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Evidence to improve practice

Scientific evidence to address priority knowledge needs for sustainable agriculture

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How can this document help you?

Are you involved in sustainable agriculture and need to make decisions about which management actions should be implemented? This document provides an assessment of the effectiveness of relevant management actions to address 35 of the priority knowledge needs for sustainable agriculture (identified by 350 people from business, practice, policy making and academia). Links are provided to summaries of the relevant scientific evidence.

Priority knowledge needs for sustainable agriculture

Priority knowledge needs for five topics relating to sustainable agriculture have been identified by 350 people from business, practice, policy making and academia: the future of global agriculture (Pretty *et al.* 2010), conservation of wild insect pollinators (Dicks *et al.* 2012), environmental sustainability of agricultural production in the UK (Dicks *et al.* 2013), the UK food system (Ingrams *et al.* 2013) and sustainable aquaculture (Jones *et al.* 2014).

Summaries of relevant scientific evidence

For 35 of the priority knowledge needs for sustainable agriculture, scientific evidence for the effectiveness of relevant management actions has been summarized and assessed by *Conservation Evidence*. This information is provided below for each knowledge need, with links to summaries of the evidence and references.

Conservation Evidence summarizes available global scientific research on the effectiveness of management actions for the conservation of biodiversity or ecosystem services in Conservation Evidence Synopses. The development of each synopsis follows a standardized protocol. First a comprehensive list of possible actions that conservationists or managers might carry out for the particular species group, habitat, or environmental issue is developed in collaboration with an expert advisory board. Relevant studies that test the effectiveness of actions are then found by carrying out a thorough search of all relevant journals, systematic reviews, reports from government departments or non-governmental organisations and other relevant papers or books frequently cited within the literature for the topic. Each study is summarized as clearly as possible, in a simple, standardised manner. Once all studies identified for a particular action have been summarized, key messages are compiled summarizing all the results. All summarized evidence is freely available from the website: conservation.evidence.com. For further details of the methods used see: synopses methods.

Assessment of the summarized evidence

For each action, groups of experts are asked to read the summarized evidence and then score to indicate their assessment of the following: effectiveness (0 = no effect, 100% = always effective), certainty of the evidence for the effectiveness of intervention (0 = no evidence, 100% = high quality evidence; complete certainty) and harms (0 = none, 100% = major negative side-effects to the group of species/habitat of concern). A modified Delphi method is used for scoring. Based on the scores, actions are categorized by their effectiveness. For further details of the methods used see: What Works in Conservation (Sutherland *et al.* 2015).

Information provided is a guide to the evidence available for different conservation actions 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 actions it is vital that you read the more detailed accounts of the evidence in order to assess their relevance for your species or system.

Full details of the evidence are available at 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.

Priority knowledge needs:

Pollinators

How can we optimise pesticide use to minimise damage and maximise foraging resources for pollinators?

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence for the effectiveness of three management interventions relating to optimising pesticide use to minimise damage and maximise foraging resources for bees and for biodiversity including pollinators has been summarized. One of the two interventions assessed was assessed as being beneficial to biodiversity including pollinators.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions relating to optimising pesticide use to minimise damage and maximise foraging resources for pollinators?	
Beneficial	• Leave headlands in fields unsprayed (conservation headlands) (for biodiversity)
Unknown effectiveness (limited evidence)	• Make selective use of spring herbicides (for biodiversity)
Evidence not assessed	• Leave field margins unsprayed within the crop (conservation headlands) (for bees)

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

Evidence to inform increased protection of existing natural or semi-natural habitats of importance to pollinators (such as species-rich grassland)

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence for the effectiveness of 10 management interventions to protect or restore natural or semi-natural habitats of importance to pollinators has been summarized. Of the 10 interventions, three were assessed as being beneficial or likely to be beneficial to pollinators or biodiversity.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to protect or restore natural or semi-natural habitats of importance to pollinators?	
Beneficial	• Restore or create species-rich semi-natural grassland (for biodiversity)
Likely to be beneficial	• Restore heathland (for bees) • Restore species-rich grassland vegetation (for pollinators)
Unknown effectiveness (limited evidence)	• Connect areas of natural or semi-natural habitat (for bees/biodiversity) • Employ areas of semi-natural habitat for rough grazing (for biodiversity) • Increase areas of rough grassland for bumblebee nesting • Increase the proportion of natural or semi-natural habitat in the farmed landscape (for bees) • Legally protect large native trees (for pollinators)
No evidence	• Protect existing natural or semi-natural habitat to prevent conversion to agriculture (for bees) • Protect in-field trees (for biodiversity)

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

New agri-environment options that provide nesting resources for bees

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence for the effectiveness of 15 management interventions that could provide nesting resources for bees has been summarized. Of the 15 interventions, five were assessed as being beneficial or likely to be beneficial to bees or biodiversity in general.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions that provide nesting resources for bees?	
Beneficial	• Create uncultivated margins around intensive arable or pasture fields (for biodiversity) • Provide artificial nest sites for solitary bees
Likely to be beneficial	• Create patches of bare ground for ground-nesting bees • Manage hedgerows to benefit wildlife • Restore heathland (for bees)
Unknown effectiveness (limited evidence)	• Increase areas of rough grassland for bumblebee nesting • Leave arable field margins uncropped with natural regeneration (for bees) • Manage ditches to benefit wildlife • Manage hedges to benefit bees • Provide nest boxes for stingless bees • Provide set-aside areas in farmland (for bees) • Reduce the intensity of farmland meadow management (for bees) • Restore species-rich grassland vegetation (for bees)
Unlikely to be beneficial	• Provide artificial nest sites for bumblebees
No evidence	• Manage woodland edges to benefit wildlife

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

Long-term objectives for agri-environment schemes that enhance their scale and effectiveness for pollinators

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Although this knowledge need cannot be answered fully, evidence for the effectiveness of all conservation interventions for bees and interventions for wildlife including pollinators in farmland has been summarized:

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

Training for conservationists, agronomists and land managers on pollinator ecology and conservation

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Two management interventions to provide training to conservationists, land managers and advisers on wildlife conservation were identified. Only one study was found and that showed that UK farmers who were trained in how to implement agri-environment schemes created better quality wildlife habitat in terms of flower resources for bees over five years.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to provide training to conservationists, land managers and advisers on wildlife conservation?	
Unknown effectiveness (limited evidence)	• Provide training for land managers, farmers and farm advisers (for biodiversity)
No evidence	• Provide training to conservationists and land managers on bee ecology and conservation

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

What habitat creation measures can most help restore pollinator populations in rural and urban scenarios (taking their full life cycle into account)?

