, before-and-after trial in the UK found that applying herbicide to control bracken increased the number of heather seedlings. However, two randomized, controlled studies in the UK found that spraying with herbicide did not increase heather cover. One randomized, controlled study in the UK found that applying herbicide to control bracken increased heather biomass. One replicated, randomized, controlled study in the UK found that the application of herbicide increased the number of plant species in a heathland site. However, one replicated, randomized, controlled study in the UK found that spraying bracken with herbicide had no effect on species richness or diversity. One randomized, controlled study in the UK found that applying herbicide to control bracken increased the cover of wavy hair-grass and sheep's fescue. One controlled study in the UK found that applying herbicide to control bracken increased the cover of

gorse and the abundance of common cow-wheat. One controlled, before-and-after trial in the UK found that the application of herbicide reduced the abundance of bracken but increased the number of silver birch seedlings. Three randomized, controlled studies in the UK found that the application of herbicide reduced the biomass or cover of bracken. However, one controlled study in the UK found that applying herbicide did not change the abundance of bracken. *Assessment: unknown effectiveness (effectiveness 50%; certainty 35%; harms 10%).*

<https://www.conservationevidence.com/actions/1652>

● **Cut to control bracken**

One randomized, controlled, before-and-after trial in Norway and one randomized, controlled study in the UK found that cutting bracken increased the cover or biomass of heather. However, two randomized, replicated, controlled studies in the UK found that cutting bracken did not increase heather cover or abundance of heather seedlings. One randomized, replicated, controlled study in the UK found that cutting to control bracken increased the species richness of heathland plant species. However, another randomized, replicated, controlled study in the UK found that cutting to control bracken did not alter species richness but did increase species diversity. One randomized, replicated, controlled study in the UK found that cutting bracken increased cover of wavy hair-grass and sheep's fescue. One controlled study in the UK found that cutting bracken did not increase the abundance of gorse or common cow-wheat. One randomized, controlled, before-and-after trial in Norway and two randomized, controlled studies in the UK found that cutting bracken reduced bracken cover or biomass. One randomized, replicated, controlled, paired study the UK found that cutting had mixed effects on bracken cover. However, one controlled study in the UK found that cutting bracken did not decrease the abundance of bracken. *Assessment: unknown effectiveness (effectiveness 50%; certainty 35%; harms 2%).*

<https://www.conservationevidence.com/actions/1653>

● **Cut and apply herbicide to control bracken**

One randomized, controlled study in the UK found that cutting and applying herbicide to control bracken did not alter heather biomass. One randomized, controlled, before-and-after trial in Norway found that

cutting and applying herbicide increased heather cover. One randomized, replicated, controlled, paired study in the UK found that cutting and using herbicide had no significant effect on the cover of seven plant species. One replicated, randomized, controlled study in the UK found that cutting bracken followed by applying herbicide increased plant species richness when compared with applying herbicide followed by cutting. Three randomized, controlled studies (one also a before-and-after trial, and one of which was a paired study) in the UK and Norway found that cutting and applying herbicide reduced bracken biomass or cover. *Assessment: unknown effectiveness (effectiveness 30%; certainty 30%; harms 4%).*

<https://www.conservationevidence.com/actions/1654>

● **Cut bracken and rotovate**

One controlled study in the UK found that cutting followed by rotovating to control bracken did not increase total plant biomass or biomass of heather. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1656>

● **Use 'bracken bruiser' to control bracken**

One randomized, replicated, controlled, before-and-after, paired study in the UK found that bracken bruising increased bracken cover, though bracken cover also increased in areas where bracken bruising was not done. There was no effect on the number of plant species or plant diversity. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 7%).*

<https://www.conservationevidence.com/actions/1726>

● **Use herbicide and remove leaf litter to control bracken**

One randomized, controlled study in the UK found that using herbicide and removing leaf litter did not increase total plant biomass after eight years. The same study found that for three of six years, heather biomass was higher in areas where herbicide was sprayed and leaf litter was removed than in areas that were sprayed with herbicide. *Assessment: unknown effectiveness (effectiveness 27%; certainty 12%; harms 2%).*

<https://www.conservationevidence.com/actions/1660>



No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Cut and burn bracken
- Use herbicide and sow seed of shrubland plants to control bracken
- Increase grazing intensity to control bracken
- Use herbicide and increase livestock numbers to control bracken.

8.8.4 Problematic animals

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of problematic animals in shrublands and heathlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Use fences to exclude large herbivores • Reduce numbers of large herbivores
No evidence found (no assessment)	<ul style="list-style-type: none"> • Use biological control to reduce the number of problematic invertebrates

Unknown effectiveness (limited evidence)

● Use fences to exclude large herbivores

One controlled study in the USA found that using fences to exclude deer increased the height of shrubs, but not shrub cover. *Assessment: unknown effectiveness (effectiveness 7%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1662>

● Reduce numbers of large herbivores

One before-and-after trial in the USA found that removing feral sheep, cattle and horses increased shrub cover and reduced grass cover. One replicated

study in the UK found that reducing grazing pressure by red deer increased the cover and height of common heather. *Assessment: unknown effectiveness (effectiveness 70%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1663>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use biological control to reduce the number of problematic invertebrates.

8.9 Threat: Pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of pollution in shrublands and heathlands?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Mow shrubland to reduce impacts of pollutants ● Burn shrublands to reduce impacts of pollutants
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Plant vegetation to act as a buffer to exclude vegetation ● Reduce pesticide use on nearby agricultural/forestry land ● Reduce herbicide use on nearby agricultural/forestry land ● Reduce fertilizer use on nearby agricultural/forestry land ● Add lime to shrubland to reduce the impacts of sulphur dioxide pollution

Unknown effectiveness (limited evidence)

● **Mow shrubland to reduce impact of pollutants**

One randomized, replicated, controlled study in the UK found that mowing to reduce the impact of nitrogen deposition did not alter shoot length of common heather or the number of purple moor grass seedlings. One controlled study in the UK found that mowing a heathland affected by nitrogen pollution did not alter the cover or shoot length of heather

compared to areas where prescribed burning was used. *Assessment: unknown effectiveness (effectiveness 0%; certainty 17%; harms 0%).*

<https://www.conservationevidence.com/actions/1669>

● **Burn shrublands to reduce impacts of pollutants**

One randomized, replicated, controlled study in the UK found that prescribed burning to reduce the impact of nitrogen deposition did not alter the shoot length of common heather or the number of purple moor grass seedlings compared to mowing. A controlled study in the UK found that burning to reduce the concentration of pollutants in a heathland affected by nitrogen pollution did not alter the cover or shoot length of heather relative to areas that were mowed. *Assessment: unknown effectiveness (effectiveness 0%; certainty 17%; harms 0%).*

<https://www.conservationevidence.com/actions/1670>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Plant vegetation to act as a buffer to exclude vegetation
- Reduce pesticide use on nearby agricultural/forestry land
- Reduce herbicide use on nearby agricultural/forestry land
- Reduce fertilizer use on nearby agricultural/forestry land
- Add lime to shrubland to reduce the impacts of sulphur dioxide pollution.

8.10 Threat: Climate change and severe weather

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for managing the impacts of climate change and severe weather in shrublands and heathlands?

No evidence found (no assessment)

- Restore habitat in area predicted to have suitable habitat for shrubland species in the future
- Improve connectivity between areas of shrubland to allow species movements and habitat shifts in response to climate change

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restore habitat in area predicted to have suitable habitat for shrubland species in the future
- Improve connectivity between areas of shrubland to allow species movements and habitat shifts in response to climate change.

8.11 Threat: Habitat protection

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for habitat protection in shrublands and heathlands?

No evidence found (no assessment)	<ul style="list-style-type: none">• Legally protect shrubland• Legally protect habitat around shrubland
--	--

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Legally protect shrubland
- Legally protect habitat around shrubland.

8.12 Habitat restoration and creation

8.12.1 General restoration

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for general restoration of shrubland and heathland habitats?	
Likely to be beneficial	<ul style="list-style-type: none">● Allow shrubland to regenerate without active management
No evidence found (no assessment)	<ul style="list-style-type: none">● Restore/create connectivity between shrublands

Likely to be beneficial

● Allow shrubland to regenerate without active management

Five before-and-after trials (two of which were replicated) in the USA, UK, and Norway, found that allowing shrubland to recover after fire without any active management increased shrub cover or biomass. One replicated, paired, site comparison in the USA found that sites that were allowed to recover without active restoration had similar shrub cover to unburned areas. One controlled, before-and-after trial in the USA found no increase in shrub cover. One before-and-after trial in Norway found an increase in heather height. One before-and-after trial in Spain found that there was an increase in seedlings for one of three shrub species. Two replicated, randomized, controlled, before-and-after trials in Spain and Portugal found that there was an increase in the cover of woody plant species. One

before-and-after study in Spain found that cover of woody plants increased, but the number of woody plant species did not. One replicated, before-and-after study in South Africa found that the height of three protea species increased after recovery from fire. One before-and-after trial in South Africa found that there was an increase in vegetation cover, but not in the number of plant species. One before-and-after trial in South Africa found an increase in a minority of plant species. Two before-and-after trials in the USA and UK found that allowing shrubland to recover after fire without active management resulted in a decrease in grass cover or biomass. One controlled, before-and-after trial in the USA found an increase in the cover of a minority of grass species. One before-and-after study in Spain found that cover of herbaceous species declined. One replicated, before-and-after study in the UK found mixed effects on cover of wavy hair grass. One controlled, before-and-after trial in the USA found no increase in forb cover. One replicated, randomized, controlled before-and-after trial in Spain found that herb cover declined after allowing recovery of shrubland after fire. *Assessment: likely to be beneficial (effectiveness 62%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1679>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Restore/create connectivity between shrublands.

8.12.2 Modify physical habitat

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for restoring shrubland and heathland habitats by modifying the physical habitat?	
Likely to be beneficial	<ul style="list-style-type: none"> • Add topsoil
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Disturb vegetation • Strip topsoil • Remove leaf litter • Add sulphur to soil

	<ul style="list-style-type: none"> ● Use erosion blankets/mats to aid plant establishment ● Add mulch and fertilizer to soil ● Add manure to soil ● Irrigate degraded shrublands
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Remove trees/crops to restore shrubland structure ● Remove trees, leaf litter and topsoil ● Add peat to soil ● Burn leaf litter

Likely to be beneficial

● Add topsoil

Two randomized, controlled studies in the UK found that the addition of topsoil increased the cover or abundance of heathland plant species. One replicated, site comparison in Spain found an increase in the abundance of woody plants. One randomized, controlled study in the UK found an increase in the number of seedlings for a majority of heathland plants. One controlled study in Namibia found that addition of topsoil increased plant cover and the number of plant species, but that these were lower than at a nearby undisturbed site. One randomized, controlled study in the UK found an increase in the cover of forbs but a reduction in the cover of grasses. *Assessment: likely to be beneficial (effectiveness 67%; certainty 45%; harms 0%).*

<https://www.conservationevidence.com/actions/1686>

Unknown effectiveness (limited evidence)

● Disturb vegetation

One randomized, replicated, controlled study in the UK found that vegetation disturbance did not increase the abundance or species richness of specialist plants but increased the abundance of generalist plants. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 7%).*

<https://www.conservationevidence.com/actions/1727>

● **Strip topsoil**

Two randomized, replicated, controlled studies in the UK found that removal of topsoil did not increase heather cover or cover of heathland species. However, one controlled study in the UK found an increase in heather cover. One randomized, replicated, controlled study in the UK found that removing topsoil increased the cover of both specialist and generalist plant species, but did not increase species richness. One randomized, replicated, paired, controlled study in the UK found that removal of topsoil increased cover of annual grasses but led to a decrease in the cover of perennial grasses. One controlled study in the UK found that removal of turf reduced cover of wavy hair grass. One controlled, before-and-after trial in the UK found that stripping surface layers of soil increased the cover of gorse and sheep's sorrel as well as the number of plant species. *Assessment: unknown effectiveness (effectiveness 30%; certainty 25%; harms 3%).*

<https://www.conservationevidence.com/actions/1685>

● **Remove leaf litter**

One randomized, controlled study in the UK found that removing leaf litter did not alter the presence of heather. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1688>

● **Add sulphur to soil**

One randomized, replicated, controlled study in the UK found that adding sulphur to the soil of a former agricultural field did not increase the number of heather seedlings in five of six cases. *Assessment: unknown effectiveness (effectiveness 2%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1691>

● **Use erosion blankets/mats to aid plant establishment**

One replicated, randomized, controlled study in the USA found that using an erosion control blanket increased the height of two shrub species. One replicated, randomized, controlled study in the USA did not find an increase in the number of shrub species, but one controlled study in China did find an increase in plant diversity following the use of erosion control blankets.

The same study found an increase in plant biomass and cover. *Assessment: unknown effectiveness (effectiveness 30%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1692>

● Add mulch and fertilizer to soil

One randomized, controlled study in the USA found that adding mulch and fertilizer did not increase the seedling abundance of seven shrub species. The same study also reported no change in grass cover. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1694>

● Add manure to soil

One replicated, randomized, controlled study in South Africa found that adding manure increased plant cover and the number of plant species. *Assessment: unknown effectiveness (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1695>

● Irrigate degraded shrublands

One replicated, randomized, controlled study at two sites in USA found that temporary irrigation increased shrub cover. *Assessment: unknown effectiveness (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1696>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Remove trees/crops to restore shrubland structure
- Remove trees, leaf litter and topsoil
- Add peat to soil
- Burn leaf litter.

8.12.3 Introduce vegetation or seeds

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for restoring shrubland and heathland habitats by introducing vegetation or seeds?	
Beneficial	<ul style="list-style-type: none"> ● Sow seeds
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Plant individual plants ● Sow seeds and plant individual plants ● Spread clippings ● Build bird perches to encourage colonization by plants ● Plant turf

Beneficial

● Sow seeds

Five of six studies (including three replicated, randomized, controlled studies, one site comparison study and one controlled study) in the UK, South Africa, and the USA found that sowing seeds of shrubland species increased shrub cover. One of six studies in the UK found no increase in shrub cover. One replicated site comparison in the USA found in sites where seed containing Wyoming big sagebrush was sown the abundance of the plant was higher than in sites where it was not sown. One replicated, randomized, controlled study in the USA found that shrub seedling abundance increased after seeds were sown. One study in the USA found very low germination of hackberry seeds when they were sown. One replicated, randomized, controlled study in the USA found that the community composition of shrublands where seeds were sown was similar to that found in undisturbed shrublands. One randomized, controlled study in the UK found an increase in the cover of heathland plants when seeds were sown. One replicated, randomized, controlled study in South Africa found that sowing seeds increased plant cover. One replicated, randomized, controlled study in the USA found that areas where seeds were sown did not differ significantly in native cover compared to areas where shrubland plants had been planted. One controlled study in the USA

found higher plant diversity in areas where seeds were sown by hand than in areas where they were sown using a seed drill. Two of three studies (one of which was a replicated, randomized, controlled study) in the USA found that sowing seeds of shrubland species resulted in an increase in grass cover. One randomized, controlled study in the UK found no changes in the cover of grasses or forbs. *Assessment: beneficial (effectiveness 70%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1698>

Unknown effectiveness (limited evidence)

● Plant individual plants

One replicated, randomized, controlled study in the USA found that planting California sagebrush plants did not increase the cover of native plant species compared to sowing of seeds or a combination of planting and sowing seeds. One replicated, randomized, controlled study in South Africa found that planting *Brownanthus pseudoschlichtianus* plants increased plant cover, but not the number of plant species. One study in the USA found that a majority of planted plants survived after one year. *Assessment: unknown effectiveness (effectiveness 40%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1697>

● Sow seeds and plant individual plants

One replicated, controlled study in the USA found that planting California sagebrush and sowing of seeds did not increase cover of native plant species compared to sowing of seeds, or planting alone. *Assessment: unknown effectiveness (effectiveness 10%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1700>

● Spread clippings

One randomized, controlled study in the UK found that the addition of shoots and seeds of heathland plants did not increase the abundance of mature plants for half of plant species. One randomized, controlled study in the UK found that the frequency of heather plants was not significantly different in areas where heather clippings had been spread and areas where

they were not spread. One replicated, randomized, controlled study in the UK found an increase in the number of heather seedlings, but not of other heathland species. One randomized, controlled study in the UK found that the addition of shoots and seeds increased the number of seedlings for a minority of species. One replicated, randomized, controlled study in South Africa found that plant cover and the number of plant species did not differ significantly between areas where branches had been spread and those where branches had not been spread. *Assessment: unknown effectiveness (effectiveness 30%; certainty 32%; harms 0%).*

<https://www.conservationevidence.com/actions/1701>

● **Build bird perches to encourage colonization by plants**

One replicated, controlled study in South Africa found that building artificial bird perches increased the number of seeds at two sites, but no shrubs became established at either of these sites. *Assessment: unknown effectiveness (effectiveness 10%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1702>

● **Plant turf**

Two randomized, controlled studies in the UK found that planting turf from intact heathland sites increased the abundance or cover of heathland species. One of these studies also found that planting turf increased the seedling abundance for a majority of heathland plant species. One randomized, controlled study in the UK found that planting turf increased forb cover, and reduced grass cover. One randomized, replicated, controlled study in Iceland found that planting large turves from intact heathland sites increased the number of plant species, but smaller turves did not. *Assessment: unknown effectiveness (effectiveness 62%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1703>

8.13 Actions to benefit introduced vegetation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to benefit introduced vegetation in shrubland heathland habitats?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Add fertilizer to soil (alongside planting/seeding)● Add peat to soil (alongside planting/seeding)● Add mulch and fertilizer to soil (alongside planting/seeding)● Add gypsum to soil (alongside planting/seeding)● Add sulphur to soil (alongside planting/seeding)● Strip/disturb topsoil (alongside planting/seeding)● Add topsoil (alongside planting/seeding)● Plant seed balls● Plant/sow seeds of nurse plants alongside focal plants● Plant/seed under established vegetation● Plant shrubs in clusters● Add root associated bacteria/fungi to introduced plants

Unknown effectiveness (limited evidence)