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence for the effectiveness of 30 management interventions relating to the creation of habitats that could restore pollinator populations in rural and urban areas has been summarized. Of the 21 interventions that have been assessed, eight were assessed as being beneficial or likely to be beneficial to pollinators or biodiversity in general.

Rural

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to create habitat to help restore pollinator populations in rural areas?	
Beneficial	• Create uncultivated margins around intensive arable or pasture fields (for biodiversity) • Plant grass buffer strips/margins around arable or pasture fields (for biodiversity) • Plant nectar flower mixture/wildflower strips (for biodiversity) • Provide artificial nest sites for solitary bees
Likely to be beneficial	• Create patches of bare ground for ground-nesting bees • Restore heathland (for bees) • Restore species-rich grassland vegetation (for pollinators)
Unknown effectiveness (limited evidence)	• Employ areas of semi-natural habitat for rough grazing (for biodiversity) • Increase areas of rough grassland for bumblebee nesting • Increase the proportion of natural or semi-natural habitat in the farmed landscape (for bees) • Leave arable field margins uncropped with natural regeneration (for bees) • Plant new hedges (for biodiversity) • Plant nettle strips (for biodiversity) • Provide nest boxes for stingless bees • Provide set-aside areas in farmland (for bees)
Unlikely to be beneficial	• Provide artificial nest sites for bumblebees

No evidence	• Plant in-field trees (for biodiversity) • Restore or create traditional orchards (for biodiversity)
Evidence not assessed	• Increase the diversity of nectar and pollen plants in the landscape (for bees) • Plant dedicated floral resources on farmland (for bees) • Provide grass strips at field margins (for bees) • Sow uncropped arable field margins with an agricultural nectar and pollen mix (for bees) • Sow uncropped arable field margins with a native wild flower seed mix (for bees)

Urban

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to create habitat to help restore pollinator populations in urban areas?	
Beneficial	• Provide artificial nest sites for solitary bees
Unknown effectiveness (limited evidence)	• Provide nest boxes for stingless bee
Unlikely to be beneficial	• Provide artificial nest sites for bumblebees
Evidence not assessed	• Manage land under power lines for wildlife (for bees) • Plant parks and gardens with appropriate flowers (for bees) • Practise wildlife gardening (for bees) • Restore species-rich grassland on road verges (for bees)

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

Do interventions to mitigate threats increase pollinator populations or just change pollinator behaviour/ local distribution?

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence for the effectiveness of 59 management interventions for the conservation of bees (not all pollinators) has been summarized. Evidence for the effects on wild populations, local abundance and behaviour has been summarized where available. Three of the 11 interventions that have been assessed were assessed as being beneficial or likely to be beneficial to bees. Evidence for the effectiveness of interventions for the conservation of biodiversity including pollinators has been summarized in the Farmland Conservation synopsis.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for bees?	
Beneficial	• Provide artificial nest sites for solitary bees
Likely to be beneficial	• Create patches of bare ground for ground-nesting bees • Restore heathland
Unknown effectiveness (limited evidence)	• Increase areas of rough grassland for bumblebee nesting • Leave arable field margins uncropped with natural regeneration • Manage hedges to benefit bees • Provide nest boxes for stingless bees • Provide set-aside areas in farmland • Reduce the intensity of farmland meadow management • Restore species-rich grassland vegetation
Unikely to be beneficial	• Provide artificial nest sites for bumblebees
Evidence not assessed	• Control fire risk using mechanical shrub control and/or prescribed burning • Convert to organic farming • Enhance bee taxonomy skills through higher education and training • Ensure commercial hives/nests are disease free • Eradicate existing non-native populations • Exclude introduced European earwigs from nest sites • Exclude ants from solitary bee nesting sites • Increase the diversity of nectar and pollen plants in the landscape

	• Introduce agri-environment schemes to benefit wild bees • Introduce mated females to small populations to improve genetic diversity • Keep pure breeding populations of native honey bee subspecies • Leave field margins unsprayed within the crop (conservation headlands) • Legally protect large native trees • Manage land under power lines for wildlife • Manage wild honey bees sustainably • Plant dedicated floral resources on farmland • Plant parks and gardens with appropriate flowers • Practise wildlife gardening • Prevent escape of commercial bumblebees from greenhouses • Prevent spread of the small hive beetle • Provide grass strips at field margins for bees • Raise awareness amongst the general public through campaigns and public information • Rear and manage populations of solitary bees • Rear declining bumblebees in captivity • Reduce grazing intensity on pastures • Reduce pesticide or herbicide use generally • Reduce tillage • Reintroduce laboratory-reared bumblebee queens to the wild • Replace honey-hunting with apiculture • Restore species-rich grassland on road verges • Restrict certain pesticides • Sow uncropped arable field margins with an agricultural nectar and pollen mix • Sow uncropped arable field margins with a native wild flower seed mix • Translocate bumblebee colonies in nest boxes • Translocate solitary bees
No evidence	• Connect areas of natural or semi-natural habitat • Conserve old buildings or structures as nesting sites for bees • Control deployment of non-native species hives/ nests • Exclude bumblebee nest predators such as badgers and mink • Increase the proportion of natural or semi-natural habitat in the farmed landscape • Increase the use of clover leys on farmland • Protect brownfield sites • Protect existing natural or semi-natural habitat to prevent conversion to agriculture • Provide training to conservationists and land managers on bee

	ecology and conservation • Reduce fertilizer run-off into margins • Re-plant native forest • Retain dead wood in forest management

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation and Farmland Conservation.