● **Add fertilizer to soil (alongside planting/seeding)**

A replicated, controlled study in Iceland found that adding fertilizer and sowing seeds increased cover of shrubs and trees in a majority of cases. The same study showed an increase in vegetation cover in two of three cases. One controlled study in the USA found that adding fertilizer increased the

biomass of four-wing saltbush in a majority of cases. *Assessment: unknown effectiveness (effectiveness 45%; certainty 25%; harms 0%).*

<https://www.conservationevidence.com/actions/1704>

● **Add peat to soil (alongside planting/seeding)**

One replicated, randomized, controlled study in the UK found that adding peat to soil and sowing seed increased the cover of common heather in the majority of cases, compared to seeding alone. One replicated, randomized, controlled study in the UK found that adding peat to soil and sowing seed increased the density of heather seedlings, and led to larger heather plants than seeding alone, but that no seedlings survived after two years. *Assessment: unknown effectiveness (effectiveness 42%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1705>

● **Add mulch and fertilizer to soil (alongside planting/seeding)**

A randomized, controlled study in the USA found that adding mulch and fertilizer, followed by sowing of seeds increased the abundance of seedlings for a minority of shrub species. The same study found that adding mulch and fertilizer, followed by sowing seeds had no significant effect on grass cover. *Assessment: unknown effectiveness (effectiveness 35%; certainty 15%; harms 0%).*

<https://www.conservationevidence.com/actions/1707>

● **Add gypsum to soil (alongside planting/seeding)**

One randomized, controlled study in South Africa found that adding gypsum to soils and sowing seeds increased survival of seedlings for one of two species. *Assessment: unknown effectiveness (effectiveness 30%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1708>

● **Add sulphur to soil (alongside planting/seeding)**

A randomized, replicated, controlled study in the UK found that adding sulphur to soil alongside sowing seeds did not increase heather cover in a majority of cases. One replicated, controlled study in the UK found that

adding sulphur and spreading heathland clippings had mixed effects on cover of common heather, perennial rye-grass, and common bent. One randomized, controlled study in the UK found that adding sulphur to soil alongside planting of heather seedlings increased their survival, though after two years survival was very low. *Assessment: unknown effectiveness (effectiveness 20%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1710>

● **Strip/disturb topsoil (alongside planting/seeding)**

Two replicated, controlled studies in the UK found that removal of topsoil and addition seed/clippings increased cover of heathland plants or cover of heather and gorse. One controlled study in the UK found that soil disturbance using a rotovator and spreading clippings of heathland plants (alongside mowing) increased the number of heathland plants. One replicated, controlled study in the UK found that stripping the surface layers of soil and adding seed reduced the cover of perennial rye-grass. One randomized, replicated, paired, and controlled study in the UK found that removal of topsoil and addition of the clippings of heathland plants did not alter the cover of annual grasses but led to a decrease in cover of perennial grasses. *Assessment: unknown effectiveness (effectiveness 60%; certainty 35%; harms 0%).*

<https://www.conservationevidence.com/actions/1711>

● **Add topsoil (alongside planting/seeding)**

One randomized, replicated, paired, controlled study in the USA found that addition of topsoil alongside sowing of seed increased the biomass of grasses but reduced the biomass of forbs in comparison to addition of topsoil alone. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1857>

● **Plant seed balls**

A randomized, replicated, controlled study in the USA found that planting seed balls resulted in lower seedling numbers than sowing seed. *Assessment: unknown effectiveness (effectiveness 0%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1712>

● **Plant/sow seeds of nurse plants alongside focal plants**

A randomized, replicated, controlled study in the UK found that sowing seeds of nurse plants and heathland plants did not increase the cover of common heather. One replicated, randomized, controlled study in the USA found that sowing seeds of nurse plants and California sagebrush seeds together reduced survival of shrubs in more than half of cases. The same study found that California sagebrush biomass was also reduced when its seeds were sown with those of nurse plants. *Assessment: unknown effectiveness (effectiveness 0%; certainty 20%; harms 10%).*

<https://www.conservationevidence.com/actions/1713>

● **Plant/seed under established vegetation**

A replicated, randomized, controlled study in the USA found that sowing seed under established shrubs had mixed effects on blackbrush seedling emergence. *Assessment: unknown effectiveness (effectiveness 20%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1714>

● **Plant shrubs in clusters**

A randomized, controlled study in South Africa found that when shrubs were planted in clumps more of them died than when they were planted alone. *Assessment: unknown effectiveness (effectiveness 0%; certainty 15%; harms 1%).*

<https://www.conservationevidence.com/actions/1715>

● **Add root associated bacteria/fungi to introduced plants**

Two controlled studies (one of which was randomized) in Spain found that adding rhizobacteria to soil increased the biomass of shrubs. One of these studies also found an increase in shrub height. *Assessment: unknown effectiveness (effectiveness 60%; certainty 15%; harms 0%).*

<https://www.conservationevidence.com/actions/1716>

8.14 Education and awareness

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for education and awareness of shrubland and heathland habitats?

No evidence found (no assessment)	<ul style="list-style-type: none">• Raise awareness amongst the general public• Provide education programmes about shrublands
--	--

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Raise awareness amongst the general public
- Provide education programmes about shrublands.

9. MANAGEMENT OF CAPTIVE ANIMALS

Coral S. Jonas, Lydia T. Timbrell, Fey Young, Silviu O. Petrovan, Andrew E. Bowkett & Rebecca K. Smith

Husbandry interventions for captive breeding amphibians

Expert assessors

Kay Bradfield, Perth Zoo, Australia

Jeff Dawson, Durrell Wildlife Conservation Trust, UK

Devin Edmonds, Association Mitsinjo, Madagascar

Jonathan Kolby, Honduras Amphibian Rescue and Conservation Center, Honduras

Stephanie Jayson, Veterinary Department, Zoological Society of London, UK

Daniel Nicholson, Queen Mary University of London, UK

Silviu O. Petrovan, Cambridge University, UK and Froglife Trust, UK

Jay Redbond, Wildfowl & Wetlands Trust, UK

Rebecca K. Smith, Cambridge University, UK

Benjamin Tapley, Herpetology Section, Zoological Society of London, UK

Scope of assessment: for husbandry interventions for captive breeding amphibians.

Assessed: 2017.

Promoting health and welfare in captive carnivores (felids, canids and ursids) through feeding practices

Expert assessors

Kathy Baker, Whitley Wildlife Conservation Trust, Newquay Zoo, UK

Marcus Clauss, University of Zurich, Switzerland

Ellen Dierenfeld, Independent comparative nutrition consultant, USA

Thomas Quirke, University College Cork, Republic of Ireland

Joanna Newbolt, Whitley Wildlife Conservation Trust, Paignton Zoo, and University of Plymouth, UK

Simon Marsh, Yorkshire Wildlife Wildlife Park, UK

Amy Plowman, Whitley Wildlife Conservation Trust, Paignton Zoo, UK

Katherine Whitehouse-Tedd, Nottingham Trent University, UK

Gwen Wirobski, University of Veterinary Medicine Vienna, Austria

Scope of assessment: for promoting health and welfare in captive carnivores (felids, canids and ursids) through feeding practices.

Assessed: 2018.

Promoting natural feeding behaviours in primates in captivity

Expert assessors

Francis Cabana, Wildlife Reserves Singapore, Singapore

Po-Han Chou, Taipei Zoo, Taiwan

Ellen Dierenfeld, Independent comparative nutrition consultant, USA

Mike Downman, Dartmoor Zoo, UK

Craig Gilchrist, Paignton Zoo, UK

Amy Plowman, Whitley Wildlife Conservation Trust, Paignton Zoo, UK

Scope of assessment: for promoting natural feeding behaviours in captive primates.

Assessed: 2017.

Effectiveness measure is the median % score for effectiveness.

Certainty measure is the median % certainty of evidence for effectiveness, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects on the species included.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

9.1 *Ex-situ* conservation – breeding amphibians

9.1.1 Refining techniques using less threatened species

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for refining techniques using less threatened species?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Identify and breed a similar species to refine husbandry techniques prior to working with target species

Unknown effectiveness (limited evidence)

● Identify and breed a similar species to refine husbandry techniques prior to working with target species

Two small, replicated interlinked studies in Brazil found that working with a less threatened surrogate species of frog first to establish husbandry interventions promoted successful breeding of a critically endangered species of frog. *Assessment: unknown effectiveness (effectiveness 68%; certainty 30%; harms 15%).*

<https://www.conservationevidence.com/actions/1862>

9.1.2 Changing environmental conditions/microclimate

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for changing environmental conditions/microclimate?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Vary enclosure temperature to simulate seasonal changes in the wild ● Vary quality or quantity (UV% or gradients) of enclosure lighting to simulate seasonal changes in the wild ● Provide artificial aquifers for species which breed in upwelling springs ● Vary artificial rainfall to simulate seasonal changes in the wild
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Vary enclosure humidity to simulate seasonal changes in the wild using humidifiers, foggers/ misters or artificial rain ● Vary duration of enclosure lighting to simulate seasonal changes in the wild ● Simulate rainfall using sound recordings of rain and/or thunderstorms ● Allow temperate amphibians to hibernate ● Allow amphibians from highly seasonal environments to have a period of dormancy during a simulated drought period ● Vary water flow/speed of artificial streams in enclosures for torrent breeding species

Unknown effectiveness (limited evidence)

● Vary enclosure temperature to simulate seasonal changes in the wild

One small, replicated study in Italy found that one of six females bred following a drop in temperature from 20-24 to 17°C, and filling of an

egg laying pond. One replicated, before-and-after study in 2006-2012 in Australia found that providing a pre-breeding cooling period, alongside allowing females to gain weight before the breeding period, along with separating sexes during the non-breeding period, providing mate choice for females and playing recorded mating calls, increased breeding success. *Assessment: unknown effectiveness (effectiveness 50%; certainty 35%; harms 0%).*

<https://www.conservationevidence.com/actions/1864>

● **Vary quality or quantity (UV% or gradients) of enclosure lighting to simulate seasonal changes in the wild**

One replicated study in the UK found that there was no difference in clutch size between frogs given an ultraviolet (UV) boost compared with those that only received background levels. However, frogs given the UV boost had a significantly greater fungal load than frogs that were not UV-boosted. *Assessment: unknown effectiveness (effectiveness 0%; certainty 33%; harms 20%).*

<https://www.conservationevidence.com/actions/1865>

● **Provide artificial aquifers for species which breed in upwelling springs**

One small study in the USA found that salamanders bred in an aquarium fitted with an artificial aquifer. *Assessment: unknown effectiveness (effectiveness 50%; certainty 15%; harms 0%).*

<https://www.conservationevidence.com/actions/1871>

● **Vary artificial rainfall to simulate seasonal changes in the wild**

Two replicated, before-and-after studies in Germany and Austria found that simulating a wet and dry season, as well as being moved to an enclosure with more egg laying sites and flowing water in Austria, stimulated breeding and egg deposition. In Germany, no toadlets survived past 142 days old. *Assessment: unknown effectiveness (effectiveness 78%; certainty 33%; harms 0%).*

<https://www.conservationevidence.com/actions/1872>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Vary enclosure humidity to simulate seasonal changes in the wild using humidifiers, foggers/misters or artificial rain
- Vary duration of enclosure lighting to simulate seasonal changes in the wild
- Simulate rainfall using sound recordings of rain and/or thunderstorms
- Allow temperate amphibians to hibernate
- Allow amphibians from highly seasonal environments to have a period of dormancy
- Vary water flow/speed of artificial streams in enclosures for torrent breeding species

9.1.3 Changing enclosure design for spawning or egg laying sites

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for changing enclosure design for spawning or egg laying sites?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Provide multiple egg laying sites within an enclosure• Provide natural substrate for species which do not breed in water (e.g. burrowing/tunnel breeders)• Provide particular plants as breeding areas or egg laying sites

Unknown effectiveness (limited evidence)

● Provide multiple egg laying sites within an enclosure

One replicated study in Australia found that frogs only bred once moved into an indoor enclosure which had various types of organic substrate, allowed temporary flooding, and enabled sex ratios to be manipulated along with playing recorded mating calls. One small, replicated, before-and-after study in Fiji found that adding rotting logs and hollow bamboo pipes to an enclosure, as well as a variety of substrates, promoted egg laying in frogs. *Assessment: unknown effectiveness (effectiveness 50%; certainty 25%; harms 0%).*

<https://www.conservationevidence.com/actions/1873>

● Provide natural substrate for species which do not breed in water (e.g. burrowing/tunnel breeders)

Two replicated studies in Australia and Fiji found that adding a variety of substrates to an enclosure, as well as rotting logs and hollow bamboo pipes in one case, promoted egg laying of frogs. The Australian study also temporarily flooded enclosures, manipulated sex ratios and played recorded mating calls. *Assessment: unknown effectiveness (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1874>

● Provide particular plants as breeding areas or egg laying sites

One small, controlled study in the USA found that salamanders bred in an aquarium heavily planted with java moss and swamp-weed. *Assessment: unknown effectiveness (effectiveness 75%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1875>

9.1.4 Manipulate social conditions

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for manipulating social conditions?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Manipulate sex ratio within the enclosure● Separate sexes in non-breeding periods● Play recordings of breeding calls to simulate breeding season in the wild● Allow female mate choice
No evidence found (no assessment)	<ul style="list-style-type: none">● Provide visual barriers for territorial species● Manipulate adult density within the enclosure

Unknown effectiveness (limited evidence)

● Manipulate sex ratio within the enclosure

One replicated study in Australia found that frogs only bred once sex ratios were manipulated, along with playing recorded mating calls and moving frogs into an indoor enclosure which allowed temporary flooding, and had various types of organic substrate. *Assessment: unknown effectiveness (effectiveness 35%; certainty 15%; harms 0%).*

<https://www.conservationevidence.com/actions/1879>

● Separate sexes in non-breeding periods

One replicated, before-and-after study in Australia found that clutch size of frogs increased when sexes were separated in the non-breeding periods, alongside providing female mate choice, playing recorded mating calls and allowing females to increase in weight before breeding. *Assessment: unknown effectiveness (effectiveness 65%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1880>

● Play recordings of breeding calls to simulate breeding season in the wild

One replicated study in Australia found that frogs only bred when recorded mating calls were played, as well as manipulating the sex ratio after frogs were moved into an indoor enclosure that allowed temporary flooding and had various types of organic substrates. One replicated, before-and-after study in Australia found that clutch size of frogs increased when playing recorded mating calls, along with the sexes being separated in the non-breeding periods, providing female mate choice, and allowing females to increase in weight before breeding. *Assessment: unknown effectiveness (effectiveness 35%; certainty 28%; harms 0%).*

<https://www.conservationevidence.com/actions/1881>

● Allow female mate choice

One replicated study in Australia found that frogs only bred after females carrying eggs were introduced to males, sex ratios were manipulated, recorded mating calls were played, and after being moved to an indoor enclosure which allowed temporary flooding and had various types of organic substrates.

One replicated, before-and-after study in Australia found that clutch size of frogs increased when female mate choice was provided, alongside playing recorded mating calls, sexes being separated in the non-breeding periods, and allowing females to increase in weight before breeding. *Assessment: unknown effectiveness (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1882>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide visual barriers for territorial species
- Manipulate adult density within the enclosure.

9.1.5 Changing the diet of adults

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for changing the diet of adults?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Supplement diets with carotenoids (including for colouration)● Increase caloric intake of females in preparation for breeding
No evidence found (no assessment)	<ul style="list-style-type: none">● Vary food provision to reflect seasonal availability in the wild● Formulate adult diet to reflect nutritional composition of wild foods● Supplement diets with vitamins/calcium fed to prey (e.g. prey gut loading)● Supplement diets with vitamins/calcium applied to food (e.g. dusting prey)

Unknown effectiveness (limited evidence)

● Supplement diets with carotenoids (including for colouration)

One study in the USA found that adding carotenoids to fruit flies fed to frogs reduced the number of clutches, but increased the number of tadpoles and successful metamorphs. *Assessment: unknown effectiveness (effectiveness 70%; certainty 28%; harms 0%).*

<https://www.conservationevidence.com/actions/1887>

● Increase caloric intake of females in preparation for breeding

One replicated, before-and-after study in Australia found that clutch size of frogs increased when females increased in weight before breeding, as well as having mate choice, recorded mating calls, and sexes being separated

during the non-breeding periods. *Assessment: unknown effectiveness (effectiveness 60%; certainty 23%; harms 0%).*

<https://www.conservationevidence.com/actions/1888>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Vary food provision to reflect seasonal availability in the wild
- Formulate adult diet to reflect nutritional composition of wild foods
- Supplement diets with vitamins/calcium fed to prey (e.g. prey gut loading)
- Supplement diets with vitamins/calcium applied to food (e.g. dusting prey).

9.1.6 Manipulate rearing conditions for young

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for manipulating rearing conditions for the young	
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Manipulate temperature of enclosure to improve development or survival to adulthood
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Formulate larval diets to improve development or survival to adulthood • Manipulate larval density within the enclosure
No evidence found (no assessment)	<ul style="list-style-type: none"> • Leave infertile eggs at spawn site as food for egg-eating larvae • Manipulate humidity to improve development or survival to adulthood • Manipulate quality and quantity of enclosure lighting to improve development or survival to adulthood • Allow adults to attend their eggs

Trade-off between benefit and harms

● Manipulate temperature of enclosure to improve development or survival to adulthood

One replicated study in Spain found that salamander larvae had higher survival rates when reared at lower temperatures. One replicated study in Germany found that the growth rate and development stage reached by harlequin toad tadpoles was faster at a higher constant temperature rather than a lower and varied water temperature. One replicated study in Australia found that frog tadpoles took longer to reach metamorphosis when reared at lower temperatures. One replicated, controlled study in Iran found that developing eggs reared within a temperature range of 12-25°C had higher survival rates, higher growth rates and lower abnormalities than those raised outside of that range. *Assessment: trade-offs between benefits and harms (effectiveness 80%; certainty 58%; harms 20%).*

<https://www.conservationevidence.com/actions/1893>

Unknown effectiveness (limited evidence)

● Formulate larval diets to improve development or survival to adulthood

One randomized, replicated, controlled study in the USA found that tadpoles had higher body mass and reached a more advanced developmental stage when fed a control diet (rabbit chow and fish food) or freshwater algae, compared to those fed pine or oak pollen. One randomized, replicated study in Portugal found that tadpoles reared on a diet containing 46% protein had higher growth rates, survival and body weights at metamorphosis compared to diets containing less protein. *Assessment: unknown effectiveness (effectiveness 65%; certainty 35%; harms 0%).*

<https://www.conservationevidence.com/actions/1889>

● Manipulate larval density within the enclosure

One randomized study in the USA found that decreasing larval density of salamanders increased larvae survival and body mass. *Assessment: unknown effectiveness (effectiveness 88%; certainty 28%; harms 0%).*

<https://www.conservationevidence.com/actions/1894>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Leave infertile eggs at spawn site as food for egg-eating larvae
- Manipulate humidity to improve development or survival to adulthood
- Manipulate quality and quantity of enclosure lighting to improve development or survival to adulthood
- Allow adults to attend their eggs.