Evidence to inform the uptake of alternative pest management methods on farms, such as the use of natural enemies

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence has been summarised for 22 of 92 possible management interventions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. Of those five were assessed as being beneficial or likely to be beneficial.

Based on the collated evidence, what is the current assessment of the effectiveness of 22 of the possible interventions for enhancing natural pest regulation?	
Beneficial	• Combine trap and repellent crops in a push-pull system
Likely to be beneficial	• Exclude ants that protect pests • Grow non-crop plants that produce chemicals that attract natural enemies • Grow plants that compete with damaging weeds • Use chemicals to attract natural enemies
Trade-offs between benefit and harms	• Leave part of the crop or pasture unharvested or uncut • Use crop rotation in potato farming systems
Unknown effectiveness (limited evidence)	• Allow natural regeneration of ground cover beneath perennial crops • Alter the timing of insecticide use • Delay herbicide use • Delay mowing or first grazing date on pasture or grassland • Incorporate parasitism rates when setting thresholds for insecticide use • Isolate colonies of beneficial ants • Plant new hedges • Use alley cropping • Use pesticides only when pests or crop damage reach threshold levels
Unlikely to be beneficial	• Create beetle banks

Likely to be ineffective or harmful	• Incorporate plant remains into the soil that produce weed-controlling chemicals • Use grazing instead of cutting for pasture or grassland management • Use mixed pasture
Evidence not assessed	• Convert to organic farming • Use mass-emergence devices to increase natural enemy populations

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

Evidence to inform amendment of pesticide accreditation to include risk assessment for wild and managed pollinators in laboratory and field conditions

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

All the evidence required to answer this knowledge need has not been summarized. However, evidence for the effectiveness of restricting certain pesticides for wild bees has been summarized. Only one study was found and that showed that a reduction in the number of solitary bee species in late autumn associated with repeated applications of the insecticide fenitrothion can be avoided by not applying the insecticide. No evidence of the effects on wild bees of restricting neonicotinoid pesticides was found.

Summarized evidence and references for this intervention can be found at www.ConservationEvidence.com within the following synopsis: Bee Conservation (Restrict certain pesticides).

Assessment of the positive and negative effects of restoring pollinator habitat on road verges

Dicks, L.V. *et al.* (2012) Identifying key knowledge needs for evidence-based conservation of wild insect pollinators: a collaborative cross-sectoral exercise. *Insect Conservation and Diversity,* 6, 435-446.

Evidence for the effectiveness of restoring species-rich grassland on road verges for bees (not all pollinators) has been summarized. Only one study was found and that showed that in the USA road verges planted with native prairie vegetation supported greater numbers and diversity of bees than frequently mown grassed verges.

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Bee Conservation (Restore species-rich grassland on road verges).

Soil management

What benefits can sustainable soil management deliver for both agricultural production and delivery of other ecosystem services?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence of the effectiveness of 27 management interventions for enhancing soil fertility has been summarized. Effects on yield were summarized where provided. Of the 27 interventions, seven were assessed as being beneficial or likely to be beneficial for aspects of soil fertility and structure, and biodiversity.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for enhancing soil fertility?	
Beneficial	• 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	• Amend the soil with formulated chemical compounds • Control traffic and traffic timing • Grow cover crops beneath the main crop (living mulches) or between crop rows • Reduce grazing intensity
Trade-offs between benefit and harms	• 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 • Change tillage practices • Convert to organic farming • Incorporate leys into crop rotation • Plant new hedges • Restore or create low input grasslands • Retain crop residues
Unknown effectiveness (limited evidence)	• 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 • Change the timing of manure application • Change the timing of ploughing • Encourage foraging waterfowl • Use alley cropping
Likely to be ineffective or harmful	• Reduce fertilizer, pesticide or herbicide use generally

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

What are the best uses of organic amendments by subsistence farmers in cropping systems to improve soil nutrients and water-holding capacities and thereby assist in restoring agroecosystems?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of 11 management interventions using organic amendments on arable farming systems for enhancing soil fertility has been summarized. Evidence for the effect on water-holding capacities was also summarized where provided by studies. Although evidence from all scales of farming systems has been included, the majority comes from fairly intensive farming systems rather than subsistence farming. Of the 11 interventions, one was assessed as being beneficial and five as having trade-offs between benefit and harms for soil fertility.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions using organic amendments on arable farming systems for enhancing soil fertility?	
Beneficial	• Amend the soil using a mix of organic and inorganic amendments
Trade-offs between benefit and harms	• 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 • Retain crop residues
Unknown effectiveness (limited evidence)	• 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

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

What are the most practical and economic methods for managing soil fertility in paddy soils and upland production systems in the tropics?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of 27 management interventions for enhancing soil fertility has been summarized. Of the 27 interventions, seven were assessed as being beneficial or likely to be beneficial. Evidence is not specifically for paddy soils and upland production systems in the tropics, but is from all farming systems, the majority comes from fairly intensive farming systems. Evidence on the economic costs and practical application has not been summarized.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for enhancing soil fertility?	
Beneficial	• 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	• Amend the soil with formulated chemical compounds • Control traffic and traffic timing • Grow cover crops beneath the main crop (living mulches) or between crop rows • Reduce grazing intensity
Trade-offs between benefit and harms	• 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 • Change tillage practices • Convert to organic farming • Incorporate leys into crop rotation • Plant new hedges • Restore or create low input grasslands • Retain crop residues
Unknown effectiveness (limited evidence)	• 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