9.1.7 Artificial reproduction

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for artificial reproduction?	
No evidence found (no assessment)	• Use artificial cloning from frozen or fresh tissue

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Use artificial cloning from frozen or fresh tissue

For summarised evidence for

- Use hormone treatment to induce sperm and egg release
- Use artificial fertilization in captive breeding

See Smith, R.K. and Sutherland, W.J. (2014) *Amphibian Conservation: Global Evidence for the Effects of Interventions*. Exeter, Pelagic Publishing.

Key messages and summaries are available here:

<https://www.conservationevidence.com/actions/834>

<https://www.conservationevidence.com/actions/883>

9.2 Promoting health and welfare in captive carnivores (felids, canids and ursids) through feeding practices

9.2.1 Diet and food type

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for diet and food type?	
Likely to be beneficial	<ul style="list-style-type: none"> ● Provide bones, hides or partial carcasses
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Feed whole carcasses (with or without organs/ gastrointestinal tract)
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Feed commercially prepared diets ● Feed plant-derived protein ● Supplement meat-based diets with prebiotic plant material to facilitate digestion ● Supplement meat-based diet with amino acids
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Supplement meat-based diet with vitamins or minerals ● Supplement meat-based diet with fatty acids ● Increase variety of food items

Likely to be beneficial

● Provide bones, hides or partial carcasses

One replicated, before-and-after study in the USA and one replicated, controlled study in Finland found that the provision of bones decreased the frequency of stereotypic behaviours in lions, tigers and Arctic foxes. Two replicated, before-and-after studies of felids and red foxes in the USA and Norway found that the provision of bones increased activity and manipulation time. *Assessment: likely to be beneficial (effectiveness 80%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1902>

Trade-off between benefit and harms

● Feed whole carcasses (with or without organs/gastrointestinal tract)

Two replicated, before-and-after studies in the USA found that feeding whole carcasses reduced pacing levels in lions, leopards, snow leopards and cougars. However, it increased pacing in tigers. One replicated, randomized, controlled study in Denmark found that when fed whole rabbit, cheetahs had lower blood protein urea, zinc and vitamin A levels compared to supplemented beef. One replicated before-and-after study in Denmark found that feeding whole rabbit showed lower levels of inflammatory bowel indicators in cheetahs. One replicated, randomized study and one controlled study in the USA found that when fed whole 1 to 3 day old chickens, ocelots had lower digestible energy and fat compared to a commercial diet and African wildcats had had lower organic matter digestibility compared to a ground-chicken diet. *Assessment: trade-offs between benefits and harms (effectiveness 80%; certainty 70%; harms 25%).*

<https://www.conservationevidence.com/actions/1901>

Unknown effectiveness (limited evidence)

● Feed commercially prepared diets

One replicated, before-and-after study in the USA found that providing a commercial diet to maned wolves led to similar dry matter intake and digestibility despite having a lower protein content. One replicated, controlled study in South Africa found that cheetahs fed a commercial diet had a similar likelihood of developing gastritis as those fed horse meat, lower levels of blood protein urea but higher levels of creatine. One study in USA found that cheetahs fed a commercial meat diet or whole chicken carcasses had plasma a-tocopherol, retinol and taurine concentrations within the ranges recommended for domestic cats. *Assessment: unknown effectiveness (effectiveness 40%; certainty 35%; harms 50%).*

<https://www.conservationevidence.com/actions/1900>

● Feed plant-derived protein

One replicated, randomized, controlled study and one replicated, controlled study in the USA found that a plant-derived protein diet increased digestible energy and dry matter digestibility but decreased mineral retention and plasma taurine levels in maned wolves compared to a (supplemented) animal-based protein diet. *Assessment: unknown effectiveness (effectiveness 10%; certainty 25%; harms 70%).*

<https://www.conservationevidence.com/actions/1903>

● Supplement meat-based diets with prebiotic plant material to facilitate digestion

One replicated, before-and-after study in India found that providing Jerusalem artichoke as a supplement increased two types of gut microbiota, faecal scores and faecal moisture content in leopards. *Assessment: unknown effectiveness (effectiveness 50%; certainty 25%; harms 0%).*

<https://www.conservationevidence.com/actions/1905>

● Supplement meat-based diet with amino acid

One replicated, before-and-after study in the USA found that supplementing an animal-protein diet with taurine, increased plasma taurine levels in

maned wolves. *Assessment: unknown effectiveness (effectiveness 90%; certainty 25%; harms 0%).*

<https://www.conservationevidence.com/actions/1908>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Supplement meat-based diet with vitamins or minerals
- Supplement meat-based diet with fatty acids
- Increase variety of food items.

9.2.2 Food presentation and enrichment

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for food presentation and enrichment?	
Beneficial	<ul style="list-style-type: none"> • Hide food around enclosure
Likely to be beneficial	<ul style="list-style-type: none"> • Present food frozen in ice • Present food inside objects (e.g. Boomer balls)
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Provide devices to simulate live prey, including sounds, lures, pulleys and bungees
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Change location of food around enclosure • Scatter food around enclosure • Provide live vertebrate prey • Provide live invertebrate prey
No evidence found (no assessment)	<ul style="list-style-type: none"> • Present food in/on water

Beneficial

● Hide food around enclosure

Four replicated, before-and-after studies in the USA, UK and Germany and one before-and-after study of a black bear, leopard cats, bush dogs, maned wolves and Malayan sun bears found that hiding food increased exploring and foraging behaviours. One replicated, before-and-after study and one before-and-after study in the USA found a decrease in stereotypical pacing

in leopard cats and black bear. One before-and-after study in the USA found that hiding food reduced the time Canadian lynx spent sleeping during the day. *Assessment: beneficial (effectiveness 90%; certainty 70%; harms 10%).*

<https://www.conservationevidence.com/actions/1915>

Likely to be beneficial

● Present food frozen in ice

Two replicated, before-and-after studies in the USA found that when presented with food frozen in ice, abnormal or stereotypic behaviours decreased and activity levels increased in bears and felids. One replicated, before-and-after study in the USA found that manipulation behaviours increased in lions, whereas a replicated study in the USA found that manipulation behaviours decreased in grizzly bears. *Assessment: likely to be beneficial (effectiveness 70%; certainty 52%; harms 10%).*

<https://www.conservationevidence.com/actions/1923>

● Present food inside objects (e.g. Boomer balls)

Two before-and-after studies in Germany and India found that exploratory and foraging behaviours increased and stereotypic behaviours decreased in sloth bears and spectacled bears when presented with food inside objects. One before-and-after study in the USA found that exploring/foraging behaviours decreased in a sloth bear when presented with food inside objects. One replicated study in the USA found that grizzly bears spent a similar time manipulating food in a box and freely available food. *Assessment: likely to be beneficial (effectiveness 60%; certainty 70%; harms 10%).*

<https://www.conservationevidence.com/actions/1924>

Trade-off between benefit and harms

● Provide devices to simulate live prey, including sounds, lures, pulleys and bungees

Two before-and-after studies in the USA and the UK found that activity levels and behavioural diversity increased in felids when presented with a lure or pulley system. One replicated, before-and-after study in the USA found that pacing behaviour decreased and walking increased in cougars,

but pacing initially increased in tigers, when provided with a carcass on a bungee. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 50%; harms 25%).*

<https://www.conservationevidence.com/actions/1927>

Unknown effectiveness (limited evidence)

● Change location of food around enclosure

One replicated, before-and-after study in Ireland found that altering the location of food decreased pacing behaviours in cheetahs. *Assessment: unknown effectiveness (effectiveness 90%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1918>

● Scatter food around enclosure

One replicated, before-and-after study in Brazil found that scattered feeding increased locomotion in maned wolves. One replicated study in Brazil found that maned wolves spent more time in the section of their enclosure with scattered food than in a section with food on a tray. *Assessment: unknown effectiveness (effectiveness 70%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1921>

● Provide live vertebrate prey

One small before-and-after study in the USA found that hunting behaviour increased and sleeping decreased when a fishing cat was provided with live fish. One replicated, before-and-after study in the USA found that there was no change in the occurrence of stereotypical behaviours in tigers when provided with live fish. *Assessment: unknown effectiveness (effectiveness 50%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1925>

● Provide live invertebrate prey

One replicated study in the USA found that provision of live prey increased explorative behaviours in fennec foxes compared to other types of enrichment. *Assessment: unknown effectiveness (effectiveness 80%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1926>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Present food in/on water
- Use food as a reward in animal training.

9.2.3 Feeding schedule

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for feeding schedule?	
Trade-off between benefit and harms	<ul style="list-style-type: none"> • Provide food on a random temporal schedule
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Allocate fast days
No evidence found (no assessment)	<ul style="list-style-type: none"> • Alter food abundance or type seasonally • Provide food during natural active periods • Use automated feeders • Alter feeding schedule according to visitor activity • Provide food during visitor experiences

Trade-off between benefit and harms

● Provide food on a random temporal schedule

Three replicated, before-and-after studies and one replicated, controlled study found that an unpredictable feeding schedule reduced the frequency of stereotypic pacing behaviours in tigers and cheetahs. One replicated, before-and-after controlled study in the USA found that an unpredictable feeding schedule increased territorial behaviour in coyotes but did not affect travelling or foraging. One before-and-after study in Switzerland found that an unpredictable feeding schedule increased behavioural diversity in red foxes. *Assessment: trade-offs between benefits and harms (effectiveness 100%; certainty 80%; harms 20%).*

<https://www.conservationevidence.com/actions/1904>

Unknown effectiveness (limited evidence)

● Allocate fast days

One replicated, before-and-after study in the UK found that large felids fed once every three days paced more frequently on non-feeding days. *Assessment: unknown effectiveness (effectiveness 6%; certainty 25%; harms 50%).*

<https://www.conservationevidence.com/actions/1906>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Alter food abundance or type seasonally
- Provide food during natural active periods
- Use automated feeders
- Alter feeding schedule according to visitor activity
- Provide food during visitor experiences.

9.2.4 Social feeding

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for social feeding?	
No evidence found (no assessment)	<ul style="list-style-type: none">• Feed individuals separately• Feed individuals within a social group• Hand-feed

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Feed individuals separately
- Feed individuals within a social group
- Hand-feed.

9.3 Promoting natural feeding behaviours in primates in captivity

9.3.1 Food Presentation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for food presentation?	
Beneficial	<ul style="list-style-type: none"> ● Scatter food throughout enclosure
Likely to be beneficial	<ul style="list-style-type: none"> ● Hide food in containers (including boxes and bags) ● Present food frozen in ice ● Present food items whole instead of processed ● Present feeds at different crowd levels ● Maximise both vertical and horizontal presentation locations
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Present food in puzzle feeders
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Present food in water (including dishes and ponds) ● Present food dipped in food colouring ● Provide live vegetation in planters for foraging
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Present food which required the use (or modification) of tools ● Paint gum solutions on rough bark ● Add gum solutions to drilled hollow feeders

Beneficial

● Scatter food throughout enclosure

Four studies, including one replicated study, in the USA, found that scattering food throughout enclosures increased overall activity, feeding and exploration and decreased abnormal behaviours and aggression. *Assessment: beneficial (effectiveness 80%; certainty 80%; harms 0%).*

<https://www.conservationevidence.com/actions/1315>

Likely to be beneficial

● Hide food in containers (including boxes and bags)

Three studies including two before-and-after studies in the USA and Ireland found that the addition of food in boxes, baskets or tubes increased activity levels in lemurs and foraging levels in gibbons. *Assessment: likely to be beneficial (effectiveness 75%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1316>

● Present food frozen in ice

Two studies in the USA and Ireland found that when frozen food was presented, feeding time increased and inactivity decreased. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1321>

● Present food items whole instead of processed

One before-and-after study in the USA found that when food items were presented whole instead of chopped, the amount of food consumed and feeding time increased in macaques. *Assessment: likely to be beneficial (effectiveness 80%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1323>

● Present feeds at different crowd levels

One before-and-after study in the USA found that when smaller crowds were present foraging and object use in chimpanzees increased. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1324>

● Maximise both vertical and horizontal presentation locations

One controlled study in the UK and Madagascar found that less time was spent feeding on provisioned food in the indoor enclosure when food was hung in trees in an outdoor enclosure. One replicated, before-and-after study in the UK reported that when vertical and horizontal food locations were increased feeding time increased. *Assessment: likely to be beneficial (effectiveness 65%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1328>

Trade-off between benefit and harms

● Present food in puzzle feeders

Three studies including two before-and-after studies in the USA and UK found that presenting food in puzzle feeders, increased foraging behaviour, time spent feeding and tool use but also aggression. *Assessment: trade-offs between benefits and harms (effectiveness 55%; certainty 80%; harms 60%).*

<https://www.conservationevidence.com/actions/1318>

Unknown effectiveness (limited evidence)

● Present food in water (including dishes and ponds)

One replicated, before-and-after study in the USA found that when exposed to water filled troughs, rhesus monkeys were more active and increased their use of tools. *Assessment: unknown effectiveness (effectiveness 60%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1320>

● Present food dipped in food colouring

One before-and-after study in the USA found that when food was presented after being dipped in food colouring, orangutans ate more and spent less time feeding. *Assessment: unknown effectiveness (effectiveness 50%; certainty 20%; harms 20%).*

<https://www.conservationevidence.com/actions/1322>

● Provide live vegetation in planters for foraging

One replicated, before-and-after study in the USA reported that chimpanzees spent more time foraging when provided with planted rye grass and scattered sunflower seeds compared to browse and grass added to the enclosure with their normal diet. *Assessment: unknown effectiveness (effectiveness 80%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1327>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Present food which required the use (or modification) of tools
- Paint gum solutions on rough bark
- Add gum solutions to drilled hollow feeders.

9.3.2 Diet manipulation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for diet manipulation?	
Likely to be beneficial	<ul style="list-style-type: none">● Formulate diet to reflect nutritional composition of wild foods (including removal of domestic fruits)● Provide cut branches (browse)● Provide live invertebrates● Provide fresh produce
No evidence found (no assessment)	<ul style="list-style-type: none">● Provide gum (including artificial gum)● Provide nectar (including artificial nectar)● Provide herbs or other plants for self-medication● Modify ingredients/nutrient composition seasonally (not daily) to reflect natural variability

Likely to be beneficial

● **Formulate diet to reflect nutritional composition of wild foods (including removal of domestic fruits)**

Two replicated, before-and-after studies in the USA and UK found that when changing the diet of captive primates to reflect nutritional compositions of wild foods, there was a decrease in regurgitation and reingestion, aggression and self-directed behaviours. *Assessment: likely to be beneficial (effectiveness 70%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1329>

● **Provide cut branches (browse)**

One replicated, before-and-after study in the Netherlands and Germany found that captive gorillas when presented with stinging nettles use the same processing skills as wild gorillas to forage. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1332>

● Provide live invertebrates

One before-and-after study in the UK found that providing live invertebrates to captive lorises increased foraging levels and reduced inactivity. *Assessment: likely to be beneficial (effectiveness 85%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1333>

● Provide fresh produce

One replicated, before-and-after study in the USA found that when fresh produce was offered feeding time increased and inactivity decreased in rhesus macaques. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 1%).*

<https://www.conservationevidence.com/actions/1335>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide gum (including artificial gum)
- Provide nectar (including artificial nectar)
- Provide herbs or other plants for self-medication
- Modify ingredients/nutrient composition seasonally (not daily) to reflect natural variability.

9.3.3 Feeding Schedule

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for feeding schedule?	
Likely to be beneficial	<ul style="list-style-type: none">• Change feeding times
Trade-off between benefit and harms	<ul style="list-style-type: none">• Change the number of feeds per day
No evidence found (no assessment)	<ul style="list-style-type: none">• Provide food at natural (wild) feeding times• Provide access to food at all times (day and night)• Use of automated feeders

Likely to be beneficial

● Change feeding times

One controlled study in the USA found that changing feeding times decreased inactivity and abnormal behaviours in chimpanzees. *Assessment: likely to be beneficial (effectiveness 70%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1338>

Trade-off between benefit and harms

● Change the number of feeds per day

Two before-and-after studies in Japan and the USA found that changing the number of feeds per day increased time spent feeding in chimpanzees but also increased hair eating in baboons. *Assessment: trade-offs between benefits and harms (effectiveness 70%; certainty 50%; harms 50%).*

<https://www.conservationevidence.com/actions/1337>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Provide food at natural (wild) feeding times
- Provide access to food at all times (day and night)
- Use of automated feeders.

9.3.4 Social group manipulation

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for social group manipulation?	
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Feed individuals in social groups
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Feed individuals separately ● Feed individuals in subgroups

Trade-off between benefit and harms

● Feed individuals in social groups

One replicated, controlled study in the USA found that an enrichment task took less time to complete when monkeys were in social groups than when feeding alone. One before-and-after study in Italy found that in the presence of their groupmates monkeys ate more unfamiliar foods during the first encounter. *Assessment: trade-offs between benefits and harms (effectiveness 60%; certainty 50%; harms 25%).*

<https://www.conservationevidence.com/actions/1343>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Feed individuals separately
- Feed individuals in subgroups.