	• Change the timing of manure application • Change the timing of ploughing • Encourage foraging waterfowl • Use alley cropping
Likely to be ineffective or harmful	• Reduce fertilizer, pesticide or herbicide use generally

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

What guidelines can be established for poor small-scale farmers to ensure that nitrogen fertilization is managed in a way that results in net accretion of soil organic carbon rather than net mineralization?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of 18 management interventions relating to nitrogen fertilization for enhancing soil fertility has been summarized. Evidence for the effects on soil organic carbon was summarized where provided by studies. Although evidence from all scales of farming systems has been included, the majority comes from fairly intensive farming systems rather than small-scale farms. Of the 18 interventions, five were assessed as being beneficial or likely to be beneficial for enhancing soil fertility.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions relating to nitrogen fertilization for enhancing soil fertility?	
Beneficial	• 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	• Amend the soil with formulated chemical compounds • Grow cover crops beneath the main crop (living mulches) or between crop rows (no evidence for soil carbon)
Trade-offs between benefit and harms	• Add mulch to crops (no evidence for soil carbon) • 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 (no evidence for soil carbon) • Incorporate leys into crop rotation • Retain crop residues
Unknown effectiveness (limited evidence)	• Amend the soil with bacteria or fungi (no evidence for soil carbon) • Amend the soil with composts not otherwise specified (no evidence for soil carbon) • Amend the soil with crops grown as green manures • Amend the soil with non-chemical minerals and mineral wastes (no evidence for soil carbon) • Amend the soil with organic processing wastes or their composts (no evidence for soil carbon) • Encourage foraging waterfowl • Use alley cropping

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

How can food production systems that reduce dependence on externally derived nitrogen, phosphorus and potassium resources be designed?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of 16 management interventions to reduce the use of externally derived nitrogen, phosphorus and potassium resources to enhance soil fertility has been summarized. Of the 16 interventions, four were assessed as being beneficial or likely to be beneficial for enhancing soil fertility.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to reduce the use of externally derived nitrogen, phosphorus and potassium resources?	
Beneficial	• 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	• Grow cover crops beneath the main crop (living mulches) or between crop rows
Trade-offs between benefit and harms	• 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)	• 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 • Change the timing of manure application

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

How should UK soils be managed for optimum productivity and environmental protection in field vegetable, arable and grassland livestock systems in the long term?

Ingram, J.S.I. *et al.* (2013) Priority research questions for the UK food system. *Food Security*, 5, 617–636.

Evidence for the effectiveness of 27 management interventions for enhancing soil fertility in agricultural systems has been summarized. Effects on yield were summarized where provided. Of the 27 interventions, seven were assessed as being beneficial or likely to be beneficial.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for enhancing soil fertility?	
Beneficial	• 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	• Amend the soil with formulated chemical compounds • Control traffic and traffic timing • Grow cover crops beneath the main crop (living mulches) or between crop rows • Reduce grazing intensity
Trade-offs between benefit and harms	• 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 • Change tillage practices • Convert to organic farming • Incorporate leys into crop rotation • Plant new hedges • Restore or create low input grasslands • Retain crop residues
Unknown effectiveness (limited evidence)	• 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 • Change the timing of manure application • Change the timing of ploughing

	• Encourage foraging waterfowl • Use alley cropping
Likely to be ineffective or harmful	• Reduce fertilizer, pesticide or herbicide use generally

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

What are the relative benefits of changing different management practices (e.g. tillage, cropping system and crop choice) for soil health?

Dicks, L.V. *et al.* (2013) What do we need to know to enhance the environmental sustainability of agricultural production? A prioritisation of knowledge needs for the UK food system. *Sustainability*, 5, 3095-3115.

Evidence for the effectiveness of 27 management interventions for enhancing soil fertility has been summarized. Of the 27 interventions, seven were assessed as being beneficial or likely to be beneficial to soil fertility. Others were assessed as having trades-offs between benefits and harms, being ineffective or harmful or as having too little evidence to determine effectiveness.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions for enhancing soil fertility?	
Beneficial	• 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	• Amend the soil with formulated chemical compounds • Control traffic and traffic timing • Grow cover crops beneath the main crop (living mulches) or between crop rows • Reduce grazing intensity
Trade-offs between benefit and harms	• 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 • Change tillage practices • Convert to organic farming • Incorporate leys into crop rotation • Plant new hedges • Restore or create low input grasslands • Retain crop residues
Unknown effectiveness (limited evidence)	• 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 • Change the timing of manure application

	• Change the timing of ploughing • Encourage foraging waterfowl • Use alley cropping
Likely to be ineffective or harmful	• Reduce fertilizer, pesticide or herbicide use generally

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Soil Fertility as an Ecosystem Service.

General topics

In intensive production systems, are agri-environment measures best deployed to buffer protected areas and areas of pristine or semi-natural habitat, or to 'soften the matrix' between patches of these habitats?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence of the effectiveness of 86 management interventions relating to buffering areas of natural or semi-natural habitat or to 'softening the matrix' between patches of these habitats has been summarized. Thirty one of the interventions to 'softening the matrix' were assessed as being beneficial or likely to be beneficial for biodiversity. Although evidence from all scales of farming systems has been included, the majority comes from intensive farming systems.