10. SOME ASPECTS OF CONTROL OF FRESHWATER INVASIVE SPECIES

David Aldridge, Nancy Ockendon, Ricardo Rocha, Rebecca K. Smith & William J. Sutherland

Expert assessors

David Aldridge, University of Cambridge, UK

Olaf Booy, Animal and Plant Health Agency, UK

Manuel A. Duenas, Centre for Ecology & Hydrology, UK

Alison Dunn, University of Leeds, UK

Robert Francis, King's College London, UK

Belinda Gallardo, Pyrenean Institute of Ecology, Spain

Nancy Ockendon, University of Cambridge, UK

Trevor Renals, Environment Agency, UK

Emmanuelle Sarat, International Union for Conservation of Nature, France

Sonal Varia, The Centre for Agriculture and Bioscience International, UK

Alexandra Zieritz, University of Nottingham, UK

Ana L. Nunes, The Centre for Agriculture and Bioscience International, UK

Deborah Hofstra, National Institute of Water and Atmospheric Research, New Zealand

Jonathan Newman, Waterland Management Ltd, UK

Johan van Valkenburg, National Plant Protection Organization, The Netherlands

Ryan Wersal, Lonza Water Care, Alpharetta, Georgia, US

Ricardo Rocha, University of Cambridge, UK

Scope of assessment: for the control of 12 invasive freshwater species.

Assessed: American bullfrog and *Procambarus* spp. crayfish 2015; parrot's feather 2017; all other species 2016.

Effectiveness measure is the median % score for effectiveness.

Certainty measure is the median % certainty of evidence for effectiveness, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects to non-target native species. This was not assessed for some species in this chapter.

Potential impacts on non-target species should be considered carefully before implementing any control action.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

10.1 Threat: Invasive plants

10.1.1 Parrot's feather *Myriophyllum aquaticum*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling parrot's feather?	
Beneficial	<ul style="list-style-type: none"> ● Chemical control using the herbicide 2,4-D
Likely to be beneficial	<ul style="list-style-type: none"> ● Chemical control using the herbicide carfentrazone-ethyl ● Chemical control using the herbicide triclopyr ● Chemical control using the herbicide diquat ● Chemical control using the herbicide endohall ● Chemical control using other herbicides ● Reduction of trade through legislation and codes of conduct
Trade-offs between benefit and harms	<ul style="list-style-type: none"> ● Biological control using herbivores
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Water level drawdown ● Biological control using plant pathogens
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Mechanical harvesting or cutting ● Mechanical excavation ● Removal using water jets ● Suction dredging and diver-assisted suction removal ● Manual harvesting (hand-weeding) ● Use of lightproof barriers

- | | |
|--|--|
| | <ul style="list-style-type: none">● Dye application● Biological control using fungal-based herbicides● Use of salt● Decontamination / preventing further spread● Public education● Multiple integrated measures |
|--|--|

Beneficial

● Chemical control using the herbicide 2,4-D

Five laboratory studies (three replicated, controlled and two randomized, controlled) in the USA and Brazil and two replicated, randomized, field studies in Portugal reported that treatment with 2,4-D reduced growth, biomass or cover of parrot's feather. *Assessment: beneficial (effectiveness 80%; certainty 80%; harms 0%).*

<https://www.conservationevidence.com/actions/1606>

Likely to be beneficial

● Chemical control using the herbicide carfentrazone-ethyl

Five laboratory studies (one replicated, controlled, before-and-after, three replicated, controlled and one randomized, controlled) in the USA reported that treatment with carfentrazone-ethyl reduced growth. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 5%).*

<https://www.conservationevidence.com/actions/1676>

● Chemical control using the herbicide triclopyr

Three replicated, controlled laboratory studies in the USA and New Zealand reported that treatment with triclopyr reduced growth or that cover was lower than that of plants treated with glyphosate. One replicated, controlled field study and one replicated, before-and-after field study in New Zealand reported that cover was reduced after treatment with triclopyr but one of these studies reported that cover later increased to near pre-treatment levels. *Assessment: likely to be beneficial (effectiveness 60%; certainty 55%; harms 0%).*

<https://www.conservationevidence.com/actions/1689>

● Chemical control using the herbicide diquat

Two replicated, controlled laboratory studies in the USA reported reduced growth after exposure to diquat. However, one replicated, randomized, controlled field study in Portugal reported no reduction in biomass following treatment with diquat. *Assessment: likely to be beneficial (effectiveness 60%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1680>

● Chemical control using the herbicide endohall

Two replicated, controlled laboratory studies in the USA and New Zealand reported a reduction in biomass after treatment with endothall. However, one replicated, controlled field study in New Zealand found that cover declined after treatment with endothall but later cover increased close to pre-treatment levels. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1681>

● Chemical control using other herbicides

One replicated, randomized, controlled field study in Portugal and one replicated, controlled, laboratory study in the USA reported reduced growth or vegetation cover after treatment with glyphosate. Two replicated, randomized, controlled laboratory studies (one of which was randomized) in the USA have found that the herbicide imazapyr reduced growth. Four replicated, controlled (one of which was randomized) laboratory studies in the USA and New Zealand reported reduced growth after treatment with the herbicides imazamox, flumioxazin, dichlobenil and florpyrauxifen-benzyl. Two replicated, controlled (one of which was randomized) field studies in Portugal and New Zealand reported a decrease in cover after treatment with dichlobenil followed by recovery. One replicated, randomized, controlled field study in Portugal reported reduced biomass after treatment with glyphosate-ammonium. Three replicated, controlled laboratory studies in New Zealand and the USA found no reduction in growth after treatment with clopyralid, copper chelate or fluridone. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1699>

● Reduction of trade through legislation and codes of conduct

One randomized, before-and-after trial in the Netherlands reported that the implementation of a code of conduct reduced the trade of invasive aquatic plants banned from sale. One study in the USA found that despite a state-wide trade ban on parrot's feather plants, these could still be purchased in some stores. *Assessment: likely to be beneficial (effectiveness 60%; certainty 45%; harms 0%).*

<https://www.conservationevidence.com/actions/1604>

Trade-off between benefit and harms

● Biological control using herbivores

Two replicated, randomized studies in Argentina and the USA found that stocking with grass carp reduced the biomass or abundance of parrot's feather. However, one controlled laboratory study in Portugal found that grass carp did not reduce biomass or cover of parrot's feather. One field study in South Africa found that one *Lysathia* beetle species retarded the growth of parrot's feather. *Assessment: trade-offs between benefits and harms (effectiveness 50%; certainty 40%; harms 20%).*

<https://www.conservationevidence.com/actions/1599>

Unknown effectiveness (limited evidence)

● Water level drawdown

One replicated, randomized, controlled laboratory study in the USA found that water removal to expose plants to drying during the summer led to lower survival of parrot's feather plants than water removal during winter. *Assessment: unknown effectiveness (effectiveness 60%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1585>

● Biological control using plant pathogens

One study in South Africa found that exposure to a strain of the bacterium *Xanthomonas campestris* did not affect the survival of parrot's feather. *Assessment: unknown effectiveness (effectiveness 5%; certainty 10%; harms 0%).*

<https://www.conservationevidence.com/actions/1601>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Mechanical harvesting or cutting
- Mechanical excavation
- Removal using water jets
- Suction dredging and diver-assisted suction removal
- Manual harvesting (hand-weeding)
- Use of lightproof barriers
- Dye application
- Biological control using fungal-based herbicides
- Use of salt
- Decontamination / preventing further spread
- Public education
- Multiple integrated measures

10.1.2 Floating pennywort *Hydrocotyle ranunculoides*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling floating pennywort?	
Beneficial	<ul style="list-style-type: none"> ● Chemical control using herbicides
Likely to be beneficial	<ul style="list-style-type: none"> ● Flame treatment ● Physical removal
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Combination treatment using herbicides and physical removal
Unlikely to be beneficial	<ul style="list-style-type: none"> ● Biological control using co-evolved, host-specific herbivores ● Use of hydrogen peroxide
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Biological control using fungal-based herbicides ● Biological control using native herbivores ● Environmental control (e.g. shading, reduced flow, reduction of rooting depth, or dredging) ● Excavation of banks ● Public education ● Use of liquid nitrogen

Beneficial

● Chemical control using herbicides

A controlled, replicated field study in the UK found that the herbicide 2,4-D amine achieved almost 100% mortality of floating pennywort, compared with the herbicide glyphosate (applied without an adjuvant) which achieved negligible mortality. *Assessment: beneficial (effectiveness 80%; certainty 70%).*

<https://www.conservationevidence.com/actions/1127>

Likely to be beneficial

● Flame treatment

A controlled, replicated study in the Netherlands found that floating pennywort plants were killed by a three second flame treatment with a

three second repeat treatment 11 days later. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%).*

<https://www.conservationevidence.com/actions/1131>

● **Physical removal**

Two studies, one in Western Australia and one in the UK, found physical removal did not completely eradicate floating pennywort. *Assessment: likely to be beneficial (effectiveness 40%; certainty 40%).*

<https://www.conservationevidence.com/actions/1126>

Unknown effectiveness (limited evidence)

● **Combination treatment using herbicides and physical removal**

A before-and-after study in Western Australia found that a combination of cutting followed by a glyphosate chemical treatment, removed floating pennywort. *Assessment: unknown effectiveness (effectiveness 70%; certainty 35%).*

<https://www.conservationevidence.com/actions/1128>

Unlikely to be beneficial

● **Biological control using co-evolved, host-specific herbivores**

A replicated laboratory and field study in South America found that the South American weevil fed on water pennywort but did not reduce the biomass. *Assessment: unlikely to be beneficial (effectiveness 20%; certainty 50%).*

<https://www.conservationevidence.com/actions/1123>

● **Use of hydrogen peroxide**

A controlled, replicated study in the Netherlands found that hydrogen peroxide sprayed on potted floating pennywort plants at 30% concentration resulted in curling and transparency of the leaves but did not kill the plants. *Assessment: unlikely to be beneficial (effectiveness 10%; certainty 60%).*

<https://www.conservationevidence.com/actions/1129>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control using fungal-based herbicides
- Biological control using native herbivores
- Environmental control (e.g. shading, reduced flow, reduction of rooting depth, or dredging)
- Excavation of banks
- Public education
- Use of liquid nitrogen.

10.1.3 Water primrose *Ludwigia spp.*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling water primrose?	
Likely to be beneficial	<ul style="list-style-type: none"> • Biological control using co-evolved, host specific herbivores • Chemical control using herbicides • Combination treatment using herbicides and physical removal
Unlikely to be beneficial	<ul style="list-style-type: none"> • Physical removal
No evidence found (no assessment)	<ul style="list-style-type: none"> • Biological control using fungal-based herbicides • Biological control using native herbivores • Environmental control (e.g. shading, altered flow, altered rooting depth, or dredging) • Excavation of banks • Public education • Use of a tarpaulin • Use of flame treatment • Use of hydrogen peroxide • Use of liquid nitrogen • Use of mats placed on the bottom of the water body

Likely to be beneficial

● Biological control using co-evolved, host specific herbivores

A controlled, replicated study in China, found a flea beetle caused heavy feeding destruction to the prostrate water primrose. A before-and-after study in the USA found that the introduction of flea beetles to a pond significantly reduced the abundance of large-flower primrose-willow. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%).*

<https://www.conservationevidence.com/actions/1135>

● Chemical control using herbicides

A controlled, replicated laboratory study in the USA found that the herbicide triclopyr TEA applied at concentrations of 0.25% killed 100% of young cultivated water primrose within two months. A before-and-after field study in the UK found that the herbicide glyphosate caused 97% mortality when mixed with a non-oil based sticking agent and 100% mortality when combined with TopFilm. A controlled, replicated, randomized study in Venezuela, found that use of the herbicide halosulfuron-methyl (Semptra) resulted in a significant reduction in water primrose coverage without apparent toxicity to rice plants. *Assessment: likely to be beneficial (effectiveness 80%; certainty 60%).*

<https://www.conservationevidence.com/actions/1139>

● Combination treatment using herbicides and physical removal

A study in the USA found that application of glyphosate and a surface active agent called Cygnet-Plus followed by removal by mechanical means killed 75% of a long-standing population of water primrose. A study in Australia found that a combination of herbicide application, physical removal, and other actions such as promotion of native plants and mulching reduced the cover of Peruvian primrose-willow by 85–90%. *Assessment: likely to be beneficial (effectiveness 70%; certainty 55%).*

<https://www.conservationevidence.com/actions/1140>

Unlikely to be beneficial

● Physical removal

A study in the USA found that hand pulling and raking water primrose failed to reduce its abundance at one site, whereas hand-pulling from the margins of a pond eradicated a smaller population of water primrose at a second site. *Assessment: unlikely to be beneficial (effectiveness 30%; certainty 50%).*

<https://www.conservationevidence.com/actions/1138>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control using fungal-based herbicides
- Biological control using native herbivores
- Environmental control (e.g. shading, reduced flow, reduction of rooting depth, or dredging)
- Excavation of banks
- Public education
- Use of a tarpaulin
- Use of flame treatment
- Use of hydrogen peroxide
- Use of liquid nitrogen
- Use of mats placed on the bottom of the waterbody.

10.1.4 Skunk cabbage *Lysichiton americanus*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling skunk cabbage?

Likely to be beneficial

- Chemical control using herbicides
- Physical removal

<p>No evidence found (no assessment)</p>	<ul style="list-style-type: none"> ● Biological control using co-evolved, host-specific herbivores ● Biological control using fungal-based herbicides ● Biological control using native herbivores ● Combination treatment using herbicides and physical removal ● Environmental control (e.g. shading, or promotion of native plants) ● Public education ● Use of a tarpaulin ● Use of flame treatment ● Use of hydrogen peroxide ● Use of liquid nitrogen
---	---

Likely to be beneficial

● Chemical control using herbicides

Two studies in the UK found that application of the chemical 2,4-D amine appeared to be successful in eradicating skunk cabbage stands. One of these studies also found glyphosate eradicated skunk cabbage. However, a study in the UK found that glyphosate did not eradicate skunk cabbage, but resulted in only limited reduced growth of plants. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%).*

<https://www.conservationevidence.com/actions/1102>

● Physical removal

Two studies in Switzerland and the Netherlands, reported effective removal of recently established skunk cabbage plants using physical removal, one reporting removal of the entire stock within five years. A third study in Germany reported that after four years of a twice yearly full removal programme, a large number of plants still needed to be removed each year. *Assessment: likely to be beneficial (effectiveness 65%; certainty 55%).*

<https://www.conservationevidence.com/actions/1101>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control using co-evolved, host-specific herbivores
- Biological control using fungal-based herbicides
- Biological control using native herbivores
- Combination treatment using herbicides and physical removal
- Environmental control (e.g. shading, or promotion of native plants)
- Public education
- Use of a tarpaulin
- Use of flame treatment
- Use of hydrogen peroxide
- Use of liquid nitrogen.

10.1.5 New Zealand pigmyweed *Crassula helmsii*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling <i>Crassula helmsii</i> ?	
Beneficial	<ul style="list-style-type: none"> • Chemical control using herbicides • Decontamination to prevent further spread
Likely to be beneficial	<ul style="list-style-type: none"> • Use lightproof barriers to control plants • Use salt water to kill plants
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Use a combination of control measures
Unlikely to be beneficial	<ul style="list-style-type: none"> • Use dyes to reduce light levels • Use grazing to control plants • Use hot foam to control plants • Use hydrogen peroxide to control plants
No evidence found (no assessment)	<ul style="list-style-type: none"> • Alter environmental conditions to control plants (e.g. shading by succession, increasing turbidity, re-profiling or dredging) • Biological control using fungal-based herbicides

	<ul style="list-style-type: none"> ● Biological control using herbivores ● Bury plants ● Dry out waterbodies ● Physical control using manual/mechanical control or dredging ● Plant other species to suppress growth ● Public education ● Surround with wire mesh ● Use flame throwers ● Use hot water ● Use of liquid nitrogen
--	---

Beneficial

● Chemical control using herbicides

Seven studies in the UK, including one replicated, controlled study, found that applying glyphosate reduced *Crassula helmsii*. Three out of four studies in the UK, including one controlled study, found that applying diquat or diquat alginate reduced or eradicated *C. helmsii*. One small trial found no effect of diquat on *C. helmsii* cover. One replicated, controlled study in the UK found dichlobenil reduced biomass of submerged *C. helmsii* but one small before-and-after study found no effect of dichlobenil on *C. helmsii*. A replicated, controlled study found that treatment with terbutryne partially reduced biomass of submerged *C. helmsii* and that asulam, 2,4-D amine and dalapon reduced emergent *C. helmsii*. *Assessment: beneficial (effectiveness 78%; certainty 75%)*.

<https://www.conservationevidence.com/actions/1279>

● Decontamination to prevent further spread

One controlled, replicated container trial in the UK found that submerging *Crassula helmsii* fragments in hot water led to higher mortality than drying out plants or a control. *Assessment: beneficial (effectiveness 80%; certainty 70%)*.

<https://www.conservationevidence.com/actions/1308>

Likely to be beneficial

● Use lightproof barriers to control plants

Five before-and-after studies in the UK found that covering with black sheeting or carpet eradicated or severely reduced cover of *Crassula helmsii*. *Assessment: likely to be beneficial (effectiveness 65%; certainty 50%).*

<https://www.conservationevidence.com/actions/1294>

● Use salt water to kill plants

Two replicated, controlled container trials and two before-and-after field trials in the UK found that seawater eradicated *Crassula helmsii*. *Assessment: likely to be beneficial (effectiveness 80%; certainty 45%).*

<https://www.conservationevidence.com/actions/1288>

Unknown effectiveness (limited evidence)

● Use a combination of control methods

One before-and-after study in the UK found that covering *Crassula helmsii* with carpet followed by treatment with glyphosate killed 80% of the plant. *Assessment: unknown effectiveness (effectiveness 75%; certainty 30%).*

<https://www.conservationevidence.com/actions/1313>

Unlikely to be beneficial

● Use dyes to reduce light levels

One replicated, controlled study in the UK found that applying aquatic dye, along with other treatments, did not reduce cover of *Crassula helmsii*. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 53%).*

<https://www.conservationevidence.com/actions/1293>

● Use grazing to control plants

One of two replicated, controlled studies in the UK found that excluding grazing reduce abundance and coverage of *Crassula helmsii*. The other study found that ungrazed areas had higher coverage of *C. helmsii* than grazed plots. *Assessment: unlikely to be beneficial (effectiveness 23%; certainty 43%).*

<https://www.conservationevidence.com/actions/1301>

● Use hot foam to control plants

One replicated, controlled study in the UK found that treatment with hot foam, along with other treatments, did not control *Crassula helmsii*. A before-and-after study in the UK found that treatment with hot foam partially destroyed *C. helmsii*. *Assessment: unlikely to be beneficial (effectiveness 20%; certainty 50%).*

<https://www.conservationevidence.com/actions/1286>

● Use hydrogen peroxide to control plants

One controlled tank trial in the UK found that hydrogen peroxide did not control *Crassula helmsii*. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 50%).*

<https://www.conservationevidence.com/actions/1281>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Alter environmental conditions to control plants (e.g. shading by succession, increasing turbidity, re-profiling or dredging)
- Biological control using fungal-based herbicides
- Biological control using herbivores
- Bury plants
- Dry out waterbodies
- Physical control using manual/mechanical control or dredging
- Plant other species to suppress growth
- Public education
- Surround with wire mesh
- Use flame throwers
- Use hot water
- Use of liquid nitrogen.