Buffer areas of natural or semi-natural habitat

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to buffer areas of natural or semi-natural habitat?	
Trade-off between benefit and harms	• Retain buffer zones around core habitat (for amphibians)
Unknown effectiveness (limited evidence)	• Plant riparian buffer strips (for amphibians)
Likely to be ineffective or harmful	• Exclude domestic animals or wild hogs by fencing (for amphibians)

‘Soften the matrix’ between patches of natural or semi-natural habitat

Based on the collated evidence, what is the current assessment of the effectiveness of interventions to ‘soften the matrix’ between patches of natural or semi-natural habitat?	
Beneficial	• Create ponds for amphibians • Create skylark plots • Create uncultivated margins around intensive arable or pasture fields (for biodiversity) • Create wetland (for amphibians) • Leave cultivated, uncropped margins or plots (includes 'lapwing plots') (for biodiversity) • Plant grass buffer strips/margins around arable or pasture fields (for biodiversity) • Plant nectar flower mixture/wildflower strips (for biodiversity) • Plant wild bird seed or cover mixture (for biodiversity, birds) • Provide (or retain) set-aside areas in farmland (for biodiversity, birds) • Restore/create species-rich, semi-natural grassland (for biodiversity) • Restore wetland (for amphibians) • Restore or create inland wetlands (for birds)
Likely to be beneficial	• Create beetle banks (for biodiversity) • Create patches of bare ground for ground-nesting bees (for bees) • Create scrapes and pools in wetlands and wet grasslands (for birds) • Create skylark plots for bird conservation • Create uncultivated margins around intensive arable or pasture fields for birds • Increase the proportion of natural/semi-natural vegetation in the farmed landscape (for birds) • Leave overwinter stubbles (for birds) • Leave uncropped, cultivated margins or plots, including lapwing and stone curlew plots • Manage ditches to benefit wildlife (for amphibians, birds) • Manage hedgerows to benefit wildlife (includes no spray, gap-filling and laying) • Plant grass buffer strips/margins around arable or pasture fields for birds • Plant nectar flower mixture/wildflower strips for birds • Protect or create wetlands as foraging habitat for bats • Reduce management intensity on permanent grasslands (for biodiversity, birds) • Restore habitat connectivity (for amphibians) • Restore heathland (for bees)

	• Restore or create grasslands (for birds) • Restore/create traditional water meadows (for biodiversity, birds) • Restore ponds (for amphibians)
Trade-off between benefit and harms	• Provide or retain un-harvested buffer strips (for birds) • Raise water levels in ditches or grassland (for birds)
Unknown effectiveness (limited evidence)	• Connect areas of natural or semi-natural habitat (for biodiversity) • Convert or revert arable land to permanent grassland (for biodiversity) • Create open patches or strips in permanent grassland (for biodiversity, birds) • Ensure connectivity between habitat patches (for birds) • Implement 'mosaic management', a Dutch agri-environment option (for biodiversity, birds) • Increase areas of rough grassland for bumblebee nesting (for bees) • Increase the proportion of semi-natural habitat in the farmed landscape (for biodiversity) • Leave arable field margins uncropped with natural regeneration (for bees) • Manage ditches to benefit wildlife • Manage hedges to benefit wildlife (for birds, bees) • Plant new hedges (for birds) • Manage the agricultural landscape to enhance floral resources (for biodiversity) • Plant nettle strips (for biodiversity) • Plant new hedges (for biodiversity) • Provide set-aside areas in farmland (for bees) • Reduce the intensity of farmland meadow management (for bees) • Re-seed grasslands (for birds) • Restore or create upland heath/moorland (for biodiversity) • Restore or create wood pasture (for biodiversity) • Restore species-rich grassland vegetation (for bees) • Retain connectivity between habitat patches (for amphibians) • Retain or plant trees on agricultural land to replace foraging habitat for bats • Take field corners out of management (for biodiversity, birds) • Use mixed stocking (for biodiversity) • Use traditional breeds of livestock (for biodiversity)
Unlikely to be beneficial	• Create beetle banks (for birds) • Use traditional breeds of livestock (for birds)
Likely to be ineffective or	• Revert arable land to permanent grassland (for birds)

harmful	
No evidence (or assessment)	• Connect areas of natural or semi-natural habitat for bees • Create corn bunting plots • Create habitat connectivity (for amphibians) • Increase the proportion of natural or semi-natural habitat in the farmed landscape (for bees) • Leave unharvested cereal headlands within arable fields (for biodiversity, birds) • Maintain in-field elements such as field islands and rockpiles (for biodiversity) • Maintain or restore hedges (for amphibians) • Manage stone-faced hedge banks to benefit wildlife (for biodiversity, birds) • Plant nettle strips (for birds) • Plant new hedges (for amphibians) • Protect in-field trees (for biodiversity, birds) • Plant in-field trees (not farm woodland) (for biodiversity, birds) • Reduce field size (or maintain small fields) (for birds) • Restore or maintain dry stone walls (for biodiversity) • 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
Evidence not assessed	• Increase the diversity of nectar and pollen plants in the landscape for bees • Plant dedicated floral resources on farmland (for bees) • Provide grass strips at field margins for bees • Reduce grazing intensity on pastures (for bees) • Sow uncropped arable field margins with an agricultural nectar and pollen mix (for bees) • Sow uncropped arable field margins with a native wild flower seed mix (for bees)

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Amphibian Conservation, Bat Conservation, Bee Conservation, Bird Conservation, Farmland Conservation.

How could agri-environment scheme options be targeted and adopted at the farm scale to meet shortfalls in ecosystem services underpinning production?

Dicks, L.V. *et al.* (2013) What do we need to know to enhance the environmental sustainability of agricultural production? A prioritisation of knowledge needs for the UK food system. *Sustainability*, 5, 3095-3115.

All the evidence required to answer this knowledge need has not been summarized. However, evidence for the effectiveness of interventions for the conservation of bees, for enhancing soil fertility and 22 of 92 possible actions to enhance natural regulation of pests in agricultural systems has been summarized.

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Bee Conservation, Enhancing Soil Fertility as an Ecosystem Service and Enhancing Natural Pest Control as an Ecosystem Service.