10.2 Threat: Invasive molluscs

10.2.1 Asian clams

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling Asian clams?	
Beneficial	<ul style="list-style-type: none">● Add chemicals to the water● Change salinity of the water● Mechanical removal
Likely to be beneficial	<ul style="list-style-type: none">● Change temperature of water● Clean equipment● Use of gas-impermeable barriers
Unlikely to be beneficial	<ul style="list-style-type: none">● Reduce oxygen in water
No evidence found (no assessment)	<ul style="list-style-type: none">● Change pH of water● Drain the invaded waterbody● Exposure to disease-causing organisms● Exposure to parasites● Hand removal● Public awareness and education

Beneficial

● Add chemicals to the water

Two replicated laboratory studies and one controlled, replicated field study found that chlorine, potassium and copper killed Asian clams. Increasing chemical concentration and water temperature killed more clams in less

time. One controlled field trial achieved 80% and 100% mortality of Asian clams using encapsulated control agents (SB1000 and SB2000 respectively) in irrigation systems. *Assessment: beneficial (effectiveness 75%; certainty 70%).*

<https://www.conservationevidence.com/actions/1118>

● **Change salinity of water**

A controlled, replicated laboratory study from the USA found that exposure to saline water killed all Asian clams. *Assessment: beneficial (effectiveness 65%; certainty 68%).*

<https://www.conservationevidence.com/actions/1115>

● **Mechanical removal**

A controlled before-and-after study from North America found suction dredging of sediment reduced an Asian clam population by 96%, and these effects persisted for a year. A replicated, controlled, before-and-after field trial in Ireland showed that three types of dredges were effective at removing between 74% and >95% of the Asian clam biomass. *Assessment: beneficial (effectiveness 80%; certainty 78%).*

<https://www.conservationevidence.com/actions/1120>

Likely to be beneficial

● **Change temperature of water**

A controlled laboratory study from the USA found that exposure to water at temperatures of 37°C and 36°C killed all Asian clams within 2 and 4 days, respectively. *Assessment: likely to be beneficial (effectiveness 60%; certainty 55%).*

<https://www.conservationevidence.com/actions/1116>

● **Clean equipment**

A field study from Portugal found that mechanical removal, followed by regular cleaning and maintenance of industrial pipes at a power plant permanently removed an Asian clam population. A field study from Portugal found that adding a sand filter to a water treatment plant reduced an Asian clam population. *Assessment: likely to be beneficial (effectiveness 75%; certainty 50%).*

<https://www.conservationevidence.com/actions/1119>

● Use of gas-impermeable barriers

One controlled study from North America found that placing gas impermeable fabric barriers on a lake bottom (several small and one large area) reduced populations of Asian clams. *Assessment: likely to be beneficial (effectiveness 78%; certainty 60%).*

<https://www.conservationevidence.com/actions/1117>

Unlikely to be beneficial

● Reduce oxygen in water

A controlled laboratory study from the USA found that Asian clams were not susceptible to low oxygen levels in the water. *Assessment: unlikely to be beneficial (effectiveness 10%; certainty 50%).*

<https://www.conservationevidence.com/actions/1113>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Change pH of water
- Drain the invaded waterbody
- Exposure to disease-causing organisms
- Exposure to parasites
- Hand removal
- Public awareness and education.

10.3 Threat: Invasive crustaceans

10.3.1 Ponto-Caspian gammarids

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling Ponto-Caspian gammarids?	
Likely to be beneficial	<ul style="list-style-type: none">● Change salinity of the water● Change water temperature● Dewatering (drying out) habitat● Exposure to parasites
Unlikely to be beneficial	<ul style="list-style-type: none">● Add chemicals to water● Change water pH● Control movement of gammarids
No evidence found (no assessment)	<ul style="list-style-type: none">● Biological control using predatory fish● Cleaning equipment● Exchange ballast water● Exposure to disease-causing organisms

Likely to be beneficial

● Change salinity of the water

One of two replicated studies, including one controlled study, in Canada and the UK found that increasing the salinity level of water killed the majority of invasive shrimp within five hours. One found that increased salinity did not kill invasive killer shrimp. *Assessment: likely to be beneficial (effectiveness 40%; certainty 50%).*

<https://www.conservationevidence.com/actions/1091>

● **Change water temperature**

A controlled laboratory study from the UK found that heating water in excess of 40°C killed invasive killer shrimps. *Assessment: likely to be beneficial (effectiveness 80%; certainty 50%).*

<https://www.conservationevidence.com/actions/1092>

● **Dewatering (drying out) habitat**

A replicated, controlled laboratory study from Poland found that lowering water levels in sand (dewatering) killed three species of invasive freshwater shrimp, although one species required water content levels of 4% and below before it was killed. *Assessment: likely to be beneficial (effectiveness 60%; certainty 50%).*

<https://www.conservationevidence.com/actions/1094>

● **Exposure to parasites**

A replicated, controlled experimental study in Canada found that a parasitic mould reduced populations of freshwater invasive shrimp. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%).*

<https://www.conservationevidence.com/actions/1089>

Unlikely to be beneficial

● **Add chemicals to water**

A controlled laboratory study from the UK found that four of nine substances added to freshwater killed invasive killer shrimp, but were impractical (iodine solution, acetic acid, Virkon S and sodium hypochlorite). Five substances did not kill invasive killer shrimp (methanol, citric acid, urea, hydrogen peroxide and sucrose). *Assessment: unlikely to be beneficial (effectiveness 35%; certainty 60%).*

<https://www.conservationevidence.com/actions/1095>

● **Change water pH**

A controlled laboratory study from the UK found that lowering the pH of water did not kill invasive killer shrimp. *Assessment: unlikely to be beneficial (effectiveness 0%; certainty 50%).*

<https://www.conservationevidence.com/actions/1093>

● Control movement of gammarids

Two replicated studies, including one controlled study, in the USA and UK found that movements of invasive freshwater shrimp slowed down or were stopped when shrimp were placed in water that had been exposed to predatory fish or was carbonated. *Assessment: likely to be beneficial (effectiveness 20%; certainty 40%).*

<https://www.conservationevidence.com/actions/1088>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control using predatory fish
- Cleaning equipment
- Exchange ballast water
- Exposure to disease-causing organisms.

10.3.2 *Procambarus* spp. crayfish

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling <i>Procambarus</i> spp. crayfish?	
Likely to be beneficial	<ul style="list-style-type: none"> • Add chemicals to the water • Sterilization of males • Trapping and removal • Trapping combined with encouragement of predators
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Create barriers
Unlikely to be beneficial	<ul style="list-style-type: none"> • Encouraging predators
No evidence found (no assessment)	<ul style="list-style-type: none"> • Draining the waterway • Food source removal • Relocate vulnerable crayfish • Remove the crayfish by electrofishing

Likely to be beneficial

● Add chemicals to the water

One replicated study in Italy found that natural pyrethrum at concentrations of 0.05 mg/l and above was effective at killing red swamp crayfish both in the laboratory and in a river, but not in drained burrows. *Assessment: likely to be beneficial (effectiveness 80%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1036>

● Sterilization of males

One replicated laboratory study from Italy found that exposing male red swamp crayfish to X-rays reduced the number of offspring they produced. *Assessment: likely to be beneficial (effectiveness 50%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1032>

● Trapping and removal

One controlled, replicated study from Italy found that food (tinned meat) was a more effective bait in trapping red swamp crayfish, than using pheromone treatments or no bait (control). Baiting with food increased trapping success compared to trapping without bait. *Assessment: likely to be beneficial (effectiveness 40%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1029>

● Trapping combined with encouragement of predators

One before-and-after study in Switzerland and a replicated, paired site study from Italy found that a combination of trapping and predation was more effective at reducing red swamp crayfish populations than predation alone. *Assessment: likely to be beneficial (effectiveness 50%; certainty 50%; harms 0%).*

<https://www.conservationevidence.com/actions/1031>

Unknown effectiveness (limited evidence)

● Create barriers

One before-and-after study from Italy found that the use of concrete dams across a stream was effective at containing spread of the population upstream. *Assessment: unknown effectiveness (effectiveness 30%; certainty 30%; harms 0%).*

<https://www.conservationevidence.com/actions/1037>

Unlikely to be beneficial

● Encouraging predators

Two replicated, controlled studies in Italy found that eels fed on the red swamp crayfish and reduced population size. One replicated, controlled study found that pike predated red swamp crayfish. *Assessment: unlikely to be beneficial (effectiveness 30%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1030>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Draining the waterway
- Food source removal
- Relocate vulnerable crayfish
- Remove the crayfish by electrofishing.

10.4 Threat: Invasive fish

10.4.1 Brown and black bullheads

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling brown and black bullheads?	
Beneficial	<ul style="list-style-type: none"> • Application of a biocide
Likely to be beneficial	<ul style="list-style-type: none"> • Netting
No evidence found (no assessment)	<ul style="list-style-type: none"> • Biological control of beneficial species • Biological control using native predators • Changing salinity • Changing pH • Draining invaded waterbodies • Electrofishing • Habitat manipulation • Increasing carbon dioxide concentrations • Public education • Trapping using sound or pheromonal lures • Using a combination of netting and electrofishing • UV radiation

Beneficial

● Application of a biocide

Two studies in the UK and USA found that rotenone successfully eradicated black bullhead. *Assessment: beneficial (effectiveness 80%; certainty 80%).*

<https://www.conservationevidence.com/actions/1050>

Likely to be beneficial

● Netting

A replicated study in a nature reserve in Belgium found that double fyke nets could be used to significantly reduce the population of large brown bullheads. *Assessment: likely to be beneficial (effectiveness 55%; certainty 55%).*

<https://www.conservationevidence.com/actions/1051>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control of beneficial species
- Biological control using native predators
- Changing salinity
- Changing pH
- Draining invaded waterbodies
- Electrofishing
- Habitat manipulation
- Increasing carbon dioxide concentrations
- Public education
- Trapping using sound or pheromonal lures
- Using a combination of netting and electrofishing
- UV radiation.

10.4.2 Ponto-Caspian gobies

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling Ponto-Caspian gobies?	
Beneficial	<ul style="list-style-type: none"> ● Changing salinity
Likely to be beneficial	<ul style="list-style-type: none"> ● Use of barriers to prevent migration
No evidence found (no assessment)	<ul style="list-style-type: none"> ● Application of a biocide ● Biological control of beneficial species ● Biological control using native predators ● Changing pH ● Draining invaded waterbodies ● Electrofishing ● Habitat manipulation ● Increasing carbon dioxide concentrations ● Netting ● Public education ● Trapping using visual, sound and pheromonal lures ● Using a combination of netting and electrofishing ● UV radiation

Beneficial

● Changing salinity

A replicated controlled laboratory study in Canada found 100% mortality of round gobies within 48 hours of exposure to water of 30% salinity. *Assessment: beneficial (effectiveness 90%; certainty 75%).*

<https://www.conservationevidence.com/actions/1072>

Likely to be beneficial

● Use of barriers to prevent migration

A controlled, replicated field study in the USA found that an electrical barrier prevented movement of round gobies across it, and that increasing electrical pulse duration and voltage increased the effectiveness of the barrier. *Assessment: likely to be beneficial (effectiveness 50%; certainty 45%).*

<https://www.conservationevidence.com/actions/1074>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Application of a biocide
- Biological control of beneficial species
- Biological control using native predators
- Changing pH
- Draining invaded waterbodies
- Electrofishing
- Habitat manipulation
- Increasing carbon dioxide concentrations
- Netting
- Public education
- Trapping using visual, sound and pheromonal lures
- Using a combination of netting and electrofishing
- UV radiation.

10.5 Threat: Invasive reptiles

10.5.1 Red-eared terrapin *Trachemys scripta*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling red-eared terrapin?	
Likely to be beneficial	<ul style="list-style-type: none">• Direct removal of adults
Unlikely to be beneficial	<ul style="list-style-type: none">• Application of a biocide
No evidence found (no assessment)	<ul style="list-style-type: none">• Biological control using native predators• Draining invaded waterbodies• Public education• Search and removal using sniffer dogs

Likely to be beneficial

● Direct removal of adults

Two studies, a replicated study from Spain using Aranzadi turtle traps, and an un-replicated study in the British Virgin Islands using sein netting, successfully captured but did not eradicate red-eared terrapin populations. *Assessment: likely to be beneficial (effectiveness 40%; certainty 50%).*

<https://www.conservationevidence.com/actions/1055>

Unlikely to be beneficial

● Application of a biocide

A replicated, controlled laboratory study in the USA, found that application of glyphosate to the eggs of red-eared terrapins reduced hatching success to 73% but only at the highest experimental concentration of glyphosate and a surface active agent. *Assessment: unlikely to be beneficial (effectiveness 15%; certainty 50%).*

<https://www.conservationevidence.com/actions/1059>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control using native predators
- Draining invaded waterbodies
- Public education
- Search and removal using sniffer dogs.

10.6 Threat: Invasive amphibians

10.6.1 American bullfrog *Lithobates catesbeiana*

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for controlling American bullfrogs?	
Likely to be beneficial	<ul style="list-style-type: none">● Biological control using native predators● Direct removal of adults● Direct removal of juveniles
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Application of a biocide
No evidence found (no assessment)	<ul style="list-style-type: none">● Biological control of co-occurring beneficial species● Collection of egg clutches● Draining ponds● Fencing● Habitat modification● Pond destruction● Public education

Likely to be beneficial

● Biological control using native predators

One replicated, controlled study conducted in northeast Belgium found the introduction of the northern pike led to a strong decline in bullfrog tadpole numbers. *Assessment: likely to be beneficial (effectiveness 70%; certainty 40%; harms 0%).*

<https://www.conservationevidence.com/actions/1039>

● Direct removal of adults

One replicated study in Belgium found catchability of adult bullfrogs in small shallow ponds using a double fyke net to be very low. One small study in the USA found that adult bullfrogs can be captured overnight in a single trap floating on the water surface. One replicated, controlled study in the USA found that bullfrog populations rapidly rebounded following intensive removal of the adults. One study in France found a significant reduction in the number of recorded adults and juveniles following the shooting of metamorphosed individuals before reproduction, when carried out as part of a combination treatment. *Assessment: likely to be beneficial (effectiveness 50%; certainty 70%; harms 0%).*

<https://www.conservationevidence.com/actions/1045>

● Direct removal of juveniles

One replicated study in Belgium found double fyke nets were effective in catching bullfrog tadpoles in small shallow ponds. One study in France found a significant reduction in the number of recorded adults and juveniles following the removal of juveniles by trapping, when carried out as part of a combination treatment. *Assessment: likely to be beneficial (effectiveness 70%; certainty 60%; harms 0%).*

<https://www.conservationevidence.com/actions/1046>

Unknown effectiveness (limited evidence)

● Application of a biocide

One replicated, controlled study in the USA reported a number of chemicals killed American bullfrogs, including caffeine (10% solution), chloroxylenol (5% solution), and a combined treatment of Permethrin (4.6% solution) and Rotenone (1% solution). *Assessment: unknown effectiveness (effectiveness 50%; certainty 20%; harms 0%).*

<https://www.conservationevidence.com/actions/1048>

No evidence found (no assessment)

We have captured no evidence for the following interventions:

- Biological control of co-occurring beneficial species
- Collection of egg clutches
- Draining ponds
- Fencing
- Habitat modification
- Pond destruction
- Public education.

11. SOME ASPECTS OF ENHANCING NATURAL PEST CONTROL

Hugh L. Wright, Joscelyne E. Ashpole, Lynn V. Dicks, James Hutchison, Caitlin G. McCormack & William J. Sutherland

Expert assessors

Barbara Smith, Game and Wildlife Conservation Trust, UK

Tony Harding, Rothamsted Research, UK

Anthony Goggin, Linking Environment and Farming (LEAF), UK

Felix Wackers, BioBest/University of Lancaster, Belgium/UK

Melvyn Fidgett, Syngenta, UK

Michael Garratt, University of Reading, UK

Michelle Fountain, East Malling Research, UK

Phillip Effingham, Greentech Consultants, UK

Stephanie Williamson, Pesticides Action Network, UK

Toby Bruce, Rothamsted Research, UK

Andrew Wilby, University of Lancaster, UK

Eve Veromann, Estonian University of Life Sciences, Estonia

Mattias Jonsson, Swedish University of Agricultural Sciences, Sweden

Vicky Kindemba, Buglife, UK

Steve Sait, University of Leeds, UK

Scope of assessment: 22 of 92 possible actions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems across the world.

Assessed: 2014.

Effectiveness measure is the median % score.

Certainty measure is the median % certainty of evidence, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects for the farmer such as reduced yield and profits or increased costs.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

11.1 Reducing agricultural pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions that reduce agricultural pollution for enhancing natural pest regulation?	
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">• Alter the timing of insecticide use• Delay herbicide use• Incorporate parasitism rates when setting thresholds for insecticide use• Use pesticides only when pests or crop damage reach threshold levels
Evidence not assessed	<ul style="list-style-type: none">• Convert to organic farming

Unknown effectiveness (limited evidence)

● Alter the timing of insecticide use

- *Natural enemies*: One controlled study from the UK reported more natural enemies when insecticides were sprayed earlier rather than later in the growing season.
- *Pests*: Two of four studies from Mozambique, the UK and the USA found fewer pests or less disease damage when insecticides were applied early rather than late. Effects on a disease-carrying pest varied with insecticide type. Two studies (including one randomized, replicated, controlled test) found no effect on pests or pest damage.

- *Yield*: Four studies (including one randomized, replicated, controlled test) from Mozambique, the Philippines, the UK and the USA measured yields. Two studies found mixed effects and one study found no effect on yield when insecticides were applied early. One study found higher yields when insecticides were applied at times of suspected crop susceptibility.
- *Profit and costs*: One controlled study from the Philippines found higher profits and similar costs when insecticides were only applied at times of suspected crop susceptibility.
- *Crops studied*: aubergine, barley, maize, pear, stringbean.
- *Assessment: unknown effectiveness (effectiveness 40%; certainty 28%; harms 13%)*.

<http://www.conservationevidence.com/actions/723>

● Delay herbicide use

- *Natural enemies*: Two randomized, replicated, controlled trials from Australia and Denmark found more natural enemies when herbicide treatments were delayed. One of the studies found some but not all natural enemy groups benefited and fewer groups benefitted early in the season.
- *Weeds*: One randomized, replicated, controlled study found more weeds when herbicide treatments were delayed.
- *Insect pests and damage*: One of two randomized, replicated, controlled studies from Canada and Denmark found more insect pests, but only for some pest groups, and one study found fewer pests in one of two experiments and for one of two crop varieties. One study found lower crop damage in some but not all varieties and study years.
- *Yield*: One randomized, replicated, controlled study found lower yields.
- *Crops studied*: beet and oilseed.
- *Assessment: unknown effectiveness (effectiveness 20%; certainty 25%; harms 50%)*.

<http://www.conservationevidence.com/actions/774>



● Incorporate parasitism rates when setting thresholds for insecticide use

- *Pest damage*: One controlled study from New Zealand found using parasitism rates to inform spraying decisions resulted in acceptable levels of crop damage from pests. Effects on natural enemy populations were not monitored.
- *The crop studied* was tomato.
- *Assessment: unknown effectiveness (effectiveness 50%; certainty 10%; harms 5%)*.

<http://www.conservationevidence.com/actions/726>

● Use pesticides only when pests or crop damage reach threshold levels

- *Natural enemies*: One randomized, replicated, controlled study from Finland found that threshold-based spraying regimes increased numbers of natural enemies in two of three years but effects lasted for as little as three weeks.
- *Pests and disease*: Two of four studies from France, Malaysia and the USA reported that pests were satisfactorily controlled. One randomized, replicated, controlled study found pest numbers were similar under threshold-based and conventional spraying regimes and one study reported that pest control was inadequate. A randomized, replicated, controlled study found mixed effects on disease severity.
- *Crop damage*: Four of five randomized, replicated, controlled studies from New Zealand, the Philippines and the USA found similar crop damage under threshold-based and conventional, preventative spraying regimes, but one study found damage increased. Another study found slightly less crop damage compared to unsprayed controls.
- *Yield*: Two of four randomized, replicated, controlled studies found similar yields under threshold-based and conventional spraying regimes. Two studies found mixed effects depending on site, year, pest stage/type or control treatment.

- *Profit*: Two of three randomized, replicated, controlled studies found similar profits using threshold-based and conventional spraying regimes. One study found effects varied between sites and years.
- *Costs*: Nine studies found fewer pesticide applications were needed and three studies found or predicted lower production costs.
- *Crops studied*: barley, broccoli, cabbages, cauliflower, celery, cocoa, cotton, grape, peanut, potato, rice, tomato, and wheat.
- *Assessment*: *unknown effectiveness (effectiveness 39%; certainty 30%; harms 20%)*.

<http://www.conservationevidence.com/actions/750>

Evidence not assessed

● Convert to organic farming

- *Parasitism and mortality (caused by natural enemies)*: One of five studies (three replicated, controlled tests and two also randomized) from Europe, North America, Asia and Australasia found that organic farming increased parasitism or natural enemy-induced mortality of pests. Two studies found mixed effects of organic farming and two randomized, replicated, controlled studies found no effect.
- *Natural enemies*: Eight of 12 studies (including six randomized, replicated, controlled tests) from Europe, North America Asia and Australasia found more natural enemies under organic farming, although seven of these found effects varied over time or between natural enemy species or groups and/or crops or management practices. Three studies (one randomized, replicated, controlled) found no or inconsistent effects on natural enemies and one study found a negative effect.
- *Pests and diseases*: One of eight studies (including five randomized, replicated, controlled tests) found that organic farming reduced pests or disease, but two studies found more pests. Three studies found mixed effects and two studies found no effect.
- *Crop damage*: One of seven studies (including five randomized, replicated, controlled tests) found less crop damage in organic fields but two studies found more. One study found a mixed response and three studies found no or inconsistent effects.

- *Weed seed predation and weed abundance:* One randomized, replicated, controlled study from the USA found mixed effects of organic farming on weed seed predation by natural enemies. Two of three randomized, replicated, controlled studies from the USA found more weeds in organically farmed fields, but in one of these studies this effect varied between crops and years. One study found no effect.
- *Yield and profit:* Six randomized, replicated, controlled studies measured yields and found one positive effect, one negative effect and one mixed effect, plus no or inconsistent effects in three studies. One study found net profit increased if produce received a premium, but otherwise profit decreased. Another study found a negative or no effect on profit.
- *Crops studied:* apple, barley, beans, cabbage, carrot, gourd, maize, mixed vegetables, pea, pepper, safflower, soybean, tomato and wheat.

<http://www.conservationevidence.com/actions/717>

11.2 All farming systems

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on all farming systems for enhancing natural pest regulation?	
Likely to be beneficial	<ul style="list-style-type: none">● Grow non-crop plants that produce chemicals that attract natural enemies● Use chemicals to attract natural enemies
Trade-offs between benefit and harms	<ul style="list-style-type: none">● Leave part of the crop or pasture unharvested or uncut
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Plant new hedges● Use alley cropping
Evidence not assessed	<ul style="list-style-type: none">● Use mass-emergence devices to increase natural enemy populations

Likely to be beneficial

- **Grow non-crop plants that produce chemicals that attract natural enemies**
 - *Natural enemies:* Four studies from China, Germany, India and Kenya tested the effects of growing plants that produce chemicals that attract natural enemies. Three (including one replicated, randomized, controlled trial) found higher numbers of natural enemies in plots with plants that produce attractive chemicals, and one also found that the plant used attracted natural enemies in lab studies. One found no effect on parasitism but the plant used was found not to be attractive to natural enemies in lab studies.

- *Pests*: All four studies found a decrease in either pest population or pest damage in plots with plants that produce chemicals that attract natural enemies.
- *Yield*: One replicated, randomized, controlled study found an increase in crop yield in plots with plants that produce attractive chemicals.
- *Crops studied*: sorghum, safflower, orange and lettuce.
- *Assessment*: likely to be beneficial (effectiveness 68%; certainty 40%; harms 0%).

<http://www.conservationevidence.com/actions/724>

● Use chemicals to attract natural enemies

- *Parasitism and predation (by natural enemies)*: One review and two of five studies from Asia, Europe and North America found that attractive chemicals increased parasitism. Two studies, including one randomized, replicated, controlled trial, found greater parasitism for some but not all chemicals, crops, sites or years and one study found no effect. One study showed that parasites found pests more rapidly. One study found lower egg predation by natural predators.
- *Natural enemies*: Five of 13 studies from Africa, Asia, Australasia, Europe and North America found more natural enemies while eight (including seven randomized, replicated, controlled trials) found positive effects varied between enemy groups, sites or study dates. Four of 13 studies (including a meta-analysis) found more natural enemies with some but not all test chemicals. Two of four studies (including a review) found higher chemical doses attracted more enemies, but one study found lower doses were more effective and one found no effect.
- *Pests*: Three of nine studies (seven randomized, replicated, controlled) from Asia, Australasia, Europe and North America found fewer pests, although the effect occurred only in the egg stage in one study. Two studies found more pests and four found no effect.
- *Crop damage*: One study found reduced damage with some chemicals but not others, and one study found no effect.
- *Yield*: One study found higher wheat yields.

- *Crops studied:* apple, banana, bean, broccoli, Chinese cabbage, cotton, cowpea, cranberry, grape, grapefruit, hop, maize, oilseed, orange, tomato, turnip and wheat.
- *Assessment:* likely to be beneficial (effectiveness 40%; certainty 50%; harms 15%).

<http://www.conservationevidence.com/actions/754>

Trade-off between benefit and harms

● Leave part of the crop or pasture unharvested or uncut

- *Natural enemies:* We found eight studies from Australia, Germany, Hungary, New Zealand, Switzerland and the USA that tested leaving part of the crop or pasture unharvested or unmown. Three (including one replicated, controlled trial) found an increase in abundance of predatory insects or spiders in the crop field or pasture that was partly uncut, while four (including three replicated, controlled trials), found more predators in the unharvested or unmown area itself. Two studies (one replicated and controlled) found that the ratio of predators to pests was higher in partially cut plots and one replicated, controlled study found the same result in the uncut area. Two replicated, controlled studies found differing effects between species or groups of natural enemies.
- *Predation and parasitism:* One replicated, controlled study from Australia found an increase in predation and parasitism rates of pest eggs in unharvested strips.
- *Pests:* Two studies (including one replicated, controlled study) found a decrease in pest numbers in partially cut plots, one of them only for one species out of two. Two studies (one replicated, the other controlled) found an increase in pest numbers in partially cut plots, and two studies (including one replicated, controlled study) found more pests in uncut areas.
- *Crops studied:* alfalfa and meadow pastures.
- *Assessment:* trade-offs between benefits and harms (effectiveness 45%; certainty 50%; harms 25%).

<http://www.conservationevidence.com/actions/725>



Unknown effectiveness (limited evidence)

● Plant new hedges

- *Natural enemies*: One randomized, replicated, controlled study from China compared plots with and without hedges and found no effect on spiders in crops. One of two studies from France and China found more natural enemies in a hedge than in adjacent crops while one study found this effect varied between crop types, hedge species and years. Two randomized, replicated, controlled studies from France and Kenya found natural enemy abundance in hedges was affected by the type of hedge shrub/ tree planted and one also found this effect varied between natural enemy groups.
- *Pests*: One randomized, replicated, controlled study from Kenya compared fallow plots with and without hedges and found effects varied between nematode (roundworm) groups.
- *Crops studied*: barley, beans, maize and wheat.
- *Assessment*: unknown effectiveness (effectiveness 20%; certainty 19%; harms 20%).

<http://www.conservationevidence.com/actions/752>

● Use alley cropping

- *Parasitism, infection and predation*: Two of four studies from Kenya and the USA (including three randomized, replicated, controlled trials) found that effects of alley cropping on parasitism varied between study sites, sampling dates, pest life stages or the width of crop alleys. Two studies found no effect on parasitism. One study found mixed effects on fungal infections in pests and one study found lower egg predation.
- *Natural enemies*: One randomized, replicated, controlled study from Kenya found more wasps and spiders but fewer ladybirds. Some natural enemy groups were affected by the types of trees used in hedges.
- *Pests and crop damage*: Two of four replicated, controlled studies (two also randomized) from Kenya, the Philippines and the UK found more pests in alley cropped plots. One study found fewer pests and

one study found effects varied with pest group and between years. One study found more pest damage to crops but another study found no effect.

- *Weeds*: One randomized, replicated, controlled study from the Philippines found mixed effects on weeds, with more grasses in alley cropped than conventional fields under some soil conditions.
- *Yield*: One controlled study from the USA found lower yield and one study from the Philippines reported similar or lower yields.
- *Costs and profit*: One study from the USA found lower costs but also lower profit in alley cropped plots.
- *Crops studied*: alfalfa, barley, cowpea, maize, pea, rice and wheat.
- *Assessment*: *unknown effectiveness (effectiveness 15%; certainty 35%; harms 50%)*.

<http://www.conservationevidence.com/actions/718>

Evidence not assessed

● **Use mass-emergence devices to increase natural enemy populations**

- *Parasitism*: One randomized, replicated, controlled study in Switzerland found higher parasitism at one site but no effect at another site when mass-emergence devices were used in urban areas.
- *Pest damage*: The same study found no effect on pest damage to horse chestnut trees.

<http://www.conservationevidence.com/actions/775>

11.3 Arable farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on arable farming systems for enhancing natural pest regulation?	
Beneficial	• Combine trap and repellent crops in a push-pull system
Trade-offs between benefit and harms	• Use crop rotation in potato farming systems
Unlikely to be beneficial	• Create beetle banks
Likely to be ineffective or harmful	• Incorporate plant remains into the soil that produce weed-controlling chemicals

Beneficial

● Combine trap and repellent crops in a push-pull system

- *Parasitism*: Two randomized, replicated, controlled studies from Kenya found that push-pull cropping systems increased parasitism of stem borer larvae. One of the studies found no effect on egg parasitism.
- *Natural enemies*: Two randomized, replicated, controlled studies from Kenya and South Africa found push-pull systems had more natural predators, both in overall totals and the abundance of different predator groups.
- *Pests*: Two of three studies (two randomized, replicated, controlled) in Ethiopia, Kenya and South Africa found fewer pests. One study

found no effect on pest infestation, but pests were scarce throughout. Two replicated, controlled studies (one also randomized) found fewer witchweeds.

- *Crop damage*: Two of three replicated, controlled studies (one randomized) found less pest damage, but one study (where pest numbers were low) found effects varied between years and types of damage symptom.
- *Yield*: Four of five replicated, controlled studies (two also randomized) found higher yields and one found no effect.
- *Profit and cost*: Two studies in Kenya and a review found greater economic benefits. One study found higher production costs in the first year, but equal or lower costs in the following five years.
- *Crops studied*: maize and beans.
- *Assessment*: beneficial (effectiveness 70%; certainty 68%; harms 5%).

<http://www.conservationevidence.com/actions/753>

Trade-off between benefit and harms

● Use crop rotation in potato farming systems

- *Pests*: Nine studies from Canada and the USA and one review investigated the effect of crop rotation on pest or pathogen populations in potato. Three studies (including two replicated studies of which one randomized and one controlled) and a review found crop rotation reduced pest populations and crop diseases in at least one year or at least one site. One paired study found pest populations increased in crop rotation. Four studies (including one replicated, randomized, controlled trial) found increases and decreases in pest populations depending on rotation crops used and other treatments. One replicated, randomized, controlled study⁶ found no effect.
- *Yield*: Three out of five studies (all replicated, controlled, two also randomized) from Canada and the USA, found that crop rotation increased crop yield in some years or with certain rotation crops. The two other studies (both replicated, one also randomized and one replicated) found yield increases and decreases depending on rotation crops used.

- *Profit*: One replicated, controlled study found that crop rotation increased profit.
- *Insecticides*: Two studies (one replicated, controlled) found that fewer insecticide treatments were needed on rotated plots.
- *Crops studied*: alfalfa, barley, broccoli, brown mustard, buckwheat, cotton, lupins, maize, oats, pearl millet, peas, potato, rye, sorghum, soybean, sugar beet, timothy grass, wheat and yellow sweet clover.
- *Assessment*: trade-offs between benefits and harms (effectiveness 50%; certainty 50%; harms 25%).

<http://www.conservationevidence.com/actions/719>

Unlikely to be beneficial

● Create beetle banks

- *Natural enemies in fields*: Six studies from Canada, the UK and USA (three replicated, controlled, of which two were also randomized) examined the effects on predator numbers in adjacent crops. A review found that predators increased in adjacent crops, but one study found effects varied with time and another found no effect. Two studies found small or slow movements of predators from banks to crops. One study found greater beetle activity in fields but this did not improve pest predation.
- *Natural enemies on banks*: Four studies and a review found more invertebrate predators on beetle banks than in surrounding crops, but one of these found that effects varied with time.
- Eight studies from the UK and USA (including two randomized, replicated, controlled trials and two reviews) compared numbers of predatory invertebrates on beetle banks with other refuge habitats. Two studies found more natural enemies on beetle banks, but one of these found only seasonal effects. One review found similar or higher numbers of predators on beetle banks and four studies found similar or lower numbers.
- *Pests*: A replicated, randomized, controlled study and a review found the largest pest reductions in areas closest to a beetle bank or on the beetle bank itself. One review found fewer pests in fields with than without a beetle bank.

- *Economics*: One replicated, randomized, controlled trial and a review showed that beetle banks could make economic savings if they prevented pests from reaching a spray threshold or causing 5% yield loss.
- *Beetle bank design*: Two studies from the UK found certain grass species held higher numbers of predatory invertebrates than others.
- *Crops studied*: barley, field bean, maize, oats, pasture, pea, radish, rapeseed, soybean and wheat.
- *Assessment*: unlikely to be beneficial (effectiveness 25%; certainty 60%; harms 10%).

<http://www.conservationevidence.com/actions/729>

Likely to be ineffective or harmful

- **Incorporate plant remains into the soil that produce weed-controlling chemicals**
 - *Weeds*: Six studies (including six randomized, replicated, controlled tests) from Asia, Europe and North America examined the effect of allelopathic plant residues on weeds by comparing amended soils with weeded controls. Three studies found a reduction in weed growth, and three found effects varied between years, weed groups, or type of weeding method in controls.
 - Four studies from Asia and North America examined the effect on weeds by comparing amended soils with unweeded controls. Two studies found a reduction in weed growth, but one found that residues applied too far in advance of crop planting had the reverse effect.
 - Two studies found that effects varied between trials, weed species or the type of residue used.
 - *Weed control*: Two studies, including one randomized, replicated, controlled laboratory study, found that the decrease in weeds did not last beyond a few days or weeks after residue incorporation.
 - *Pests*: One randomized, replicated, controlled study in the Philippines found mixed effects on pests.

- *Crop growth:* Two of three studies found that crop growth was inhibited by allelopathic residues, but these effects could be minimized by changing the timing of application. One study found effects varied between years.
- *Yield:* Three randomized, replicated, controlled studies compared crop yields in amended plots with weeded controls and found positive, negative and mixed effects. Three studies compared amended plots with unweeded controls, two found positive effects on yield and one found mixed effects (depending on crop type).
- *Profit:* One study found that amending soils increased profit compared to unweeded controls, but not compared to weeded controls.
- *Crops studied:* beans, cotton, maize, rice and wheat.
- *Assessment:* likely to be ineffective or harmful (effectiveness 39%; certainty 47%; harms 30%).