What type and specific combinations of improved technologies, farming practices, institutions and policies will result in the maintenance of ecosystem services, including soil fertility, in agricultural systems undergoing intensification in developing countries, in particular in sub- Saharan Africa?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of sustainable farming practices for bee conservation, biodiversity in farmland, enhanced soil fertility and natural pest control has been summarized. Although evidence from all scales of farming systems has been included, the majority comes from intensive farming systems in developed countries. Evidence for types of institutions and policies or combinations of interventions, institutions and policies for the maintenance of ecosystem services have not been summarized.

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bee Conservation, Farmland Conservation, Enhancing Natural Pest Control as an Ecosystem Service and Enhancing Soil Fertility as an Ecosystem Service.

Organic production systems

What are the advantages and disadvantages of organic production systems in terms of biodiversity, ecosystem services, yield and human health, particularly in resource-poor developing countries?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of organic production systems has been summarized for bees, bats, soil fertility and natural pest control. Although evidence from all scales of farming systems has been included, the majority comes from intensive farming systems in developed countries. Evidence on human health has not been summarized. Evidence for aspects of organic production systems such as reduced chemical inputs have also been summarized for amphibians, birds, bees, biodiversity in European farmland, soil fertility and natural pest control (see individual synopses).

Based on the collated evidence, what is the current assessment of the effectiveness of converting to organic farming?	
Likely to be beneficial	• Convert to organic farming – bats
Trade-offs between benefit and harms	• Convert to organic farming – soil fertility
Evidence not assessed	• Convert to organic farming – bees • Convert to organic farming – natural pest control

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopses: Bat Conservation, Bee Conservation, Enhancing Natural Pest Control as an Ecosystem Service, Enhancing Soil Fertility as an Ecosystem Service, Amphibian Conservation, Bird Conservation and Farmland Conservation.

Pest and disease management

How can perennial-based farming systems include cover crops as a pest management method and what are the economic and noneconomic costs and benefits?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Five management interventions relating to the use of cover crops in pest and disease management were identified from summarised evidence for 22 of 92 possible actions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. Of those two were assessed as being likely to be beneficial and two as having trade-offs between benefit and harms in non-economic terms. Evidence on the economic costs and benefits has not been summarized.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions using cover crops in perennial-based farming systems for enhancing natural pest regulation?	
Likely to be beneficial	• Combine trap and repellent crops in a push-pull system • Grow non-crop plants that produce chemicals that attract natural enemies
Trade-offs between benefit and harms	• Leave part of the crop or pasture unharvested or uncut • Use crop rotation in potato farming systems
Unknown effectiveness (limited evidence)	• Use alley cropping

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

How can increasing both crop and non-crop biodiversity help in pest and disease management?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Eleven management interventions relating to increasing crop and non-crop biodiversity to help in pest and disease management were identified from summarised evidence for 22 of 92 possible actions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. Of those four were assessed as being beneficial or likely to be beneficial.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions that increase crop and non-crop biodiversity for enhancing natural pest regulation?	
Beneficial	• Combine trap and repellent crops in a push-pull system
Likely to be beneficial	• Grow non-crop plants that produce chemicals that attract natural enemies • Grow plants that compete with damaging weeds • Use chemicals to attract natural enemies
Trade-offs between benefit and harms	• Use crop rotation in potato farming systems
Unknown effectiveness (limited evidence)	• Allow natural regeneration of ground cover beneath perennial crops • Plant new hedges • Use alley cropping
Unlikely to be beneficial	• Create beetle banks
Likely to be ineffective or harmful	• Use mixed pasture
Evidence not assessed	• Convert to organic farming

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

How can food supply be maintained as the functionality or use of pesticides, anti-microbials, antibiotics and biocides decreases?

Ingram, J.S.I. *et al.* (2013) Priority research questions for the UK food system. *Food Security*, 5, 617–636.

Evidence has been summarised for 22 of 92 possible management interventions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. Of those five were assessed as being beneficial or likely to be beneficial and two as having trade-offs between benefit and harms.

Based on the collated evidence, what is the current assessment of the effectiveness of 22 of the possible interventions for enhancing natural pest regulation?	
Beneficial	• Combine trap and repellent crops in a push-pull system
Likely to be beneficial	• Exclude ants that protect pests • Grow non-crop plants that produce chemicals that attract natural enemies • Grow plants that compete with damaging weeds • Use chemicals to attract natural enemies
Trade-offs between benefit and harms	• Leave part of the crop or pasture unharvested or uncut • Use crop rotation in potato farming systems
Unknown effectiveness (limited evidence)	• Allow natural regeneration of ground cover beneath perennial crops • Alter the timing of insecticide use • Delay herbicide use • Delay mowing or first grazing date on pasture or grassland • Incorporate parasitism rates when setting thresholds for insecticide use • Isolate colonies of beneficial ants • Plant new hedges • Use alley cropping • Use pesticides only when pests or crop damage reach threshold levels
Unlikely to be beneficial	• Create beetle banks

Likely to be ineffective or harmful	• Incorporate plant remains into the soil that produce weed-controlling chemicals • Use grazing instead of cutting for pasture or grassland management • Use mixed pasture
Evidence not assessed	• Convert to organic farming • Use mass-emergence devices to increase natural enemy populations

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

Can integrated control strategies protect crop yield and quality as the number of available plant protection products falls?

Dicks, L.V. *et al.* (2013) What do we need to know to enhance the environmental sustainability of agricultural production? A prioritisation of knowledge needs for the UK food system. *Sustainability*, 5, 3095-3115.

Seventeen management interventions relating to integrated control strategies to help in pest and disease management were identified from summarised evidence for 22 of 92 possible actions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. Effects on yield were summarized where provided. Of the 17 interventions, five were assessed as being beneficial or likely to be beneficial.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions relating to integrated control strategies for enhancing natural pest regulation?	
Beneficial	• Combine trap and repellent crops in a push-pull system
Likely to be beneficial	• Exclude ants that protect pests • Grow non-crop plants that produce chemicals that attract natural enemies • Grow plants that compete with damaging weeds • Use chemicals to attract natural enemies
Trade-offs between benefit and harms	• Leave part of the crop or pasture unharvested or uncut • Use crop rotation in potato farming systems
Unknown effectiveness (limited evidence)	• Allow natural regeneration of ground cover beneath perennial crops • Delay mowing or first grazing date on pasture or grassland • Isolate colonies of beneficial ants • Plant new hedges • Use alley cropping
Unlikely to be beneficial	• Create beetle banks
Likely to be ineffective or harmful	• Incorporate plant remains into the soil that produce weed-controlling chemicals • Use grazing instead of cutting for pasture or grassland management • Use mixed pasture

Evidence not assessed	• Use mass-emergence devices to increase natural enemy populations

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

How are we going to reduce losses due to soil-borne pests and diseases in the longterm (for example nematodes in potatoes)?

Dicks, L.V. *et al.* (2013) What do we need to know to enhance the environmental sustainability of agricultural production? A prioritisation of knowledge needs for the UK food system. *Sustainability*, 5, 3095-3115.

Fifteen management interventions for enhancing natural pest regulation including soil-borne pests and diseases were identified from summarised evidence for 22 of 92 possible actions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. Of those three were assessed as being beneficial or likely to be beneficial.

Based on the collated evidence, what is the current assessment of the effectiveness of 15 interventions for enhancing natural pest regulation including soil-borne pests and diseases?	
Beneficial	• Combine trap and repellent crops in a push-pull system
Likely to be beneficial	• Grow non-crop plants that produce chemicals that attract natural enemies • Use chemicals to attract natural enemies
Trade-offs between benefit and harms	• Leave part of the crop or pasture unharvested or uncut • Use crop rotation in potato farming systems
Unknown effectiveness (limited evidence)	• Alter the timing of insecticide use • Delay mowing or first grazing date on pasture or grassland • Incorporate parasitism rates when setting thresholds for insecticide use • Plant new hedges • Use pesticides only when pests or crop damage reach threshold levels
Unlikely to be beneficial	• Create beetle banks
Likely to be ineffective or harmful	• Use grazing instead of cutting for pasture or grassland management • Use mixed pasture
Evidence not assessed	• Convert to organic farming • Use mass-emergence devices to increase natural enemy populations

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

How can insecticide application in agriculture be modified to lessen the evolution of pesticide resistance in mosquitoes and other major vectors of human disease?

Pretty *et al*. (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Three management interventions relating to the modification of insecticide application for sustainable pest and disease management (not specifically mosquitoes and other vectors of human disease) were identified from summarised evidence for 22 of 92 possible actions to enhance natural regulation of pests (including animals, plants, fungi, bacteria and viruses) in agricultural systems. The effectiveness of the interventions could not be assessed as only limited evidence was available.

Based on the collated evidence, what is the current assessment of the effectiveness of interventions that modify insecticide use for enhancing natural pest regulation?	
Unknown effectiveness (limited evidence)	• Alter the timing of insecticide use • Incorporate parasitism rates when setting thresholds for insecticide use • Use pesticides only when pests or crop damage reach threshold levels

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Enhancing Natural Pest Control as an Ecosystem Service.

Aquaculture

Mechanisms for knowledge exchange, to communicate and interpret current scientific knowledge to the practitioner audience

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Conservation Evidence is a mechanism for knowledge exchange to communicate and interpret current scientific knowledge to a practitioner audience. Evidence for the effectiveness of 25 management interventions to enhance the sustainability of aquaculture using Atlantic salmon (Salmo salar) as a case study has been summarized. Summarized evidence and references can be found at www.ConservationEvidence.com.

How can aquaculture and open water farming be developed so that impacts on wild fish stocks and coastal and aquatic habitats are minimized?

Pretty *et al.* (2010) The top 100 questions of importance to the future of global agriculture. *International Journal of Agricultural Sustainability*, 8, 219-236.

Evidence for the effectiveness of 25 management interventions to enhance the sustainability of aquaculture using Atlantic salmon* Salmo salar *as a case study has been summarized. Summarized evidence has not been assessed for effectiveness. Evidence for other species has not been summarized.

Interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study	
Evidence not assessed	**Pathogen transfer and therapeutic treatments** • Alter cage size • Alter lighting • Bathe in freshwater • Breed for resistance traits • Establish fallowing to reduce parasites/disease • Use aerobic training • Use natural control agents: cleaner wrasse • Use probiotics and immunostimulants • Use vaccinations **Artificial feed** • Reduce fish meal in diet • Use an alternative oil source: plant-based • Use an alternative protein source: animal • Use an alternative protein source: bacteria • Use an alternative protein source: krill • Use an alternative protein source: plant-based • Use an alternative protein source: yeast • Use genetically modified alternatives • Use supplements **Pollution** • Construct artificial reefs • Dry sludge in beds • Establish fallowing to reduce pollution • Integrated aquaculture systems • Use exclusion nets

	Bioinvasive species • Eco friendly biofouling prevention **Wild escapes** • Domestication: sterility/triploidy

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study

What are the alternative sources of protein and oil for use in aquaculture feeds that are sustainable, technically and economically feasible and nutritionally suitable for the cultured livestock, and that also meet consumer nutritional needs and acceptability?

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Evidence for the effectiveness of seven management interventions using alternative sources of protein and oil for sustainable aquaculture of Atlantic salmon* Salmo salar *as a case study has been summarized. Summarized evidence has not been assessed for effectiveness. Details of costs and evidence for other species or consumer nutritional needs and acceptability have not been summarized.