<http://www.conservationevidence.com/actions/728>

11.4 Perennial farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on perennial farming systems for enhancing natural pest regulation?	
Likely to be beneficial	<ul style="list-style-type: none">● Exclude ants that protect pests
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Allow natural regeneration of ground cover beneath perennial crops● Isolate colonies of beneficial ants

Likely to be beneficial

● Exclude ants that protect pests

- *Parasitism*: One of two replicated, controlled studies (one also randomized) from Japan and the USA found greater parasitism of pests by natural enemies when ants were excluded from trees. The other study found greater parasitism at one site but no effect at another.
- *Natural enemies*: Five studies (including four randomized, replicated, controlled trials) from Japan, Switzerland and the USA found effects varied between natural enemy species and groups, sampling dates, sites, crop varieties and ground cover types beneath trees.
- *Pests*: Three of seven studies (including four randomized, replicated, controlled trials) found fewer pests and another found fewer pests at times of peak abundance only. One study found mixed effects depending on date and other actions taken simultaneously (predator attractant and ground cover treatments). One study found no effect.

- *Damage and tree growth:* One study found no effect on damage to tree foliage but one study found greater tree growth.
- *Ants:* Six studies found that glue or pesticide barriers reduced ant numbers in tree or vine canopies. One study found that citrus oil barriers had no effect.
- *Crops studied:* cherimoyas, cherry, grape, grapefruit, orange, pecan and satsuma mandarin.
- *Assessment: likely to be beneficial (effectiveness 40%; certainty 50%; harms 12%).*

<http://www.conservationevidence.com/actions/886>

Unknown effectiveness (limited evidence)

● Allow natural regeneration of ground cover beneath perennial crops

- *Natural enemies on crop trees and vines:* Five studies (including one replicated, randomized, controlled test) from Australia, China, Italy and Portugal compared natural and bare ground covers by measuring numbers of natural enemies in fruit tree or vine canopies. Three found effects varied between groups of natural enemies, two found no difference. Two studies from Australia and France compared natural to sown ground cover and found no effect on enemies in crop canopies.
- *Natural enemies on the ground:* Five studies (including three replicated, randomized, controlled trials) from Australia, Canada, China, France, and Spain compared natural and bare ground covers by measuring natural enemies on the ground. Two studies found more natural enemies in natural ground cover, but in one the effects were only short-term for most natural enemy groups. Three studies found mixed effects, with higher numbers of some natural enemy groups but not others. Two studies compared natural and sown ground covers, one study found more natural enemies and one found no effect.
- *Pests and crop damage:* Four studies (three controlled, one also replicated and randomized) from Italy, Australia and China measured pests and crop damage in regenerated and bare ground

covers. Two studies found fewer pests, whilst two studies found effects on pests and crop damage varied for different pest or disease groups. One study found more pests in natural than in sown ground covers.

- *Crops studied:* apple, grape, lemon, olive and pear.
- *Assessment:* unknown effectiveness (effectiveness 35%; certainty 29%; harms 20%).

<http://www.conservationevidence.com/actions/720>

● **Isolate colonies of beneficial ants**

- *Natural enemies:* One replicated, controlled study from Australia found predatory ants occupied more cashew trees when colonies were kept isolated.
- *Pest damage and yield:* The same study found lower pest damage to cashews and higher yields.
- *The crop studied* was cashew.
- *Assessment:* unknown effectiveness (effectiveness 60%; certainty 19%; harms 0%).

<http://www.conservationevidence.com/actions/773>

11.5 Livestock farming and pasture

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on livestock and pasture farming systems for enhancing natural pest regulation?	
Likely to be beneficial	<ul style="list-style-type: none"> • Grow plants that compete with damaging weeds
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> • Delay mowing or first grazing date on pasture or grassland
Likely to be ineffective or harmful	<ul style="list-style-type: none"> • Use grazing instead of cutting for pasture or grassland management • Use mixed pasture

Likely to be beneficial

● Grow plants that compete with damaging weeds

- *Weed weight and cover*: Nine studies from Australia, Slovakia, the UK and the USA tested the effects of planting species to compete with weeds. All (including four replicated, randomized, controlled trials) found reduced weed plant weight or ground cover, although two found this only in some years or conditions.
- *Weed reproduction and survival*: Five studies (including three replicated, randomized, controlled trials) also found that competition reduced weed reproduction, survival or both. One of these found an effect only in one year only.

- *Crops studied:* clovers, fescues, ryegrass, other grasses and turnip.
- *Assessment:* likely to be beneficial (effectiveness 70%; certainty 60%; harms 5%).

<http://www.conservationevidence.com/actions/722>

Unknown effectiveness (limited evidence)

● Delay mowing or first grazing date on pasture or grassland

- *Natural enemy abundance:* One replicated, randomized, controlled study found fewer predatory spiders with delayed cutting. Three studies from the UK (two of them replicated, randomized and controlled) found no change in insect predator numbers and one replicated study from Sweden found mixed effects between different predator groups.
- *Natural enemy diversity:* One replicated study from Sweden found a decrease in ant diversity with delayed cutting and one replicated, randomized, controlled study from the UK found no effect on spider and beetle diversity.
- *Pests:* One of two replicated, randomized, controlled studies from the UK and USA found more pest insects in late-cut plots and one found no effect.
- *Insects in general:* Four replicated, randomized, controlled studies measured the abundance of insect groups without classifying them as pests or natural enemies. One UK study found lower numbers in late-cut plots, while two found effects varied between groups. Two studies from the UK and USA found no effect on insect numbers.
- *Crops studied:* barley, bird's-foot trefoil, clovers, fescues, rapeseed, ryegrass, other grasses and wheat.
- *Assessment:* unknown effectiveness (effectiveness 5%; certainty 20%; harms 15%).

<http://www.conservationevidence.com/actions/727>



Likely to be ineffective or harmful

● Use grazing instead of cutting for pasture or grassland management

- *Natural enemies*: Two studies (one before-and-after and one replicated trial) from Australia and the UK found grazing instead of cutting had mixed effects on natural enemies, with some species and groups affected on some dates but not others. One replicated study from New Zealand found no effect.
- *Pests and diseases*: One of five studies (including three replicated trials) from Australia, New Zealand, the UK and the USA found more pests, and two studies found effects varied between pest groups and sampling dates. Two studies found no effect on pests. One study found no effect on disease when grazing was used in addition to cutting.
- *Pasture damage and plant survival*: One randomized study found more ryegrass shoots were attacked by pests. One study found lower survival of alfalfa plants but another found no effect.
- *Yield*: One of four randomized, replicated studies (one also controlled) found lower yields and two found no effect. One study found lower ryegrass and higher clover yields, but no difference between clover varieties. Another randomized study found more ryegrass shoots.
- *Crops studied*: alfalfa, cock's-foot, perennial ryegrass, other grasses and white clover.
- *Assessment*: likely to be ineffective or harmful (effectiveness 10%; certainty 45%; harms 40%).

<http://www.conservationevidence.com/actions/885>

● Use mixed pasture

- *Weeds*: Two of two studies (randomized and replicated and one also controlled) from the USA found weeds were negatively affected by mixed compared to monoculture pasture.

- *Pests*: Five studies from North America measured pests including four randomized, replicated, controlled tests. One study found fewer pests and two studies found negative or mixed effects depending on different pests groups or pasture mixes. One study found no effect and another found more pests, although the effect was potentially inseparable from grazing treatments.
- *Crop mortality*: One randomized, replicated study from the USA found no effect on forage crop mortality caused by nematodes.
- *Yield*: Two of five studies (including two randomized, replicated, controlled tests) from North America found increased forage crop yields and two studies found mixed effects depending on the crop type and year. One study found no effect.
- *Crops studied*: alfalfa, bird's-foot trefoil, chicory, cicer milkvetch, clovers, fescues, oats, plantain, ryegrass, other grasses, other legumes, rapeseed and turnip.
- *Assessment*: likely to be ineffective or harmful (effectiveness 35%; certainty 45%; harms 20%).

<http://www.conservationevidence.com/actions/721>

12. ENHANCING SOIL FERTILITY

Georgina Key, Mike Whitfield, Lynn V. Dicks, William J. Sutherland & Richard D. Bardgett

Expert assessors

Martin Collison, Collison and Associates Limited, UK

Julia Cooper, Newcastle University, UK

Thanasis Dedousis, PepsiCo Europe

Richard Heathcote, Heineken, S&N UK Ltd

Shamal Mohammed, Agriculture and Horticulture Development Board, Cranfield University, UK

Andrew Molyneux, Huntapac Produce Ltd, UK

Wim van der Putten, Netherlands Institute of Ecology

Brendan Roth, Department for Environment, Food & Rural Affairs, UK

Franciska de Vries, University of Manchester, UK

Scope of assessment: actions to enhance soil fertility for agricultural systems across the world.

Assessed: 2014.

Effectiveness measure is the median % score.

Certainty measure is the median % certainty of evidence, determined by the quantity and quality of the evidence in the synopsis.

Harm measure is the median % score for negative side-effects for the farmer such as reduced yield, crop quality or profits, or increased costs.

This book is meant as a guide to the evidence available for different conservation interventions and as a starting point in assessing their effectiveness. The assessments are based on the available evidence for the target group of species for each intervention. The assessment may therefore refer to different species or habitat to the one(s) you are considering. Before making any decisions about implementing interventions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your study species or system.

Full details of the evidence are available at
www.conservationevidence.com

There may also be significant negative side-effects on the target groups or other species or communities that have not been identified in this assessment.

A lack of evidence means that we have been unable to assess whether or not an intervention is effective or has any harmful impacts.

12.1 Reducing agricultural pollution

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to reduce agricultural pollution for enhancing soil fertility?	
Unknown effectiveness (limited evidence)	• Change the timing of manure application
Likely to be ineffective or harmful	• Reduce fertilizer, pesticide or herbicide use generally

Unknown effectiveness (limited evidence)

● Change the timing of manure application

- One controlled, randomized, replicated, site comparison study from the UK found less nitrate was lost from the soil when manure application was delayed from autumn until December or January.
- *Soil types covered:* sandy loam.
- *Assessment:* unknown effectiveness (effectiveness 50%; certainty 33%; harms 24%).

<http://www.conservationevidence.com/actions/893>

Likely to be ineffective or harmful

● Reduce fertilizer, pesticide or herbicide use generally

- *Biodiversity*: Two site comparison studies from Italy and Pakistan (one also replicated) found a higher diversity of soil invertebrates and microorganisms in low chemical-input systems.
- *Nutrient loss*: One study from Canada found lower nutrient levels and yields in low-input systems.
- *Soil types covered*: coarse sandy, loam, sandy loam, and silt.
- *Assessment*: likely to be ineffective or harmful (effectiveness 26%; certainty 40%; harms 48%).

<http://www.conservationevidence.com/actions/904>

12.2 All farming systems

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on all farming systems for enhancing soil fertility?

Likely to be beneficial	<ul style="list-style-type: none">● Control traffic and traffic timing
Trade-off between benefit and harms	<ul style="list-style-type: none">● Change tillage practices● Convert to organic farming● Plant new hedges
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none">● Change the timing of ploughing

Likely to be beneficial

● Control traffic and traffic timing

- *Biodiversity*: One randomised, replicated study from Poland found higher numbers and bacterial activity under controlled traffic. One replicated site comparison study from Denmark found higher microbial biomass when farm traffic was not controlled.
- *Erosion*: Five trials from Europe and Australia (including three replicated trials, one controlled before-and-after trial, and one review) found a higher number of pores in the soil, less compaction, reduced runoff and increased water filtration into soil under controlled traffic. One controlled, replicated trial in India found increased soil crack width when traffic was not controlled.

- *Yield*: One replicated trial from Australia found increased yield under controlled traffic.
- *Soil types covered*: clay, loamy silt, sandy loam, silty, silty clay, silt-loam.
- *Assessment*: likely to be beneficial (effectiveness 55%; certainty 62%; harms 18%).

<http://www.conservationevidence.com/actions/899>

Trade-off between benefit and harms

● Change tillage practices

- *Biodiversity loss*: Nine studies from Canada, Europe, Mexico, or the USA measured effects of reduced tillage on soil animals or microbes. Of these, six (including three replicated trials (two also randomized and one also controlled) found more microbes, more species of earthworm, or higher microbe activity under reduced tillage. One replicated trial found increased numbers of soil animals and earthworms under reduced tillage. Two (including one controlled, replicated trial), found no effect of reduced tillage on earthworm activity or microbe activity.
- *Compaction*: Five studies from Australia, Canada, and Europe measured the effect of controlled traffic and reduced tillage on compacted soils. Of these, two (including one before-and-after trial and one replicated trial) found reduced compaction and subsequent effects (reduced water runoff, for example) under controlled traffic, and one also found that crop yields increased under no-tillage. Three replicated trials, including one site comparison study, found higher compaction under reduced tillage.
- *Drought*: Three replicated trials from Europe and India (one randomized) found the size of soil cracks decreased, and ability of soil to absorb water and soil water content increased with conventional tillage and sub-soiling.
- *Erosion*: Ten replicated trials from Brazil, Europe, India, Nigeria and the USA, and one review showed mixed results of tillage on soil



erosion. Seven trials (one also controlled and randomized) showed reduced soil loss and runoff under reduced tillage compared to conventional ploughing. One trial showed no differences between tillage systems, but demonstrated that across-slope cultivation reduced soil loss compared to up-and-downslope cultivation. Two trials, showed that no-tillage increased soil loss in the absence of crop cover.

- *Soil organic carbon*: Twelve studies from Australia, Canada, China, Europe, Japan and the USA compared the effect of no-tillage and conventionally tilled systems on soil organic carbon. All (including two randomized, five replicated, two randomized, replicated, and one controlled, randomized, replicated) found higher soil organic carbon in soils under a no-tillage or reduced tillage system compared to conventionally tilled soil. One review showed that no-tillage with cover cropping plus manure application increased soil organic carbon. One randomized, replicated trial from Spain found greater soil organic carbon in conventionally tilled soil.
- *Soil organic matter*: Twelve studies from Canada, China, Europe, Morocco, and the USA measured effects of reduced tillage on soil organic matter content and nutrient retention. Of these, six studies (including three replicated, two site comparisons (one also replicated) and one controlled) found maintained or increased soil organic matter and improved soil structure under reduced tillage. Four trials (including two replicated and two site comparison studies) found higher nutrient retention under reduced tillage. One controlled, replicated trial from the USA found less carbon and nitrate in no-till compared to conventionally tilled soil, but conventionally tilled soil lost more carbon and nitrate.
- *Soil types covered*: anthrosol, calcareous silt-loam, chalky, clay, clay-loam, fine sandy loam, loam, loamy clay, loam/sandy loam, loam silt-loam, loamy silt, non-chalky clay, sandy, sandy clay-loam, sandy loam, sandy silt-loam, silt-loam, silty, silty clay, silty clay-loam, silty loam.
- *Assessment: trade-offs between benefit and harms (effectiveness 61%; certainty 72%; harms 46%)*.

<http://www.conservationevidence.com/actions/906>

● Convert to organic farming

- *Biodiversity*: Four studies in Asia, Europe, and the USA (including two site comparison studies and three replicated trials) found higher numbers, diversity, functional diversity (see background) or activity of soil organisms under organic management.
- *Soil organic carbon*: Two replicated trials in Italy and the USA showed that organically managed orchards had higher soil carbon levels compared to conventionally managed orchards. One randomised, replicated trial in the USA found soil carbon was lower under organic management compared to alley cropping.
- *Soil organic matter*: One replicated trial in Canada found that soil nutrients were lower in organically managed soils.
- *Yield*: One replicated trial in Canada found lower yields in organically managed soils. Two replicated trials in the USA (one also randomised) found that fruit was of a higher quality and more resistant to disease, though smaller or that organic management had mixed effects on yield.
- *Soil types covered*: clay, clay-loam, fine sandy loam, loam, sandy loam, sandy clay-loam, silt, silty clay, silt-loam.
- *Assessment: trade-offs between benefit and harms (effectiveness 55%; certainty 52%; harms 64%)*.

<http://www.conservationevidence.com/actions/895>

● Plant new hedges

- Five studies in Slovakia, Kenya and Thailand measured the effects of planting grass or shrub hedgerows on soil animals and soil fertility. All five found hedgerows to maintain or improve soil fertility and soil animal activity. Of these, three replicated studies found reduced soil erosion and higher soil organic matter levels. Another replicated trial found a higher diversity of soil animals near to the hedgerows. One of the replicated studies and one review found that adding woody species to the hedgerows improved many factors contributing to soil fertility.
- *Soil types covered*: alluvial, clay, sandy loam.



- *Assessment: trade-offs between benefit and harms (effectiveness 49%; certainty 45%; harms 20%).*

<http://www.conservationevidence.com/actions/744>

Unknown effectiveness (limited evidence)

● Change the timing of ploughing

- *Nutrient loss:* Two replicated site comparison studies from Denmark and Norway (one also randomised) found reduced erosion soil loss and nitrate leaching when ploughing was delayed until spring.
- *Soil types covered:* Sandy, sandy loam, silty clay loam.
- *Assessment: unknown effectiveness (effectiveness 46%; certainty 38%; harms 33%).*

<http://www.conservationevidence.com/actions/712>

12.3 Arable farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on arable farming systems for enhancing soil fertility?	
Beneficial	<ul style="list-style-type: none"> ● Amend the soil using a mix of organic and inorganic amendments ● Grow cover crops when the field is empty ● Use crop rotation
Likely to be beneficial	<ul style="list-style-type: none"> ● Amend the soil with formulated chemical compounds ● Grow cover crops beneath the main crop (living mulches) or between crop rows
Trade-off between benefit and harms	<ul style="list-style-type: none"> ● Add mulch to crops ● Amend the soil with fresh plant material or crop remains ● Amend the soil with manures and agricultural composts ● Amend the soil with municipal wastes or their composts ● Incorporate leys into crop rotation ● Retain crop residues
Unknown effectiveness (limited evidence)	<ul style="list-style-type: none"> ● Amend the soil with bacteria or fungi ● Amend the soil with composts not otherwise specified ● Amend the soil with crops grown as green manures ● Amend the soil with non-chemical minerals and mineral wastes ● Amend the soil with organic processing wastes or their composts ● Encourage foraging waterfowl ● Use alley cropping



Beneficial

● Amend the soil using a mix of organic and inorganic amendments

- *Biodiversity*: Five controlled trials from China and India (four also randomized and replicated), and one study from Japan found higher microbial biomass and activity in soils with a mix of manure and inorganic fertilizers. Manure alone also increased microbial biomass. One trial found increased microbial diversity.
- *Erosion*: One controlled, replicated trial from India found that mixed amendments were more effective at reducing the size of cracks in dry soil than inorganic fertilizers alone or no fertilizer.
- *Soil organic carbon loss*: Four controlled, randomized, replicated trials and one controlled trial all from China and India found more organic carbon in soils with mixed fertilizers. Manure alone also increased organic carbon. One trial also found more carbon in soil amended with inorganic fertilizers and lime.
- *Soil organic matter loss*: Three randomized, replicated trials from China and India (two also controlled), found more nutrients in soils with manure and inorganic fertilizers. One controlled, randomized, replicated trial from China found inconsistent effects of using mixed manure and inorganic fertilizers.
- *Yield*: Two randomized, replicated trials from China (one also controlled) found increased maize or rice and wheat yields in soils with mixed manure and inorganic fertilizer amendments. One study found lower yields of rice and wheat under mixed fertilizers.
- *Soil types covered*: clay, clay-loam, sandy loam, silt clay-loam, silty loam.
- *Assessment: beneficial (effectiveness 69%; certainty 64%; harms 15%)*.