Interventions using alternative sources of protein and oil for Atlantic salmon *Salmo salar* as a case study	
Evidence not assessed	• Use an alternative oil source: plant-based • Use an alternative protein source: animal • Use an alternative protein source: bacteria • Use an alternative protein source: krill • Use an alternative protein source: plant-based • Use an alternative protein source: yeast • Use genetically modified alternatives

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study

Development of technology to enable safe, sustainable and economically feasible offshore aquaculture

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Evidence for the effectiveness of 25 management interventions to enhance the sustainability of aquaculture using Atlantic salmon* Salmo salar *as a case study has been summarized. Summarized evidence has not been assessed for effectiveness. Details of safety and costs, and evidence for other species have not been summarized.

Interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study	
Evidence not assessed	**Pathogen transfer and therapeutic treatments** • Alter cage size • Alter lighting • Bathe in freshwater • Breed for resistance traits • Establish fallowing to reduce parasites/disease • Use aerobic training • Use natural control agents: cleaner wrasse • Use probiotics and immunostimulants • Use vaccinations **Artificial feed** • Reduce fish meal in diet • Use an alternative oil source: plant-based • Use an alternative protein source: animal • Use an alternative protein source: bacteria • Use an alternative protein source: krill • Use an alternative protein source: plant-based • Use an alternative protein source: yeast • Use genetically modified alternatives • Use supplements **Pollution** • Construct artificial reefs • Dry sludge in beds • Establish fallowing to reduce pollution • Integrated aquaculture systems • Use exclusion nets

	Bioinvasive species • Eco friendly biofouling prevention **Wild escapes** • Domestication: sterility/triploidy

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study

What technologies can be developed to increase the range and flexibility of available treatments and integrated management techniques to control sea lice infections on marine-farmed fish?

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Evidence for the effectiveness of seven management interventions to control sea lice infections on marine-farmed fish using Atlantic salmon* Salmo salar *as a case study has been summarized. Summarized evidence has not been assessed for effectiveness. Evidence for other species has not been summarized.

Interventions to control sea lice infections in sustainable aquaculture using Atlantic salmon *Salmo salar* as a case study.	
Evidence not assessed	• Alter lighting • Establish fallowing to reduce parasites/disease • Use natural control agents: cleaner wrasse • Use probiotics and immunostimulants
No evidence	• Alter cage size • Bathe in freshwater • Use aerobic training

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study

Globally, which elements of best practice in pest management and biosecurity from advanced aquaculture systems can be applied in emerging aquaculture systems?

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Evidence for the effectiveness of 11 management interventions for pest management and biosecurity in sustainable aquaculture using Atlantic salmon* Salmo salar *as a case study has been summarized. Summarized evidence has not been assessed for effectiveness. Evidence for other species or from advanced aquaculture systems has not been summarized.

Interventions for pest management and biosecurity in sustainable aquaculture using Atlantic salmon *Salmo salar* as a case study	
Evidence not assessed	• Alter cage size • Alter lighting • Bathe in freshwater • Breed for resistance traits • Wild escapes - Domestication: sterility/triploidy • Eco friendly biofouling prevention • Establish fallowing to reduce parasites/disease • Use aerobic training • Use natural control agents: cleaner wrasse • Use probiotics and immunostimulants • Use vaccinations

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study

What environmental impacts might result from an expansion of aquaculture in the freshwater environment and what precautions can be taken to mitigate for these impacts?

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Evidence for the potential impacts of the expansion of aquaculture in the freshwater environment has not been summarized. However, evidence for the effectiveness of 25 management interventions to enhance the sustainability of aquaculture using Atlantic salmon Salmo salar ***as a case study has been summarized. Summarized evidence has not been assessed for effectiveness. Evidence for other species has not been summarized.***

Interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study	
Evidence not assessed	**Pathogen transfer and therapeutic treatments** • Alter cage size • Alter lighting • Bathe in freshwater • Breed for resistance traits • Establish fallowing to reduce parasites/disease • Use aerobic training • Use natural control agents: cleaner wrasse • Use probiotics and immunostimulants • Use vaccinations **Artificial feed** • Reduce fish meal in diet • Use an alternative oil source: plant-based • Use an alternative protein source: animal • Use an alternative protein source: bacteria • Use an alternative protein source: krill • Use an alternative protein source: plant-based • Use an alternative protein source: yeast • Use genetically modified alternatives • Use supplements **Pollution** • Construct artificial reefs • Dry sludge in beds

	• Establish fallowing to reduce pollution • Integrated aquaculture systems • Use exclusion nets **Bioinvasive species** • Eco friendly biofouling prevention **Wild escapes** • Domestication: sterility/triploidy

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study

How can amoebic gill disease of salmonids be avoided, prevented or effectively treated at sustainable economic cost in the UK?

Jones, A.C. *et al.* (2014) Prioritization of knowledge needs for sustainable aquaculture: a national and global perspective. *Fish and Fisheries*, doi: 10.1111/faf.12086

Evidence for the effectiveness of seven management interventions for avoiding or treating amoebic gill disease of Atlantic salmon* Salmo salar *in sustainable aquaculture has been summarized. Summarized evidence has not been assessed for effectiveness. Evidence for other species and details of costs have not been summarized.

Interventions to avoid or treat amoebic gill disease in sustainable aquaculture using Atlantic salmon *Salmo salar* as a case study.	
Evidence not assessed	• Alter cage size • Establish fallowing to reduce parasites/disease
No evidence	• Bathe in freshwater • Breed for resistance traits • Use aerobic training • Use probiotics and immunostimulants • Use vaccinations

Summarized evidence and references for these interventions can be found at www.ConservationEvidence.com within the following synopsis: Aquaculture - Evidence for the effects of interventions to enhance the sustainability of aquaculture using Atlantic salmon *Salmo salar* as a case study