<http://www.conservationevidence.com/actions/902>

● Grow cover crops when the field is empty

- *Biodiversity*: One controlled, randomized, replicated experiment in Martinique found that growing cover crops resulted in more diverse nematode communities. One replicated trial from the USA found

greater microbial biomass under ryegrass compared to a ryegrass/vetch cover crop mix.

- *Soil structure*: Three randomized, replicated studies from Denmark, Turkey and the UK found that growing cover crops improved soil structure and nutrient retention. One trial found higher soil porosity, interconnectivity and one lower resistance in soil under cover crops, and one found reduced nitrate leaching.
- *Soil organic carbon*: One replicated study from Denmark and one review based mainly in Japan found increased soil carbon levels under cover crops. One study also found soil carbon levels increased further when legumes were included in cover crops.
- *Soil organic matter*: Two controlled, randomized, replicated studies from Australia and the USA found increased carbon and nitrogen levels under cover crops, with one showing that they increased regardless of whether those crops were legumes or not. Two studies from Europe (including one controlled, replicated trial) found no marked effect on soil organic matter levels.
- *Yield*: One replicated trial from the USA found higher tomato yield from soils which had been under a ryegrass cover crop.
- *Soil types covered*: clay, loam, sandy clay, sandy loam, silty clay, silty loam.
- *Assessment*: beneficial (effectiveness 75%; certainty 67%; harms 16%).

<http://www.conservationevidence.com/actions/898>

● Use crop rotation

- *Biodiversity*: Three randomized, replicated trials from Canada and Zambia measured the effect of including legumes in crop rotations and found the number of microbes and diversity of different soil animals increased.
- *Erosion*: One randomized, replicated trial from Canada found that including forage crops in crop rotations reduced rainwater runoff and soil loss, and one replicated trial from Syria showed that including legumes in rotation increased water infiltration (movement of water into the soil).

- *Soil organic carbon*: Three studies from Australia, Canada, and Denmark (including one controlled replicated trial and one replicated site comparison study), found increased soil organic carbon under crop rotation, particularly when some legumes were included.
- *Soil organic matter*: Two of four replicated trials from Canada and Syria (one also controlled and randomized) found increased soil organic matter, particularly when legumes were included in the rotation. One study found lower soil organic matter levels when longer crop rotations were used. One randomized, replicated study found no effect on soil particle size.
- *Soil types covered*: clay, clay-loam, fine clay, loam, loam/silt loam, sandy clay, sandy loam, silty loam.
- *Assessment*: beneficial (effectiveness 66%; certainty 75%; harms 8%).

<http://www.conservationevidence.com/actions/857>

Likely to be beneficial

● Amend the soil with formulated chemical compounds

- *Nutrient loss*: Three of five replicated trials from New Zealand and the UK measured the effect of applying nitrification inhibitors to the soil and three found reduced nitrate losses and nitrous oxide emissions, although one of these found that the method of application influenced its effect. One trial found no effect on nitrate loss. One trial found reduced nutrient and soil loss when aluminium sulphate was applied to the soil.
- *Soil organic matter*: Four of five studies (including two controlled, randomised and replicated and one randomised and replicated) in Australia, China, India, Syria and the UK testing the effects of adding chemical compounds to the soil showed an increase in soil organic matter or carbon when nitrogen or phosphorus fertilizer was applied. One site comparison study showed that a slow-release fertilizer resulted in higher nutrient retention. One study found higher carbon levels when NPK fertilizers were applied with straw, than when applied alone, and one replicated study from France found higher soil carbon when manure rather than chemical compounds were applied.

- *Yield*: One replicated experiment from India showed that maize and wheat yield increased with increased fertilizer application.
- *Soil types covered*: clay, fine loamy, gravelly sandy loam, loam, sandy loam, silty, silty clay, silt-loam.
- *Assessment*: likely to be beneficial (effectiveness 64%; certainty 46%; harms 19%).

<http://www.conservationevidence.com/actions/909>

● **Grow cover crops beneath the main crop (living mulches) or between crop rows**

- *Biodiversity*: One randomized, replicated study from Spain found that cover crops increased bacterial numbers and activity.
- *Erosion*: Two studies from France and the USA showed reduced erosion under cover crops. One controlled study showed that soil stability was highest under a grass cover, and one randomized replicated study found that cover crops reduced soil loss.
- *Soil organic matter*: Two controlled trials from India and South Africa (one also randomized and replicated) found that soil organic matter increased under cover crops, and one trial from Germany found no effect on soil organic matter levels.
- *Soil types covered*: gravelly sandy loam, sandy loam, sandy, silty loam.
- *Assessment*: likely to be beneficial (effectiveness 65%; certainty 54%; harms 19%).

<http://www.conservationevidence.com/actions/897>

Trade-off between benefit and harms

● **Add mulch to crops**

- *Biodiversity*: Three replicated trials from Canada, Poland and Spain (including one also controlled, one also randomised and one also controlled and randomised) showed that adding mulch to crops (whether shredded paper, municipal compost or straw) increased soil animal and fungal numbers, diversity and activity. Of these, one trial also showed that mulch improved soil structure and increased soil organic matter.

- *Nutrient loss*: One replicated study from Nigeria found higher nutrient levels in continually cropped soil.
- *Erosion*: Five studies from India, France, Nigeria and the UK (including one controlled, randomised, replicated trial, one randomised, replicated trial, two replicated (one also controlled), and one controlled trial) found that mulches increased soil stability, and reduced soil erosion and runoff. One trial found that some mulches are more effective than others.
- *Drought*: Two replicated trials from India found that adding mulch to crops increased soil moisture.
- *Yield*: Two replicated trials from India found that yields increased when either a live mulch or vegetation barrier combined with mulch was used.
- *Soil types covered*: clay, fine loam, gravelly sandy loam, sandy, sandy clay, sandy loam, sandy silt-loam, silty, silty loam.
- *Assessment: trade-offs between benefit and harms (effectiveness 60%; certainty 64%; harms 23%)*.

<http://www.conservationevidence.com/actions/887>

● Amend the soil with fresh plant material or crop remains

- *Biodiversity*: One randomized, replicated experiment from Belgium found increased microbial biomass when crop remains and straw were added.
- *Compaction*: One before-and-after trial from the UK found that incorporating straw residues by discing (reduced tillage) did not improve anaerobic soils (low oxygen levels) in compacted soils.
- *Erosion*: Two randomized, replicated studies from Canada and India measured the effect of incorporating straw on erosion. One found straw addition reduced soil loss, and one found mixed effects depending on soil type.
- *Nutrient loss*: Two replicated studies from Belgium and the UK (one also controlled and one also randomized) reported higher soil nitrogen levels when compost or straw was applied, but mixed results when processed wastes were added.

- *Soil organic carbon*: Three randomized, replicated studies (two also controlled) from China and India, and one controlled before-and-after site comparison study from Denmark found higher carbon levels when plant material was added. One found higher carbon levels when straw was applied along with NPK fertilizers. One also found larger soil aggregates.
- *Soil types covered*: clay, clay-loam, loam/sandy loam, loamy sand, sandy, sandy clay-loam, sandy loam, silt-loam, silty, silty clay.
- *Assessment: trade-offs between benefit and harms (effectiveness 53%; certainty 53%; harms 34%)*.

<http://www.conservationevidence.com/actions/910>

● Amend the soil with manures and agricultural composts

- *Biodiversity loss*: Three controlled, replicated studies from the UK and USA found higher microbial biomass when manure or compost was applied, and higher microbial respiration when poultry manure was applied.
- *Erosion*: One controlled, randomized, replicated study from India found lower soil loss and water runoff with manure application in combination with other treatments.
- *Nutrient management*: Two randomized, replicated studies from Canada and the UK (one also controlled) found lower nitrate loss or larger soil aggregates (which hold more nutrients) when manure was applied, compared to broiler (poultry) litter, slurry or synthetic fertilizers. One study found that treatment in winter was more effective than in autumn and that farmyard manure was more effective than broiler (poultry) litter or slurry in reducing nutrient loss. One controlled, replicated study from Spain found higher nitrate leaching.
- *Soil organic carbon*: Three studies (including two controlled, replicated studies and a review) from India, Japan and the UK found higher carbon levels when manures were applied.
- *Soil organic matter*: One controlled, randomized, replicated study from Turkey found higher organic matter, larger soil aggregations

and a positive effect on soil physical properties when manure and compost were applied. One study from Germany found no effect of manure on organic matter levels.

- *Yield*: Four controlled, replicated studies (including four also randomized) from India, Spain and Turkey found higher crop yields when manures or compost were applied. One study found higher yields when manure were applied in combination with cover crops.
- *Soil types covered*: clay-loam, loam, loamy, sandy loam, sandy clay-loam, silty loam, sandy silt-loam.
- *Assessment: trade-offs between benefit and harms (effectiveness 70%; certainty 59%; harms 26%).*

<http://www.conservationevidence.com/actions/911>

● Amend the soil with municipal wastes or their composts

- *Erosion*: Two controlled, replicated trials in Spain and the UK measured the effect of adding wastes to the soil. One trial found that adding municipal compost to semi-arid soils greatly reduced soil loss and water runoff. One found mixed results of adding composts and wastes.
- *Soil types covered*: coarse loamy, sandy loam.
- *Assessment: trade-offs between benefit and harms (effectiveness 45%; certainty 44%; harms 54%).*

<http://www.conservationevidence.com/actions/890>

● Incorporate leys into crop rotation

- *Nutrient loss*: One replicated study from Denmark showed that reducing the extent of grass pasture in leys reduced the undesirable uptake of nitrogen by grasses, therefore requiring lower rates of fertilizer for subsequent crops.
- *Soil types covered*: sandy loam.
- *Assessment: trade-offs between benefit and harms (effectiveness 46%; certainty 45%; harms 36%).*

<http://www.conservationevidence.com/actions/900>

● Retain crop residues

- *Biodiversity*: One replicated study from Mexico found higher microbial biomass when crop residues were retained.
- *Erosion*: One review found reduced water runoff, increased water storage and reduced soil erosion. One replicated site comparison from Canada found mixed effects on soil physical properties, including penetration resistance and the size of soil aggregates. One replicated study from the USA found that tillage can have mixed results on soil erosion when crop remains are removed.
- *Soil organic matter*: One randomized, replicated trial from Australia found higher soil organic carbon and nitrogen when residues were retained, but only when fertilizer was also applied.
- *Yield*: One randomized, replicated trial from Australia found higher yields when residues were retained in combination with fertilizer application and no-tillage.
- *Soil types covered*: clay, loam, sandy loam, silt-loam.
- *Assessment*: trade-offs between benefit and harms (effectiveness 63%; certainty 54%; harms 29%).

<http://www.conservationevidence.com/actions/907>

Unknown effectiveness (limited evidence)

● Amend the soil with bacteria or fungi

- *Biodiversity*: One randomised, replicated trial from India showed that adding soil bacteria and arbuscular mycorrhizal fungi resulted in higher microbial diversity.
- *Soil organic matter*: One controlled, randomised, replicated trial from Turkey found increased soil organic matter content in soil under mycorrhizal-inoculated compost applications.
- *Yield*: Two randomised, replicated trials (including one also controlled) from India and Turkey found higher crop yields.
- *Soil types covered*: clay-loam, sandy loam.
- *Assessment*: unknown effectiveness (effectiveness 40%; certainty 31%; harms 17%).

<http://www.conservationevidence.com/actions/888>



● Amend the soil with composts not otherwise specified

- *Soil organic matter*: One controlled, randomised, replicated trial in Italy found that applying a high rate of compost increased soil organic matter levels, microbial biomass and fruit yield.
- *Soil types covered*: silty clay.
- *Assessment: unknown effectiveness (effectiveness 54%; certainty 29%; harms 19%)*.

<http://www.conservationevidence.com/actions/889>

● Amend the soil with crops grown as green manures

- *Soil organic matter*: Two controlled, randomized, replicated studies from India and Pakistan found higher soil organic carbon, and one found increased grain yields when green manures were grown.
- *Soil types covered*: clay-loam.
- *Assessment: unknown effectiveness (effectiveness 53%; certainty 36%; harms 16%)*.

<http://www.conservationevidence.com/actions/908>

● Amend the soil with non-chemical minerals and mineral wastes

- *Nutrient loss*: Two replicated studies from Australia and New Zealand measured the effects of adding minerals and mineral wastes to the soil. Both found reduced nutrient loss and one study found reduced erosion.
- *Soil types covered*: sandy clay, silt-loam.
- *Assessment: unknown effectiveness (effectiveness 35%; certainty 37%; harms 23%)*.

<http://www.conservationevidence.com/actions/892>

● Amend the soil with organic processing wastes or their composts

- *Nutrient loss*: Two controlled, replicated trials from Spain and the UK (one also randomized) measured the effect of adding composts to soil. One trial found applying high rates of cotton gin compost and poultry manure improved soil structure and reduced soil loss, but

increased nutrient loss. One trial found improved nutrient retention and increased barley *Hordeum vulgare* yield when molasses were added.

- *Soil types covered:* sandy clay, sandy loam, silty clay.
- *Assessment: unknown effectiveness (effectiveness 58%; certainty 35%; harms 20%).*

<http://www.conservationevidence.com/actions/891>

● Encourage foraging waterfowl

- *Soil organic matter:* One controlled, replicated experiment from the USA found increased straw decomposition when ducks were allowed to forage.
- *Soil types covered:* silty clay.
- *Assessment: unknown effectiveness (effectiveness 14%; certainty 34%; harms 20%).*

<http://www.conservationevidence.com/actions/711>

● Use alley cropping

- *Biodiversity:* A controlled, randomized, replicated study from Canada found that intercropping with trees resulted in a higher diversity of arbuscular mycorrhizal fungi.
- *Soil types covered:* sandy loam.
- *Assessment: unknown effectiveness (effectiveness 36%; certainty 23%; harms 19%).*

<http://www.conservationevidence.com/actions/903>

12.4 Livestock and pasture farming

Based on the collated evidence, what is the current assessment of the effectiveness of interventions on livestock and pasture farming systems for enhancing soil fertility?	
Likely to be beneficial	● Reduce grazing intensity
Trade-off between benefit and harms	● Restore or create low input grasslands

Likely to be beneficial

● Reduce grazing intensity

- *Compaction*: One replicated study from Australia found compacted soils recovered when sheep were excluded for 2.5 years.
- *Erosion*: Two replicated studies from New Zealand, and Syria (one also controlled) measured the effect of grazing animals on soil nutrient and sediment loss. Of these, one trial found increased soil carbon and nitrogen when grazing animals were excluded. One trial found higher soil phosphate levels, and less sediment erosion when grazing time in forage crops was reduced.
- *Soil types covered*: clay, clay-loam, loamy, silt-loam.
- *Assessment*: likely to be beneficial (effectiveness 51%; certainty 58%; harms 14%).

<http://www.conservationevidence.com/actions/901>

Trade-off between benefit and harms

● Restore or create low input grasslands

- *Biodiversity*: One randomized, replicated trial in the Netherlands and one controlled trial from France found that restoring grasslands increased the diversity of soil animals. One trial also found higher microbial biomass, activity and carbon under grassland.
- *Soil types covered*: sandy loam, silty.
- *Assessment*: trade-offs between benefit and harms (effectiveness 53%; certainty 59%; harms 32%).

<http://www.conservationevidence.com/actions/905>

This book need not end here...

At Open Book Publishers, we are changing the nature of the traditional academic book. The title you have just read will not be left on a library shelf, but will be accessed online by hundreds of readers each month across the globe. OBP publishes only the best academic work: each title passes through a rigorous peer-review process. We make all our books free to read online so that students, researchers and members of the public who can't afford a printed edition will have access to the same ideas.

This book and additional content is available at:

<https://www.openbookpublishers.com/product/696>

Customise

Personalise your copy of this book or design new books using OBP and third-party material. Take chapters or whole books from our published list and make a special edition, a new anthology or an illuminating coursepack. Each customised edition will be produced as a paperback and a downloadable PDF.

Find out more at:

<https://www.openbookpublishers.com/section/59/1>

Donate

If you enjoyed this book, and feel that research like this should be available to all readers, regardless of their income, please think about donating to us. We do not operate for profit and all donations, as with all other revenue we generate, will be used to finance new Open Access publications:

<https://www.openbookpublishers.com/section/13/1/support-us>

Like Open Book Publishers



Follow @OpenBookPublish



Read more at the Open Book Publishers

BLOG

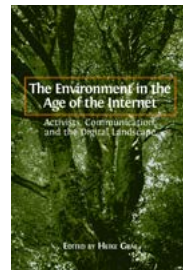
You may also be interested in:

The Environment in the Age of the Internet

Edited by Heike Graf

<https://doi.org/10.11647/OBP.0096>

<https://www.openbookpublishers.com/product/484>



Forests and Food: Addressing Hunger and Nutrition Across Sustainable Landscapes

Edited by Bhaskar Vira, Christoph Wildburger and Stephanie Mansourian

<https://doi.org/10.11647/OBP.0085>

<https://www.openbookpublishers.com/product/399>

